Numerical study on pressure fluctuations in a variable speed pump-turbine with head variations

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Abstract.

Grid regulation capacities of Pumped Storage Hydropower Plants (PSHPs) are of great importance for today's and future power supply systems. In this context, variable speed technologies provide solutions for enhanced operational flexibility of PSHP units. Especially for turbine operation with variable head and part load conditions, the adaptation of the rotational speed offers benefits in terms of hydraulic efficiency, mitigation of pressure fluctuations and accordingly the fatigue behavior of hydromechanical components. The present work deals with numerical assessments of the pressure fluctuations on the runner of a 5 MW reversible Francis pump-turbine prototype equipped with a Full Size Frequency Converter (FSFC). The study aims to asses the impact of head and rotational speed on the pressure fluctuations at different load levels. Three power levels with a speed variation of ± 12% are investigated by single phase unsteady CFD simulations considering two different net head values with a variation of 20%. The numerical results give some insights on the scalability of the pressure fluctuations on the runner at the different operating conditions. It is demonstrated that rotor-stator interaction (RSI) related fluctuations are well scalable. Important transposition errors are found for low frequency fluctuations and stochastic content which is partially explainable by the limited statistical information provided by the numerical results. Finally it is shown that important mitigation of the pressure fluctuations can be achieved at deep part load conditions thanks to variable speed.

1. Introduction

The need for enhanced balancing capabilities of hydropower plants embedded in modern electricity grids, that are subject to growing volatile energy providers, is of great actuality. The demonstration of different flexibility technologies like variable speed is performed in the framework of the XFLEX HYDRO project [1]. A 5 MW reversible Francis pump-turbine with Full Size Frequency Convert (FSFC) located in the Z'Mutt pumping plant represents one demonstration case for variable speed technology. Francis turbines may be optimized in terms of efficiency, lifespan and flexibility enabling variable speed operation [2]. New FSFC technologies are promising for application in power ranges up to a few hundred MW [3]. Advantages of variable speed Francis turbines regarding mitigation of pressure fluctuations and improvement of hydraulic efficiency are studied by Iliev [4] and Heckelsmueller [5]. Pressure fluctuations and cavitation phenomena in variable speed Francis turbines are numerically investigated by