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Refurbishment of high head Francis turbines

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Abstract

Increasingly, operating utilities assess upgrading and refurbishment options of existing hydro-electric power plants in the view of the changed competitive environment of the electricity market. Refurbishment projects have to be economically feasible, and the outage times of existing power plants have to follow tight schedules. Additionally, the modernization of high head Francis units poses specific challenges as high performance levels have to be achieved while mechanical safety and smooth operation of the plant are essential to the success of a plant modernization. The high operating heads require special care to ensure operation of the plant without cavitation and vibration.

ANDRITZ HYDRO has long standing experience in design, model testing and manufacturing of high head Francis turbines. Since 1930, the company has installed over 190 units with heads above 300 m with a total output of more than 12'000 MW. Among these is the 180 MW power plant in Häusling (Austria) with the record head of 734 m. In the past years, ANDRITZ HYDRO has carried out a significant number of high head projects for both rehab contracts and new power plants dealing with turbines of a specific speed of n_{QE} = 0.10 (n_{sq} = 120) and lower. Contracts under execution today include high head plants in Switzerland, China, Iceland and Norway.

Especially for rehab projects, where existing parts have to be modified, it is essential to ensure the mechanical safety of the upgraded plant. ANDRITZ HYDRO has established a procedure in which the hydraulic optimization and the analysis of the mechanical behaviour are carried out in parallel. In high head machines, the radial distance between wicket gate trailing edge and runner is usually very small, therefore rotor/stator interaction (RSI) has to be looked at very closely during refurbishment. ANDRITZ HYDRO uses a design tool, in which the oscillating pressure loads from unsteady CFD calculations are transformed as loads to the dynamic finite element mechanics (FEM) model taking into account possible excitation frequencies from RSI. Additionally, a dynamic analysis of the natural frequencies of the runner structure is obtained. Its spectra of eigen-frequencies (in water) are compared with the excitation frequencies, and the blade is designed to avoid excitation.

To make specifically modernization projects more economical, they often include an increase in turbine output and consequently in flow rate. If a runner upgrade can be carried out without a model test, significant speed-up of the project and cost reductions are possible.

Based on long-standing experience in the rehab of hydro turbines and in close cooperation with the specific clients, ANDRITZ HYDRO has decided to carry out most of the recent high head refurbishment projects without model test. The successful site measurement of the high head plants Songa, Kvaenangsbotn and Hove (no model testing) as well as Tokke (including model test) in Norway are current examples of how refurbishment projects can be carried out using the necessary tools to ensure hydraulic quality and mechanical integrity while keeping tight project schedules as well.