Damage prediction of turbine start-up sequence of a full size frequency converter variable speed pump-turbine using transient stress signals

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Abstract. Hydropower plants have a high ability to control the stability of the electrical power system, since they are dispatchable energy sources and have a fast response time for providing ancillary services. Therefore, they are key players to guarantee the energy balance of renewable power systems being deployed today. It is well-known that these ancillary services lead to an extended and flexible operation of hydraulic machines, resulting in accelerated degradation of the mechanical components. The number of start-ups and stops is significantly increasing, and, therefore, the assessment and forecast of the damage of a specific start-up sequence is an essential stage to minimize the impact on the lifetime of mechanical components. This paper presents a method for predicting the damage of a start-up sequence by using stresses measurements on the runner blades. Reduced-scale model tests of a Francis-type pump-turbine under transient and steady state conditions have been performed at EPFL Technology Platform for Hydraulic Machines. These experimental measurements include on-board runner strain gauges and pressure fluctuations sensors which are used to build a transient signal map by means of discretized transient signals and predict the runner damage. By using this transient mapping method, the cumulative runner damage can be forecasted while recombining the entire time stress signal of a start-up sequence by taking into account the mean stress value, which is one of the parameters influencing the total damage of the runner. The preliminary results with the proposed method predict a fairly accurate shape of the stress signal in the time domain of a given start-up sequence. Additionally, it predicts the damage runner's order of magnitude by using standard stress-life cumulative damage calculation. This study is part of the European innovation project XFLEX HYDRO, which aims to demonstrate the flexibility of hydropower plants, such as the Z'Mutt 5 MW reversible Francis-type pump-turbine variable speed unit equipped with a Full Size Frequency Converter (FSFC), which is used as case study in the framework presented in this article.

1. Introduction

In order to meet the European Union's decarbonization targets by 2050, the electricity supply system will have to adapt strongly to the dynamics of variable renewable energies [1]. These energy productions are stochastic and non-dispatchable, which implies challenges in terms of managing the stability of the power network. The European XFLEX HYDRO H2020 project aims to demonstrate, using new approaches, the control and flexibility capabilities of hydroelectric power plants and, consequently, their key role in the future electricity supply system [1]. The Z'Mutt pumping station in Zermatt, Switzerland, which is part of the Grande Dixence hydroelectric power plant, feeds the reservoir of Lacs des Dix, has