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Increase of the Annual Energy Output in Hydraulic Powerplants through Active Flow Control

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Abstract

Traditionally, hydraulic powerplants have been strongly contributing to energy generation. At present, with the expanding participation of other non-storable renewable energy sources in the electrical market composition, water turbines can importantly contribute to the electrical grid stability and to energy storage. With the increasing demand for such services, new procedures have to be developed, in order to allow the hydraulic turbines to operate in critical load conditions, as part load, for example. The technique proposed here, based on pitching guide vanes, was numerically tested with instationary CFD models and delivered possibly promising results, concerning the machine performance and stability, at part load conditions. The extension of the operating range of hydraulic powerplants, through the turbine active flow control, yields even greater flexibility to them in providing regulation services to the electrical grid. This technique has also the potential to extend the operational life of main turbine components and may lead to the increase of the annual energy output in some cases.

Keywords

Hydraulic turbines, instationary fluid flow, active flow control, turbulence modelling, numerical simulation.

1. Introduction

Waterpower corresponds to one of the earliest sources of renewable energy in commercial use. Still current days, it corresponds to an important part of the installed energy generation facilities, ranging from small complexes with less than 1 MW up to Itaipu, in Brazil, and Three Gorges, in China, with rated capacity of, respectively, 14,0 GW and 18,2 GW and annual energy output of, respectively, 91,6 TWh and 79,4 TWh in 2009.

Most recently, with the increasing demand for clean energy sources, hydraulic energy appears once again as an interesting solution. In the current context of the energy market, where other renewable energy sources, such as wind and solar energy, enjoy increasing market shares, the hydraulic powerplants offer a very attractive solution for grid stabilization and energy storage. The energy output of wind and solar energy parks is influenced by variations of the weather conditions, sometimes producing more or less energy as in the moment needed and introducing a strong dynamic component in the electrical grid. With their increasing importance, their impact on the grid tends to be even greater, as well as the need for regulation and storage services. Hydraulic turbines can efficiently supply this dynamic balance to the electrical grid and in a faster way than traditional thermal plants. However, with the increasing need for such services, water turbines must also offer increasing flexibility.

At this point, it comes to the current challenge in the design of water turbines. The operating range of the hydraulic plants must be extended, in order to offer more possibilities in the regulation of energy generation as whole. It means, that the turbines must be able to be smoothly operated along a larger portion of their hill chart than in the past. Common customer requirements for modern water turbines are, for example, that they shall be capable to operate at deep part load, sometimes even considerably below the half of their rated power.

At deep part load in hydraulic turbines, with less than 60% of the optimal flow, $Q < 0{,}60\,Q_{\mathrm{opt}}$, strong pressure pulsations, with amplitudes up to 10% of the nominal head, may arise in the machine, typically due to the formation of an oscillating vortex rope in the draft tube cone. The pressure pulsations are diffused through the hydraulic active parts of the turbine. In the case of strong pressure oscillations, they may affect