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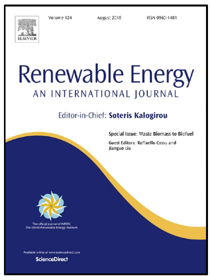

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Unsteady Flow Characteristics Regarding Hump Instability in the First Stage of a Multistage Pump-Turbine in Pump Mode

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Abstract: This article reports the fluid-dynamical analyses of unsteady flow in the first stage of a multistage pump-turbine where hump instability occurs. This stage can be seen as a centrifugal pump with multistage guide vanes in pump mode. Experimental and numerical approaches are adopted to contribute the understanding of the highly complex flow regime inner the test pump. In the experimental test, both dynamic pressure measurement and flow visualization techniques are adopted. A commercial code with detached eddy simulation (DES) model is used to compute the flow regime. The frequency analysis indicates that two unsteady flow patterns with a constant frequency occur in the hump instability region. The numerical and experimental unsteady flow fields are analysed to study the fluid-dynamical features of these unsteady patterns, in order to investigate the origin and reveal their contributions to the hump instability.

Keywords: Unsteady Flow, Return Channel, Pump Mode, Hump Instability, Pump-Turbine

1. Introduction

With the development of variable renewable energy power generation and the demand of improving the stability of power grid, the pumped hydro energy storage (PHES) is increasingly playing an important role in power system worldwide [1-4]. Due to the intermittent nature of renewable energy power generation, reversible pump-turbines, as the key device of PHES, are supposed to change their operating condition quickly and frequently in order to meet the fluctuations of the power load. In such case, pump-turbines should have better flexibility of the operating, and wider operating range[5]. Hump instability in pump mode and S-shaped characteristic in turbine mode, as unique instabilities in pump turbines, are becoming more severe to restrict the flexibility and stable operating range.

In pump mode, hump instability presents a positive slope at the head-flow curve (${}^{dH}\!/_{dQ}>0$), and energy transferred to the fluid does not contribute to the head rise, but dissipates and gives a rise of unsteady flow patterns such as vortices, rotating stall and so on. This instability not only affects the start-up and operation of pump turbines under high head conditions, but also leads to strong vibration and noise, affecting the safe and stable operation of the unit [6]. The results show that the backflow regimes at the impeller inlet, which is called part-load whirl (PLW), may lead to hump instability on the performance curve under part load condition. Furthermore, for the centrifugal pump with vaned diffuser