HSLU Lucerne University of Applied Sciences and Arts

**Engineering and Architecture**
B.Sc.. Energy and Environmental Systems Engineering
Bachelor-Thesis

# Numerical Analysis of a Water Pump-Turbine

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## 1. Introduction, Goals and Research Questions

Investigation of pumped hydroelectricity storage systems under unsteady flow conditions is essential for the safe and reliant design of such systems. Reversible pump-turbines, which often exhibit instable behavior under off-design conditions, are typically employed in such plants (Hasmatuchi, 2012, pp. 19-24).

In the following study, the characteristic maps of a pump-turbine are numerically reproduced, by means of Computational Fluid Dynamics (CFD) simulations. Furthermore, a transient load rejection case was setup.

This work provides a valuable base for future investigations of pumped hydroelectricity storage systems by means of 1D-3D coupled simulation environments.

## 2. Method Overview and Materials

The pump-turbine was investigated through Computational Fluid Dynamics (CFD) simulations.

The CFD solver used was internally developed by the Competence Center of Fluid Dynamics and Numerical Methods of HSLU, and is called *CoupledNumerics*. It is a pressure-based coupled solver, which solves the discretized Reynolds-Averaged Navier-Stokes (RANS) equations.

The machine geometry is based on the pump-turbine installed a powerplant in India, and was designed by Andritz.

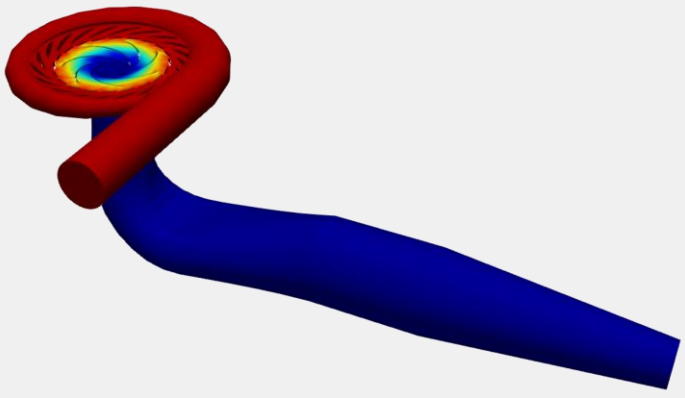

*Figure: Computational mesh of the pump-turbine*

The simulation results are compared with laboratory data obtained via experiments at the HSLU fluid dynamics laboratory.

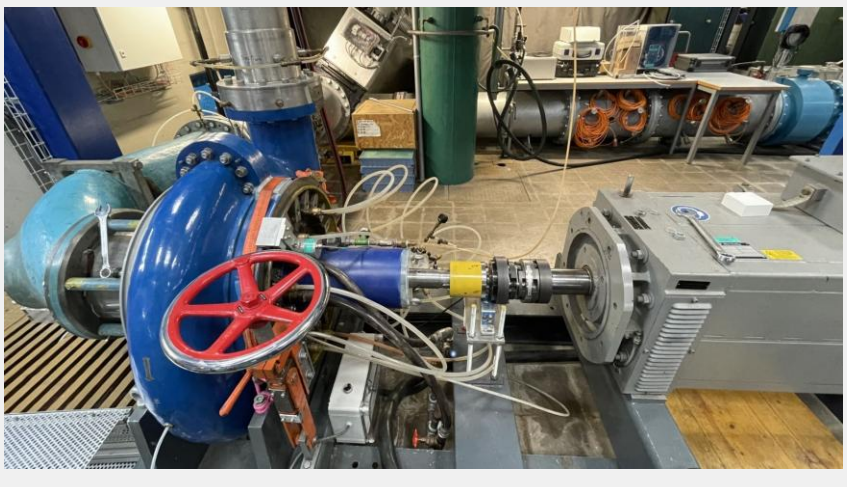

*Figure: Experimental setup*

Industry Partner: CCFNUM (HSLU)

## 3. Results and Discussion

The results show good agreement with the experimental data. Especially important was the selection of the turbulence model, which influences greatly the results

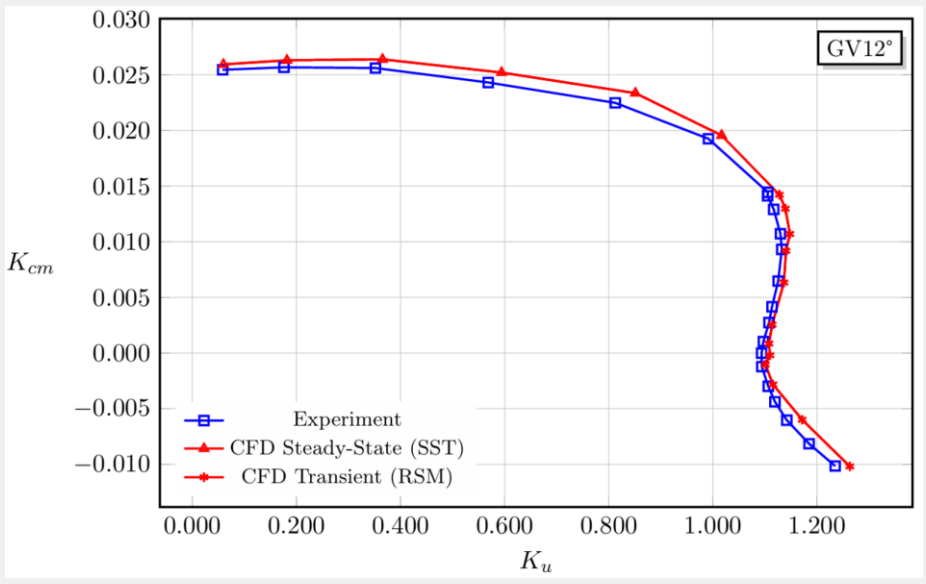


*Figure: Characteristic map for a guide vane opening angle of 12°*

Here, the Shear Stress Transport (SST) and the Reynolds Stress Model (RSM) turbulence models were used, which allowed for a correct representation of the machine behavior.

Above, the famous “S-Shaped” curve is shown. Such instable behavior of this machine is correctly predicted also by the simulations, which indicates a high fidelity of the results.

## 4. Conclusion and Recommendations

Pump-turbines can be successfully analyzed via CFD simulations, provided the appropriate turbulence model is used. Further work should focus on the coupling of 1D-3D simulation environments, to fully represent and investigate unsteady flow phenomena within a pumped hydroelectricity storage system. Such approach is shown in the figure below.

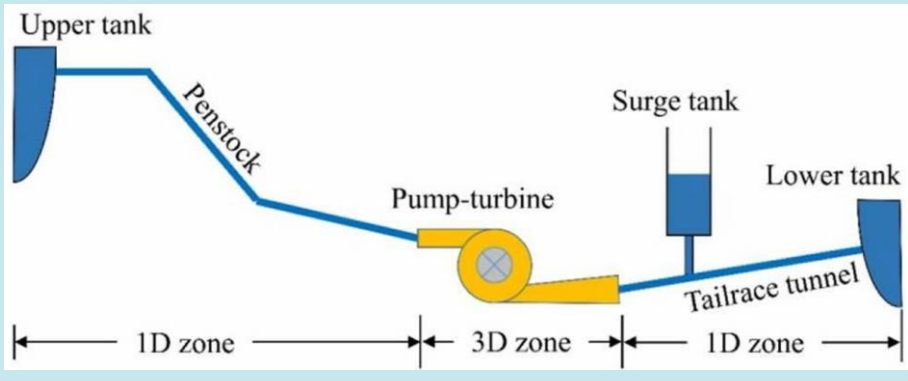


*Figure: Coupling approach of 1D-3D simulations*

## References

1.Hasmatuchi, V. (2012). *Hydrodynamics of a Pump-Turbine Operating at Off-Design Conditions in Generating Mode* (Thèse No. 5373, Doctoral dissertation, École Polytechnique Fédérale de Lausanne). EPFL Infoscience.

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