Flat free runner with outer ring for reducing the hydraulic instabilities developed in the discharge cone of a Francis turbine.

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Abstract. When the Francis turbines are operated far from the best efficiency point, the decelerated swirling flow from the discharge cone leads to the development of the so-called vortex rope. The development of the vortex rope is accompanied by high pressure pulsations in the draft tube cone and usually hinders the stable and safe operation of the hydraulic turbines.
The paper proposes a practical solution in order to diminish the influence of the vortex rope by using a flat free runner mounted downstream the main Francis runner and at the inlet in the discharge cone. The new approach assumes that the flat free runner it has no main shaft, instead it has an outer ring mounted to support the blades. The interior shaft was removed in order to direct the main flow in the centre of the discharge cone and eliminate the development of the vortex rope. The paper concentrates on validating the new concept by using the 3D numerical simulations. The development of the vortex rope is investigated for two cases: without and with free runner with outer ring. Further, the FFT pressure pulsations and the pressure recovery induced by the flat free runner are analysed, to determine how they influence the operating point of the hydraulic turbine.

1. Introduction

The development of solar and wind energy introduces in the electrical grid large energy fluctuations. For compensating the excess or the deficit of energy, the hydraulic powerplants remain the only capacities able to perform this task [1]. However, recent developments in the research stage, propose the hybridisation of hydraulic turbines with batteries, for a fast response in the electrical grid and protect the mechanical components, [2]. For hydraulic turbines the energy compensations means the operating of the hydraulic runner at variable flow rates, from deep part load operations up to full load operations, [3][4]. The operations of the hydraulic turbines at part load, involves the development at the outlet of the runner and the inlet in the discharge cone, the formation of the so called the vortex rope, which is usually accompanied by high pressure pulsations and vibrations, [5].
Different control techniques have been tested and implemented in powerplants for diminishing this phenomenon. Active control technics as air or water injections thru various zones of the hydraulic turbine were investigated [7][8]. Passive control techniques have been studied also, [9], by using radial rods in the discharge cone of the hydraulic turbine. However, both passive and active control technics have some advantages and drawbacks as presented by Kougias et al. [1].
The concept of the free runner, is relatively a new idea, and is found in the hydraulic machinery domain in [10] who implemented a stay apparatus downstream of a Francis runner and [11] where it was studied numerically. Recently Bosioc et al [12] studied in the laboratory the possibility of mounting the free runner at the inlet in a discharge cone and how the geometry of a simple free runner with straight blades influences the decelerated swirling flow.
The research on this paper proposes a new free runner, more precisely a flat free runner with an outer ring. For the flat free runner with outer ring the main shaft is missing, in order to redirect the main flow