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CFD investigation of a Francis turbine to help the experimental measurements and the definition of start-up procedures

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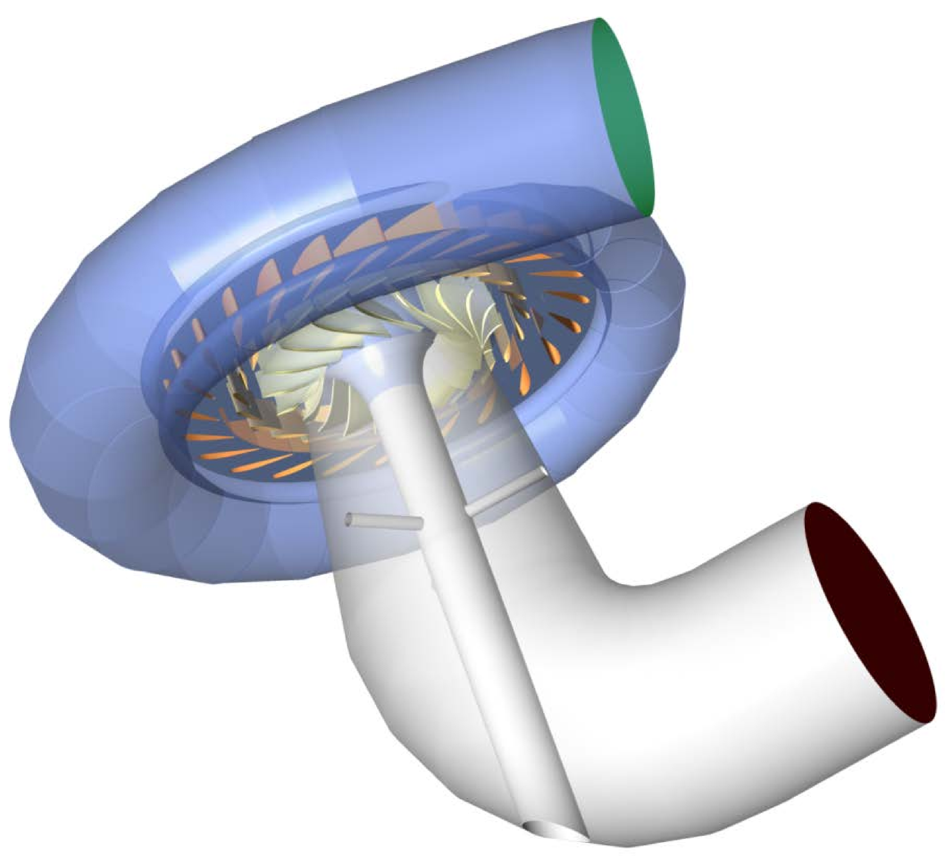
Motivation

Due to the development and the integration of renewable energies, the electrical grid undergoes instabilities [1]. Hydraulic turbines and pump-turbines are a key technology to stabilize the grid. However to reach this objective, the hydraulic machines have to extend their operating range. Such an extension requires to deal with start-up and stand-by operation, which often leads to a reduction of the lifespan of the machines [2].
Nowadays, numerical simulations reached a robustness allowing to investigate unstable operating points such as rotor/stator interaction, low head operating condition and start-up [3].
By coupling numerical and measurements investigations, several features can be drawn and solutions can be found to extend the operating range of the machine whilst the lifespan is weakly affected.

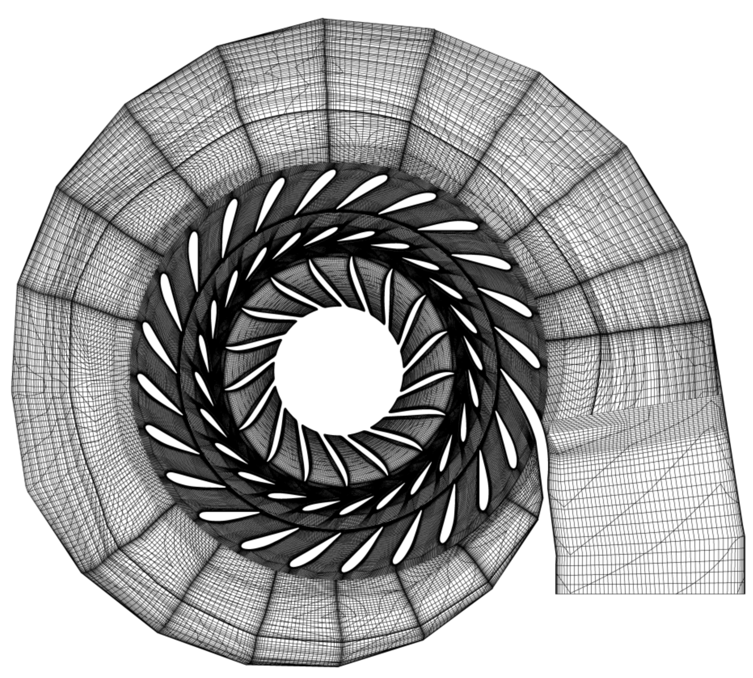
Test Case

The machines of hydropower plant Grimsel 2 is equipped with horizontal ternary units with a complete motor-generator coupled with a Francis turbine on one hand and a single stage radial pump on another hand.
The Francis turbine undergoes cracks at the junction between the trailing edge of the blades and the shroud. The cracks appeared after the operating conditions of the turbine changes from few stop and start per day to a large number of stop and start per day.
The origin of the cracks is however not yet understood.
The phenomenon responsible for the development of the cracks is investigated using numerical simulations to complete the experimental approach.



Numerical Set Up

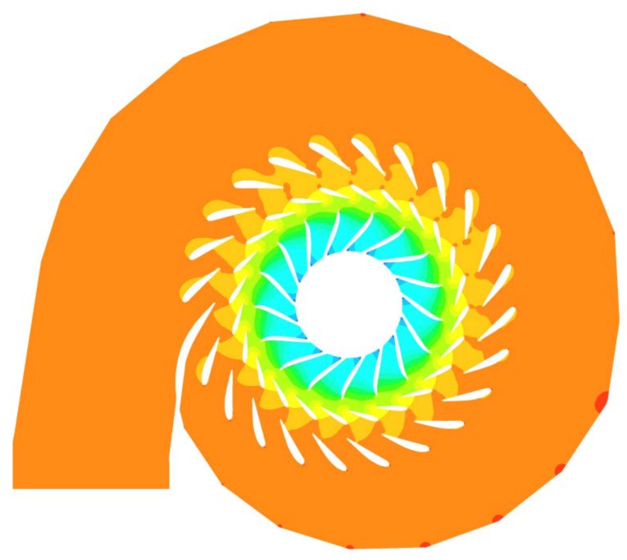
The computational domain takes into account the spiral case, the distributor, the runner and the draft tube. The tripod inside the draft tube is also considered.
An hexahedral mesh is generated for each part of the turbine and then put together.
Reynolds-Averaged Navier-Stokes simulations are performed using the SST k-ω model.
The operating points investigated are clustered around the best efficiency point. Both inlet flow rate or inlet total pressure boundary conditions have been considered.

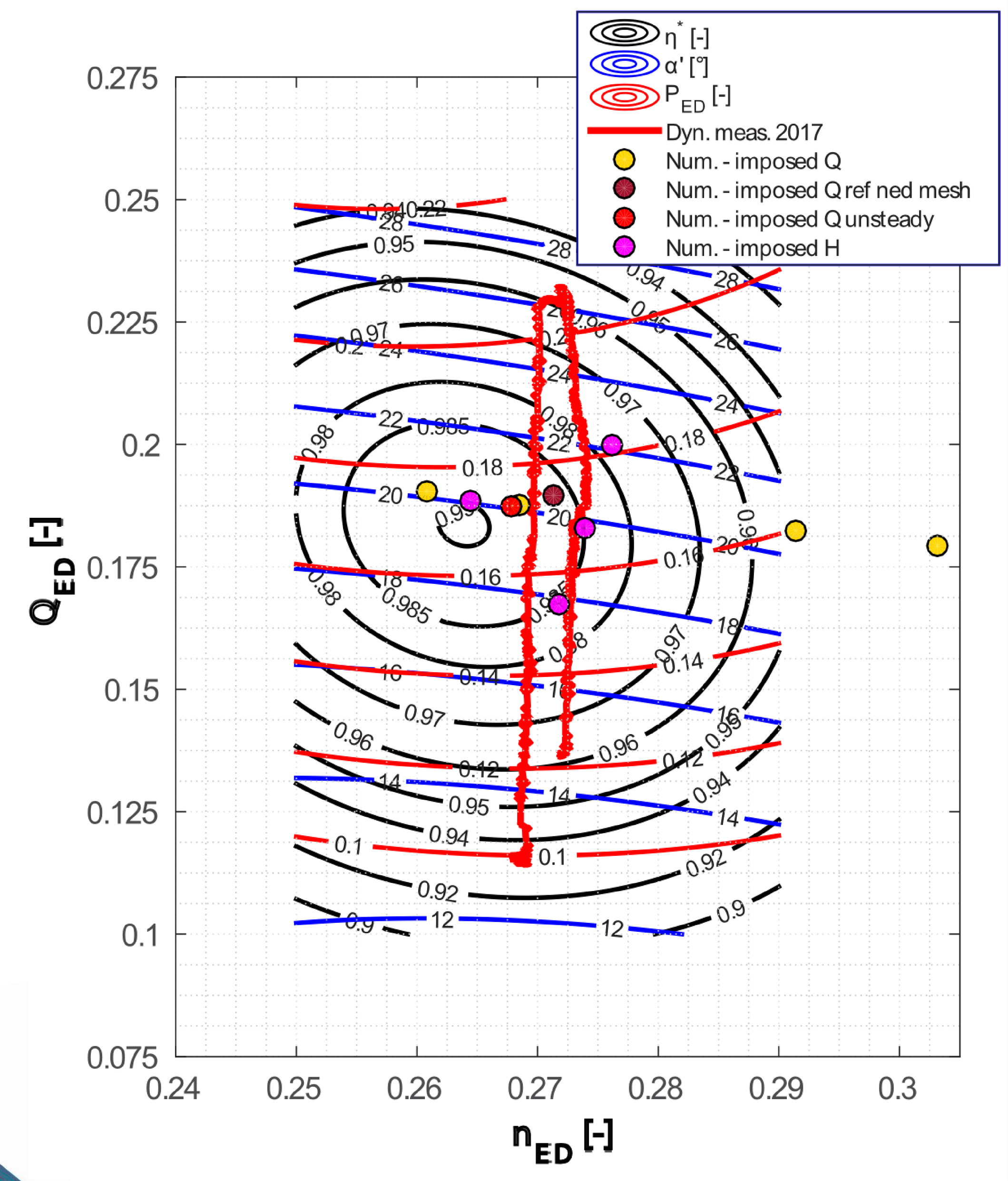


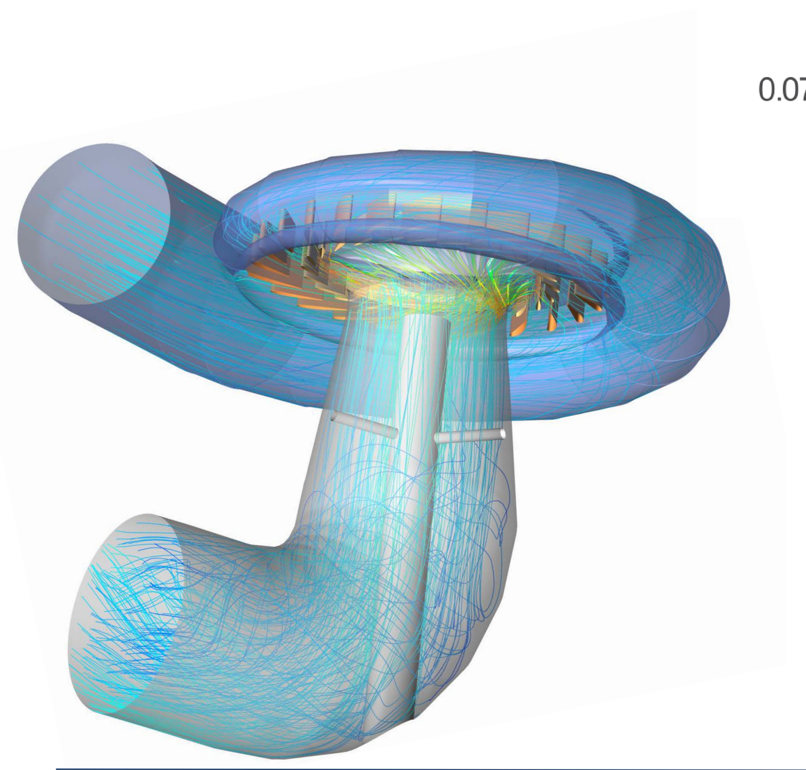
Results

The performance of the turbine predicted by the simulations are plotted on the hillchart of the Francis turbine. The agreement between the simulations and the measurements is good, whatever the operating points considered.

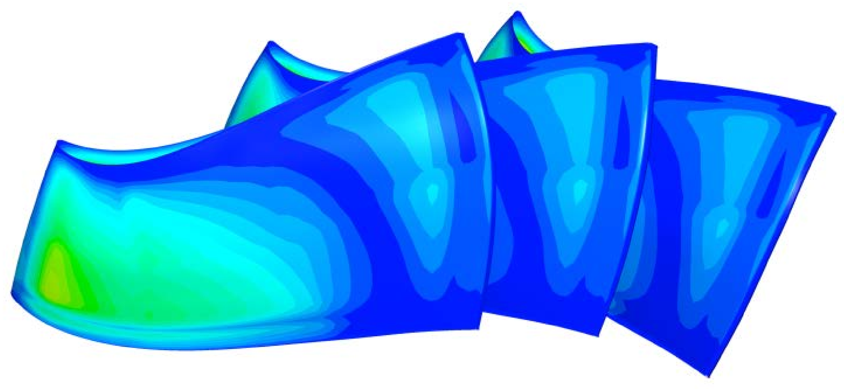
Pressure field







Blades Pressure field



Conclusions & Perspectives

The numerical simulations are able to predict the performance of the turbine for different operation points clustering the best efficiency point with a good agreement compared to the measurements.
Therefore, the confidence in the simulations will allow the investigation of unstable operating points mainly those corresponding to the start-up procedure of the turbine in order to determine the phenomenon responsible of the blade cracks.

References

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Acknowledgements

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