FLOW
INSTABILITIES & DYNAMICS
TECHNISCHE UNIVERSITÄT BERLIN

MASTER'S THESIS: Physics-based and data-driven analysis of the vortex rope in a Francis turbine to optimize current flow control methods

The increasing share of renewable energy sources such as wind and solar power entails an increasing volatility of the energy grid due to their intermittent nature of energy supply. This imposes additional requirements to the remaining power plants that need to operate and respond much more flexibly. Hydropower plants offer a sustainable way to compensate for the volatility, which requires the plants to operate at off-design conditions more frequently. A large number of hydropower plants are operated with Francis turbines that are designed for one specific best efficiency point at full load. At part load conditions, the flow inside the draft tube undergoes vortex breakdown, which may support a vortical flow instability called the vortex rope. The vortex rope generates strong pressure pulsations in the draft tube that are detrimental to the turbine efficiency and that can lead to hazardous structural vibrations and resonance. Therefore, a current goal pertaining to the design and operation of Francis turbines is the control of the vortex rope that allows for an extension of the stable operational range.

Figure 1: Cavitating vortex rope in the draft tube of a Francis turbine (Seidel et al. (2014). Dynamic loads in Francis runners and their impact on fatigue life. IOP conference series: earth and environmental science, 22(3), 032054)

In the present master's thesis, the **goal of optimizing current flow control methods** with regard to the vortex rope is pursued. **State-of-the-art physics-based and data-driven methods** are utilized for this optimization process, with the focus on **linear stability analysis** and **spectral proper orthogonal decomposition**. In order to identify the vortex rope, these advanced methods are applied to a flow field stemming from a large-eddy simulation of a realistic Francis turbine in a highly complex turbulent flow. Subsequently, an **adjoint analysis** is performed to identify the most receptive and sensitive regions of the vortex rope. Based on these results, current **passive and active flow control methods** can be optimized.

The master's student will work on a **highly relevant problem in the renewable energy sector**. She or he will profit from **an interdisciplinary research environment** that combines industry-relevant research with modern data analysis methods and fundamental physics-based concepts.

For any further questions, feel free to contact Jens Müller (jens.mueller@tu-berlin.de). If you are interested in working on this thesis, please attach a CV and a transcript of grades.