Dynamic Stress Prediction during Load Rejections in Hydraulic Turbines

C-L Bénard, S Afara, C Monette, B Nennemann

Andritz Hydro Canada Inc., 6100 aut. Transcanadienne, Pointe-Claire, H9R 1B9

E-mail: charles-li.benard@andritz.com

Abstract. Load rejections occur when a hydraulic turbine, producing power, is disconnected from the electric grid. The sudden loss of load will trigger the emergency guide vane closing sequence, and the turbine will accelerate to a maximum speed before decelerating. During this event, the runner can experience large dynamic stresses, which can significantly decrease its fatigue life if load rejections occur frequently. So far in the reported literature the approach of simulating a load rejection is to perform a transient analysis, which includes the guide vane closing sequence. This approach is difficult to setup, due to the moving mesh required for closing the guide vanes and demands large computational effort. In the current work, an alternative quasi-steady approach of predicting the maximum dynamic stresses during load rejection is presented and validated against prototype measurements. The method involves a one-way fluid-structure interaction simulation with pressure loads obtained from an unsteady CFD simulation performed at the guide vane opening corresponding to the maximum speed during the load rejection. At this speed, the runner is momentarily in a no-load condition, and measurements show that the dynamic stresses are at a maximum. With this approach, it is shown that the maximum dynamic stresses are well predicted during a load rejection. Given the high level of uncertainty in the measurements and the stochastic nature of load rejections, it can be concluded that the approach gives conservative and satisfactory results, thus validating the quasi-steady assumption.

1. Introduction

A load rejection (LR) occurs when there is a disconnection of the generator from the electrical grid. Subsequently, the runner (Rn) in a hydraulic turbine will accelerate and trigger the guide vane (GV) closing sequence. Once the maximum speed $n_{max,LR}$ is reached, the runner will experience a no-load condition before starting to decelerate. No-load conditions are known to be rich in dynamic behaviour and can significantly affect the life expectancy of hydraulic turbines [1, 2, 3].

With the change in demand in the energy market, transient events such as start-ups, shutdowns and LRs, are becoming more frequent. Such events are often the source of the largest stress cycles and can have a significant impact on the runner's life [4]. A single start-up by a Francis or propeller runner can be more damaging than operating a full day at speed-no-load (SNL) or deep part load (DPL) [2, 5]. While start-ups occur more frequently than LRs, they can be both critical to the runner's life expectancy. It is documented in [6] that in Francis runners, LRs could generate higher dynamic stress ranges than any other operating condition, including start-ups. One of the runners analysed in this paper is shown in Figure 1, which compares the measured strain during a LR versus a start-stop cycle. The figure shows that the strain ranges during the LR are significantly larger than the entire start-stop cycle.