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Specific speed effect on Francis runner reliability under various operating conditions

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Abstract

Energy market deregulation and arrival of new players, such as solar and wind turbines, led to an increasing demand for flexible operation of hydraulic turbines. Instead of continuous close to peak operation, it is nowadays not uncommon to see turbines being operated over the whole range, with many start/stops, extensive low load operation, synchronous condenser mode and power/frequency regulation. This new way to operate the units, however, does not come without cost on the machine life expectancy due to increased number of high and low amplitude cycles introduced in the operation of the unit. To assess machine reliability, it therefore becomes critical for the owner to understand the real effects of these dynamic phenomena.

The purpose of this paper is to show how dynamic phenomena occurring at various operating conditions may affect the lifetime expectancy of different specific speed Francis runners. Runner blade strain gage and pressure site measurements, performed at various locations, and correlated to Computational Fluid Dynamics (CFD) results and structural Finite Element Analysis (FEA) using Fluid Structure Interaction (FSI) techniques, are used to discuss these dynamic phenomena. Techniques such as rainflow diagrams are applied to the measured and calculated dynamic stresses. The study includes full load operating conditions, in addition to steady state operations at low load and part load. Start-up transient events are also considered.

Francis runners with different hydraulic specifications will be used and compared for the various operating conditions. The paper will present how the relative importance of the dynamic hydraulic phenomena occurring in the runners may vary with specific speed. For instance, low specific speed machines (high head) are more sensitive to Rotor Stator Interactions (RSI) than high specific (low head) machines while the opposite occurs for low load operation. Mitigation options for various operating points and events will be discussed together with their global effects on the runner reliability.