On the flow-induced pulsating forces during load rejection of a Kaplan turbine model

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Abstract. Intermittent renewable energy sources have become a significant part of the electric grid in the last few decades. With their implementation into the energy system and varying electricity demands from the market, certain challenges in maintaining a stable electric grid have arisen. Hydropower here finds an important role in the stabilisation of the grid with its possibilities to regulate frequency and power. However, this causes hydropower to operate in transient modes more frequently. Consequentially, more studies are necessary in order to safely operate the turbines during transients, to plan maintenance, and to predict the lifetime of the hydropower plants and the costs associated with new operating circumstances. There has been an extensive series of studies on transient operation of Francis turbines and pump turbines in recent years. However, transient operation of Kaplan turbines needs more in-depth studies. Therefore, the present work is focusing on the formation of oscillating flow structures and the evolution of the resulting flow-induced forces during load rejection of the U9-400 Kaplan turbine model. The study of the flow field is performed using the OpenFOAM open-source CFD code. The flow-induced horizontal and axial forces, and consequential bending moments and torque acting on the runner are analysed together with the flow structures forming in the draft tube at the best efficiency point (BEP) and at part load (PL).

1. Introduction

The world's energy demand has been growing continuously in the last years, which combined with the recent energy crisis [1] results in the extensive installation of new power plants that use intermittent sources of energy like solar and wind. This causes instabilities in the electric grid, which is why controllable energy sources need to be used in order to stabilise the grid. Since hydropower is a renewable and controllable source of energy, it will be used more often to maintain the stability of the grid. This means that hydro turbines have to be more flexible [2] and work with variable loads, while they were designed to continuously operate at their best efficiency point (BEP). This can negatively affect the lifetime of the machines. Consequentially, more studies are necessary to predict the effects on the machines during transient operation. Computational Fluid Dynamics (CFD) provides a possibility to simulate the flow in the turbines during transients. Extensive research studies have in recent years been reported on CFD simulations during transient operation of Francis turbines [3, 4, 5, 6, 7, 8] and pump-turbines [9, 10, 11]. However, there is still a need for in-depth studies of transients in Kaplan turbines. For this purpose, we have recently developed an open-source framework for performing numerical studies of transient operation of Kaplan turbines [12, 13].