Machine learning for transient test sequences in closed-loop hydraulic turbine rigs: optimization of pump operation for stable head

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Abstract. This study utilizes machine learning methods to alleviate head oscillation and shorten the response time during start-up sequences of a Kaplan turbine in a closed-loop test rig. A large amount of experimental data is collected from the test rig. Artificial neural networks (ANNs) are implemented to describe the non-linear relationship between the head, and other operational parameters, such as pump speeds, guide vane opening, etc., during the transient start-up sequences. Then a proportional-integral-derivate (PID) controller is designed to optimize the pump speed operation under a fixed runner blade angle and predetermined change of guide vane opening during the start-up sequences. With the help of the ANN prediction model and the PID controller, a proper pump speed operation is recommended to alleviate head fluctuations. The numerical results are validated and compared against the experimental data in terms of accuracy and usability. The pros and cons of the proposed method are also discussed.

1. Introduction

With the rise of intermittent renewable electric energy sources, such as wind and solar power, hydropower plants (HPPs) have become an important asset for grid balancing and support [1]. It means that hydroelectric turbines need to frequently change their operating conditions, resulting in transient sequences that can cause more wear and tear on the units [2, 3]. At the design stage and for specific studies, hydro turbines are tested in hydraulic turbine rigs. Such tests are traditionally conducted at stationary operating conditions. However, due to the new role of hydropower, there is a need also to perform studies during transient sequences, and today more test rigs are upgraded and adapted for testing transient turbine sequences [4, 5].

In a closed-loop hydraulic turbine rig system, the model turbine is usually installed between two tanks, i.e. an upstream and a downstream tank, where both tanks communicate with one or several pumps. Transient test sequences pose a challenge, as any change in the turbine settings will influence the entire system. A change in the turbine settings requires a corresponding change in the pump speed settings to keep the head constant. The inertia of the water passing through