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Hydraulic development of high specific-speed Pump-turbines by means of an inverse design method, numerical flow-simulation (CFD) and model testing

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Abstract

In recent years an increased interest in pump-turbines has been recognized in the market. The rapid availability of pumped storage schemes and the benefits to the power system by peak lopping, providing reserve and rapid response for frequency control are becoming of growing advantage. In that context it is requested to develop pump-turbines that reliably stand dynamic operation modes, fast changes of the discharge rate by adjusting the variable diffuser vanes as well as fast changes from pump to turbine operation.

Within the present study various flow patterns linked to the operation of a pump-turbine system are discussed. In that context pump and turbine mode are presented separately and different load cases at both operation modes are shown. In order to achieve modern, competitive pump-turbine designs it is further explained which design challenges should be considered during the geometry definition of a pump-turbine impeller. Within the present study a runner-blade profile for a low head pump-turbine has been developed. For the initial hydraulic runner-blade design, an inverse design method has been applied. Within this design procedure, a first blade geometry is generated by imposing the pressure loading-distribution and by means of an inverse 3D potential-flow-solution. The hydraulic behavior of both, pump-mode and turbine-mode is then evaluated by solving the full 3D Navier-Stokes equations in combination with a robust turbulence model.

Based on this initial design the blade profile has been further optimized and redesigned considering various hydraulic pump-turbine requirements. Finally, the progress in hydraulic design is demonstrated by model test results which show a significant improvement in hydraulic performance compared to an existing reference design.