Assessing the mileage reduction of a Kaplan turbine hybridized with a battery using digital twins

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Abstract. Kaplan turbines are well suited for the provision of frequency containment reserve (FCR) to the electrical power system thanks to their adjustable guide vanes and runner blades, allowing to quickly regulate its power output while maintaining high efficiency for different flow rates and heads. However, continuous power regulation, induces a heavy load on the actuator mechanism of the moving parts, leading to a significant increase of the wear and tear. The integration of batteries with hydropower turbines has gained attention as a promising approach to reduce the amount of movements in the regulation servomotors by advantageously splitting the load between the Battery Energy Storage System (BESS) and the hydraulic unit when providing FCR service. To demonstrate this approach, one of the four Kaplan units of Vogelgrun Run-of-River (RoR) power plant which has been hybridized with a small size battery within the frame of the XFLEX HYDRO H2020 European research. The battery is used to compensate for small fluctuations in the frequency of the power network by supplying or absorbing active power while working in tandem with the hydro unit through a dedicated control algorithm. However, assessing the actual mileage reduction of the hybridized Kaplan turbine is challenging due to the constantly changing operating conditions and grid frequency, such that comparing between days with and without the BESS in operation proved to be inappropriate. In this study, the use of digital twins for mileage reduction assessment is presented. Several 1D SIMSEN numerical models of the hydropower plant were created, including the hydraulic system dynamics and the turbine governor system. These models were then run in real time, using the grid frequency and reservoir levels of the real unit, to accurately simulate the behaviour and performance of the hydro unit in different operating modes, such as standalone, hybrid, or without FCR. This allowed an effective comparison of the performance of the hybrid mode and the associated control algorithm. In addition, digital twins can also be used to predict the system dynamics and performance, enabling a more efficient and cost-effective optimization of the regulator parameters as well as benchmarking of different hybrid control strategies.