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Designing Francis runners for 0-100 per cent operation

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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 dynamic 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 more frequent start and stop cycles. These vibrations induce dynamic stresses which do not come without cost on the runner life expectancy. Assessing the damage induced to the runner under these various conditions has been discussed previously and is still a key topic of development. Most of the time, runner blade strain gauge measurements performed at different sites are used to demonstrate how the different operating conditions affect the runners and how their combinations, under various scenarios, change their overall lifetime expectancy.

Assessing runner life expectancy for an existing machine for which there are measurements is one thing, but what about the new runners? This paper will discuss how it became possible to design reliable new runners for 0-100% operation. Using the knowledge obtained from previous measurements, which were correlated with Computer Fluid Dynamic (CFD) results and structural Finite Element Analysis (FEA) coupled using Fluid Structure Interaction (FSI) techniques, design procedures have been defined. These procedures allow Andritz Hydro to design reliable runners for pre-defined operation scenarios which include operating conditions over the complete possible operating range of the machine.

This paper describes how modern runners are designed and how actual projects have been lately successfully completed, hydraulically and mechanically, with this approach. Real examples are presented to better illustrate the process.