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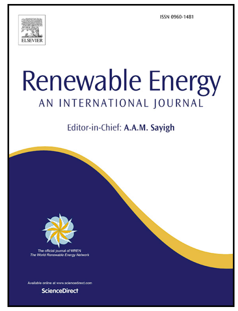

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Numerical Analysis for Detecting Head Losses in Trifurcations of High Head in Hydropower Plants

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Abstract. *Many different types of branching have been developed, such as bifurcation, trifurcation, and manifolds, among others. These configurations are used in penstocks to transport water from surge tanks to power houses in order to feed several turbines at the same time. This arrangement allows for smaller assembly costs in comparison with independent penstock systems. Nevertheless, such installations can generate higher head losses in the system in comparison with single systems. This study focuses on the quantification of these head losses as a function of volumetric flow rate using Computational Fluid Dynamics (CFD) and later validated with previously published results. To determine the coefficient of head losses three mesh settings were analyzed: hexahedral, tetrahedral and hybrid, for both a steady state and transitory flow. Based on the literature, the k-ω turbulence model was used, with refinement to elements near the wall to check y+. To the simulation transitory, the SAS model was used for analysis of the instability in the trifurcation.*

Keyword: Trifurcation, CFD, Loss coefficient, SAS, Transient

1. Introduction

Extensive research has been carried out in order to quantify losses in adduction systems, particularly in the high pressure components of hydroelectric plants in order to maximize their performance. Common types of branching seen in studies are bifurcations, while a few studies have looked into trifurcations in penstocks. This can be attributed to the uneven flow at the turbine entrances and higher variable loss coefficients. It is important to note that turbine performance depends on the flow behavior on the penstock, and therefore the research on trifurcations could be made through numerical or experimental analyses to provide vital information for an appropriate turbine design. In hydroelectric plants that only use one penstock, it is essential to use branches for the flow distribution of the hydraulic machines. Three geometric configurations of the ramifications are mainly used in penstocks; bifurcations, trifurcations and manifolds. The bifurcations and trifurcations can be classified into two categories based on the geometry employed, considering the structural advantages. The first geometrical arrangement is comprised by trunk cones which intersect in the middle of the branches, while the second geometry uses a sphere between at the branches.

Both geometrical arrangements need to be designed carefully to enable an even flow, avoiding excessive pressure drops, vibration and cavitation [1]. Other important design aspects to take into account for the pressure loss are the geometrical supports that reinforces the branches, the branching angles, the transition between the penstock and the branches (expansion and contraction). It is important to highlight the relationships between these design aspects and the construction limitations.

An early research study focused on the analysis of load losses caused by the geometric variations of branches in a pipe, and was carried out by Petermann cited in Mayr [2]. Gladwell and Tinney [3], conducted a study of the trifurcation of Round Butte project of 367 MW in the United States. Cone trunk geometry was analyzed through several tests applying changes to the input conditions by changing the flow and output for each branch, the branch being kept open or closed. This study enabled the detection of vortex formations due to the separation of the boundary layer in the clearance section of the lateral branches, so it was possible to obtain the pressure drop curves in the various settings. The results of the coefficients in the xxx configuration were in the range from 0.45 to 0.55 for the side branches, and from 0.37 to 0.47 in the central branch. The symbol xxx, was based on the reference from Gladwell and Tinney [3], representing the situation with three open branches and xox represent the lateral branches opened and the central closed (x = opened, o = closed)