Temporal interaction of water hammer factors during the load rejection regimes in a hydropower plant equipped with Francis turbines

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Abstract. The modernization of hydropower fleets is a strategic goal leading to several benefits in terms of the power generation, flexibility and safety operation. The transient regimes (e.g. start-up procedure, load rejection, speed-no-load, and so on) shorten the lifetime [1], increase hydropower plant operation costs and produce power generation loss [2]. Therefore, the objective of this study is the analysis of the temporal interaction between the factors during the load ejection of the Francis turbines. The approach aims to identify transient hydrodynamic phenomena, especially in the framework of operating hydropower units equipped with Francis turbines as main regulating factor for the electrical grid. The investigations focus on evaluating the maximum pressure generated in the hydraulic pathway and comparing them with the admissible pressure value. Thus, the influence of certain physical factors identified in the flow passing through the turbine operated in transient regimes is explored. Also, the effect of some operating parameters of the hydropower plant on water hammer generation was examined. The investigation is based on the analysis of the experimental data connected with the analytical calculation of the maximum overpressure and a numerical simulation of the temporal interaction between the factors. The phenomena associated with the emergency shutdown (load rejection) of the Francis turbine from different wicket gate openings (e.g. 100%, 75%, 50% and 25%WG) considering the same wicket gate closing slope are analysed. The conclusions are drawn in the last section together with a few recommendations to reduce the overpressure with a direct impact on the required maintenance, lifetime of the hydropower unit and the safe operation of the equipment.

1. Introduction

Lately, with the advent of different types of renewable energy (e.g. photovoltaic panels, wind turbines) the demand on the electrical grid has changed significantly. Consequently, Hydraulic Power Generators (HPG) are increasingly required for flexible operation to regulate the grid and to compensate the lack of availability and flexibility of these alternative energies [3].

In order to equilibrate the grid, the HPG are operated more often in transient regimes (e.g. start-up procedure, load rejection, speed-no-load, and so on) leading to a diminished lifetime of the units [1], increased operational costs and additional power generation losses [2]. To meet these challenges, the

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