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Investigations of fluid-structure interactions in Francis turbines during no-load operation and start-ups using novel model measurements & simulations.

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ABSTRACT

This presentation outlines the results of the Tr-Francis project aimed at investigating fluid-structure interactions in a Francis turbine. Tr-Francis rests on an innovative investigation approach coupling simulations and numerical developments with measurements on a 1/14 scale Francis turbine model designed to provide homologous fluid-structure responses with a 150 MW turbine operated by Hydro-Québec. Tr-Francis was a research effort financed by the Research Consortium on Hydraulic Machines involving the three leading manufacturers of hydraulic turbines (Andritz Hydro, GE Vernova, and Voith Hydro), three utilities (Électricité de France, Hydro-Québec, Vattenfall) and three Universities (Université Laval, Polytechnique Montréal, Polytechnical University of Catalonia).

The model was instrumented to explore the origins of high-stress levels in different steady operating conditions, including no-load and during start-up. The fluid-structure interactions were investigated using synchronized structural and flow measurements.

The presentation discusses the following innovations introduced in Tr-Francis:

- A runner manufactured to provide transposable fluid and structural responses concerning the prototype unit.
- The implementation of homologous start-up sequences based on prototype data.
- Extensive instrumentation of the runner and test stand to investigate the structural dynamics and correlations between fixed reference frame signals and stress levels in the runner.
- Operational Modal Analysis (OMA) of the runner in different operating conditions using piezo actuators mounted on the runner band to evaluate added damping.
- Unique flow measurements in the inter-blade channels of a Francis turbine using stereoscopic TR-PIV and endoscopes for both cameras and the laser.
- An experimental test case to study rotor-stator-induced resonances during the acceleration of a simplified turbine runner.
- The development of simulation techniques based on different methods, including Physics Informed Neural Networks, to reproduce fluid interactions at a reduced computational cost.

The presentation includes results from graduate students' projects and an overview of the collaboration between industrial partners and universities underpinning the consortium's activities. It outlines how innovations in measurement and simulation technology were essential to yielding scientific contributions in fluid-structure interactions that will improve the design and operation of Francis turbines.

**Max 400 words