

Virtual sensors for indirect strain measurements during Francis turbine startup

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Abstract. It is not possible to measure strains on Francis turbine blades continuously, those are only available from dedicated measurement campaigns. We propose using the data from the continuous surveillance system of the turbine to estimate the blade's strain indirectly. The methodology uses neural networks (NN) to estimate the strain signal envelope during the turbine startup. This allows for further optimization of the turbine startup scheme even after the strain gages are removed. Our methodology allows uncertainty quantification and credibility assessment across a wide range of head and downstream water level given historical data from the unit surveillance system.

1. Introduction

Measurement campaign with strain gages on turbine blades is a difficult and costly endeavor at the prototype scale [1]. Typically, such measurements are only carried out after the runner commissioning. A part of these measurement campaigns is dedicated to minimizing blade strain dynamic range during startup to improve the runner's fatigue life and reliability [2-5]. However, due to time constraints, only a small subset of possible startup schemes can be evaluated. From this subset, the startup scheme featuring the lowest level of dynamic strain while satisfying the turbine's requirements is selected. However, this approach leaves potential for optimization untapped given the limited number of schemes tested. To overcome these limitations, we propose the use of virtual sensors based on machine learning to estimate turbine blade strain once the strain gage sensors are no longer available [6]. Ultimately, this approach may help define a startup scheme closer to the optimum through estimating turbine blade strains over a larger range of startup control parameters without additional dedicated experimental campaigns.

In this study, data measured during various startups is used to train neural network (NN) models. The models are specifically built to estimate the dynamic strain range from the signal envelope using indirect measurements available in the unit surveillance system. The estimated dynamic strain range is then used as the objective function for *a posteriori* optimization. Operational startup data recorded by the surveillance system over one year is used to assess the model's performance. Finally, the credibility and applicability of the methodology are assessed using the discrepancy between the models' results.

2. Study case

The test case is a medium head Francis turbine recently commissioned by Hydro-Québec, with a specific speed $N_q = 57$. The data used in this study comes from two different sources. The first set of data (field data) is used for model training and comes from a measurement campaign conducted after commissioning. Field data includes turbine strain measurements during different startup scenarios. The