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CFD and FEM investigations of a Francis turbine at speed no-load

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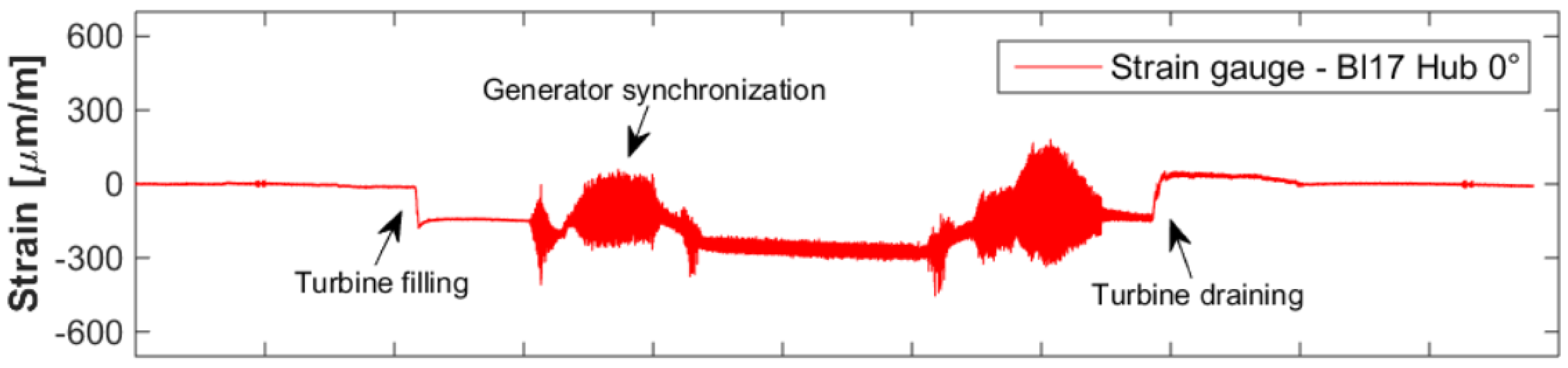
Motivation

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 operations, which often leads to a reduction of the lifespan of the machines [2].
Nowadays, CFD and FEM simulations allow dealing with fluid-structure interactions, which help better understanding of the life time of hydraulic machines [3].

Context

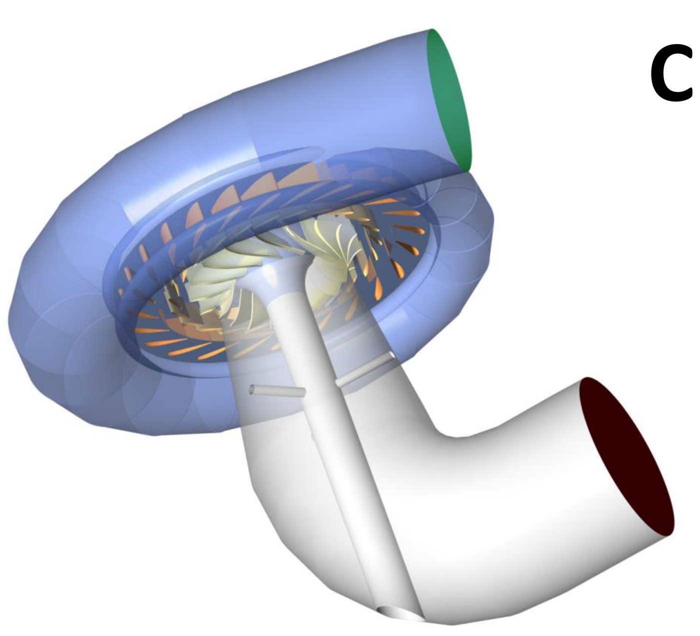
The Grimsel 2 hydropower plant is equipped with horizontal ternary units with a complete motor-generator coupled with a Francis turbine on one hand and a single stage radial pump on another hand.
The Francis turbine undergoes cracks at the junction between the trailing edge of the blades and the hub. The cracks appeared after the operating conditions of the turbine changed from a few to a large daily number of start and stops.
The origin of the cracks is however not yet fully understood despite the fact that the case has been already studied [4].
A recent measurement campaign put in evidence the large fluctuations of the strain rate at the trailing edge of the runner blades close to the junction with the hub during the operation of the turbine at speed no-load (*i.e* during synchronization procedure) [5].

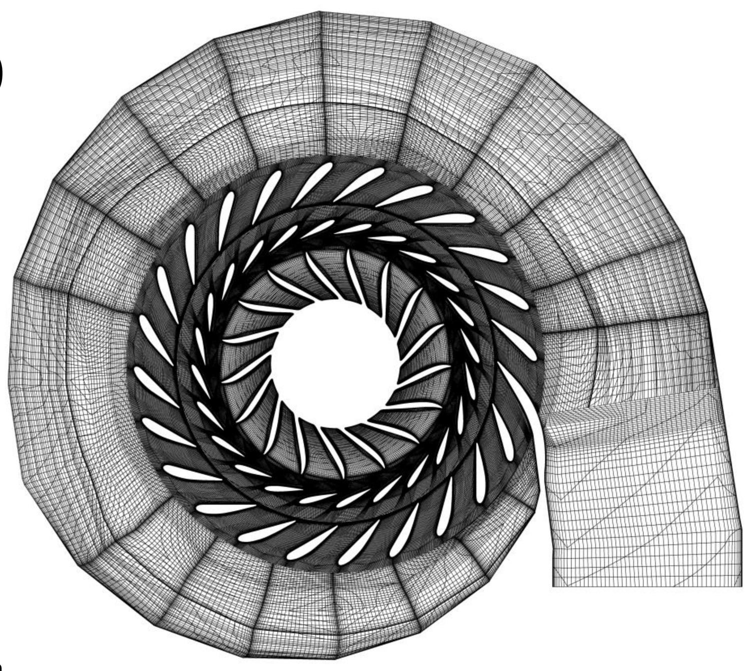


CFD and FEM set up

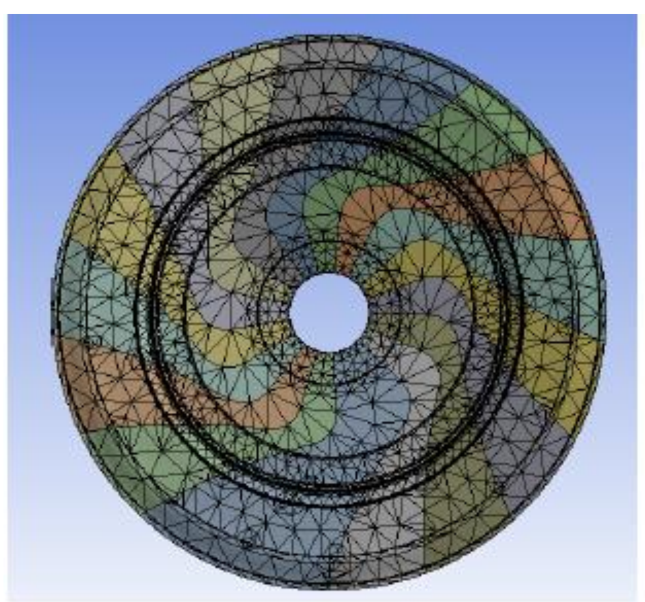
For the CFD analysis, the SST-SAS turbulence model is used to compute the flow. The inlet flow discharge is set at the inlet of the spiral according to the measured value at speed no-load.
For the stress analysis, the pressure field provided by the CFD simulation is applied on the runner blade, whereas no displacement is imposed at the junction between the runner and the shaft.
For the modal analysis of the runner, the surrounding water is taken into account in order to capture the damping of the natural runner frequency due to the added mass effect.

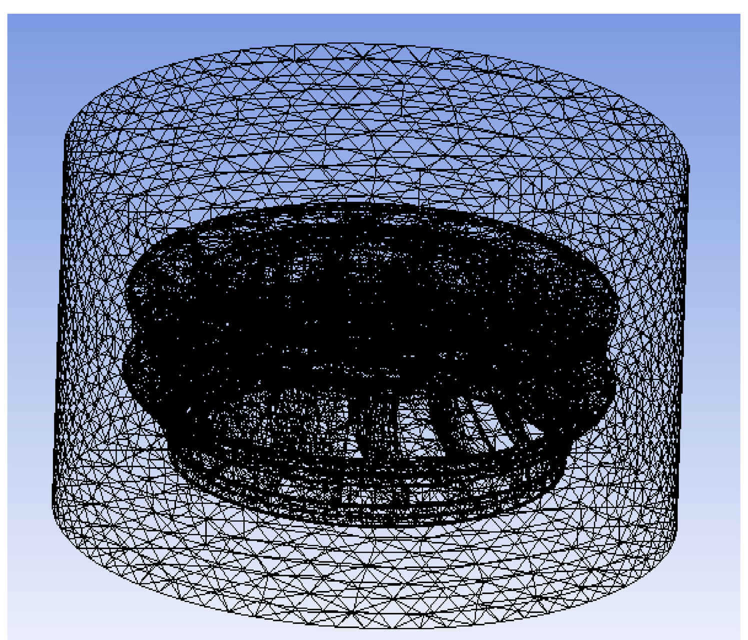
CFD





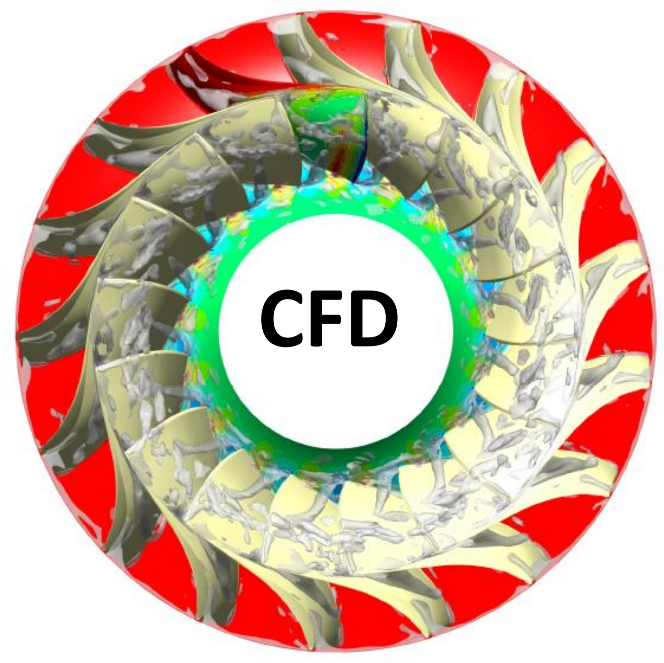
FEM

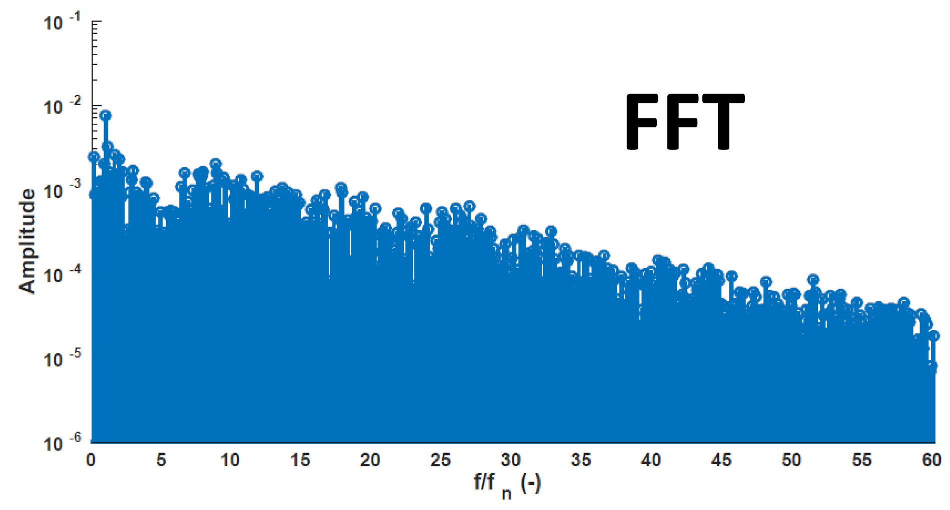


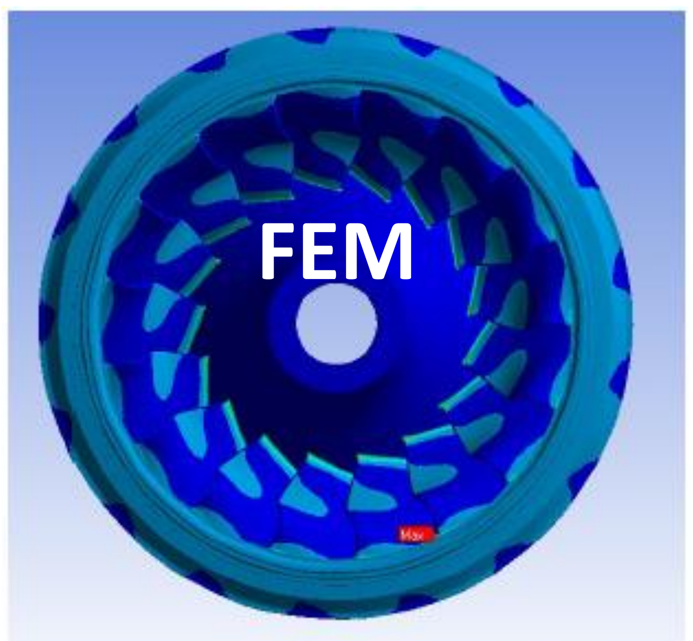


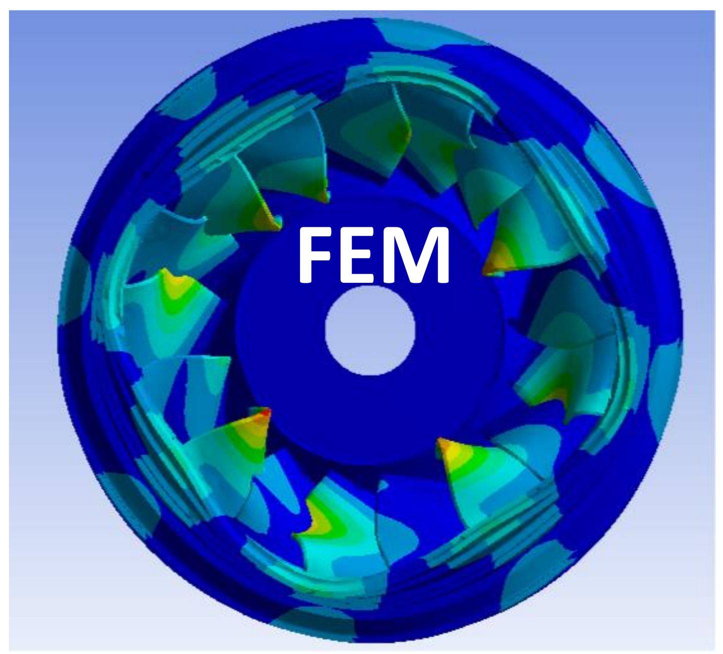
Results

The CFD simulation shows the presence of several vortices close to the trailing edge of the blade. The vortices lead to local pressure fluctuations. However, no specific frequency is observed on the pressure spectra of a probe located at the junction between the runner blade and the hub.
The stress analysis confirms that the maximum stresses are located at the junction between the runner blade and the hub.
The modal analysis put in evidence the existence of a natural mode of the runner around 600 Hz close to the dominant frequency deduced from the signal provided by the strain gauges.









Conclusions & Perspectives

The CFD simulation does not show any evident excitation at the frequency observed on the strain gauges. The FEM analysis confirms the weakness region at junction between the runner blade and the hub. The modal analysis suggests the existence of a natural mode of the runner close to the frequency observed on the strain gauges. Therefore, this mode could be excited by a source, which does not seem for instance clearly related to the fluid.

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