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Cost of operation of Francis runners

André Coutu, Joël Chamberland-Lauzon

Abstract

Although hydro power plants have traditionally been operated close to best efficiency point as base load providers, they have always been very well suited to contribute to grid stability because of their high operating flexibility. Indeed, they can contribute to grid stability by providing considerable output and, at the same time, being regulated from part load to full load to deliver primary control within very short notice. The recent increase of grid instabilities due to the arrival of new players in the energy market, such as solar and wind power, coupled with market deregulation, increases the demand for such flexible operation of hydraulic turbines. It is therefore not uncommon nowadays to see these machines being operated over the whole range, with many start/stops, extensive low load operation, synchronous condenser mode and power/frequency regulation.

Although hydraulic turbines are among the most robust and reliable structures and equipment ever produced, such operating scheme increases drastically the number of high and low amplitudes vibration cycles the machines have to go through. More specifically, Francis runners have now to withstand strong vibrations induced by higher pressure pulsations at part load, low part load, speed-no-load and during start and stop cycles. These vibrations induce dynamic stresses which do not come without cost on the runner life expectancy. To assess machine reliability, it therefore becomes critical for the owner to understand the real damages caused by these dynamic phenomena, especially at off-design conditions.

This paper demonstrates how flexible operation affects the lifetime expectancy of Francis runners. Runner blade strain gauge measurements performed at various sites are used to achieve this objective. Since the Francis runners are subject to complex dynamic stresses showing stochastic behaviour at low loads, techniques such as waterfall and rainflow counting are used to obtain the number of cycles and amplitudes for various operating conditions. Applying Miner's rule, a linear cumultative fatigue damage theory, relative cost of operation under each operating condition is calculated. The study includes normal operating conditions, steady state operation at low load and part load, and transient events such as start-stops. The operating conditions are then being combined under different Design Reference Missions (DRMs) to show how the cumulative damage varies with the usage of the machine. Two runners with various hydraulic characteristics are used as example.

To reliably predict cost of operation of Francis runners under various usage schemes is a considerable challenge. This paper presents and discusses new analyses and simulation approaches applied to real cases and will contribute in a better understanding of this complex problem.