Analysis of the modal behavior of a Francis model with different sensors

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ABSTRACT

The interest in determining the dynamic characteristics of hydraulic turbines has increased in the last years. Due to the harsher conditions in which hydraulic turbines are operated and the detrimental effect of resonance on their structural integrity, it has become of utmost importance to locate the runner natural frequencies in operation.

The modal characteristics of a hydraulic runner depend on different parameters, such as the connection to the shaft, the surrounding fluid, the distance to nearby walls, etc. Thus, a thorough analysis must be carried out to determine the effect of each parameter. In operation, the modal characteristics of the turbine also experience some variations due to the rotation and hydrodynamics of the fluid surrounding the runner. Even though numerical simulations can provide a good orientation on the location of the frequencies, it is mandatory to undertake experimental measurements on the turbine to determine the natural frequencies in actual operating conditions. These campaigns usually require the installation of sensors such as strain gauges on the runner, which provide an accurate record of the frequencies excited but are costly to install and can only be used for a short period of time. Therefore, the use of external sensors is becoming of more and more interest when it comes to assessing the dynamic behavior of hydraulic turbines.

In the work presented here, the modal behavior of a reduced-scale Francis turbine has been studied. In addition, the feasibility of detecting the natural frequencies with sensors located at different external locations has been investigated. The modal analysis of the runner has been carried out with numerical simulations and experimental measurements. The natural frequencies and mode shapes have been obtained in air and in water, and the effect of the boundary conditions has been determined with the runner installed inside the turbine housing. Next, the capability to determine the main frequencies and mode shapes of the runner with sensors located at various locations of the test stand has been investigated in still water and in operation. Finally, the relevance of each sensor in detecting the natural frequencies of the runner is discussed.