Thesis project:

Numerical study of the hydrodynamic instabilities at low opening in pump-turbines

Thesis supervision:

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Context:

This thesis is part of the NETHUNS project, an Industrial Chair supported conjointly by French National Research Agency (ANR) and General Electric Renewable Energy. The Chair is part of a close collaboration between the LEGI laboratory and the Center of Excellence in Hydraulics of General Electric Renewable Energy, both located at Grenoble. This collaboration aims to deal with various scientific and technological challenges related to the design of hydraulic turbines of the future.

To be able to use various intermittent renewable energy sources in the energy mix, hydraulic machines have to be used more and more frequently outside their initial design points, i.e. their best optimal efficiency point. This is particularly the case for Pumped-Storage Plants (PSP) using pump-turbines groups. Predicting the performance of these machines, for a wide operating range of operating condition, is therefore a crucial issue in terms of competitiveness.

For "out of design" operating conditions, pump-turbines can have undesirable effects, due to the development of hydrodynamic instabilities. In pump mode, the phenomenon is a combination of flow separation in the casing, and high incidence of the flow on the runner blades. It can lead to some instabilities during the operation of the pump with abrupt change of discharge and input power (see Figure 1).

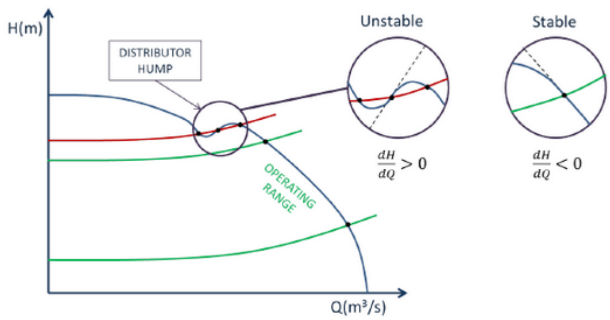

Figure 1 - Pump instabilities under high head

In an on-going PhD, it has been shown that the phenomena that occurs in pump mode can be well predicted using LES (see Figure 2). The aim of this work is to go one step further in the low discharge to analyze the instability due to the runner as well as the hysteresis behavior of the flow.

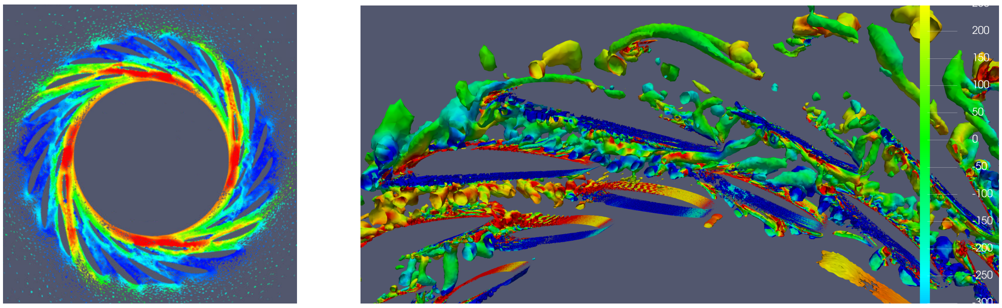

Figure 2 - Structure of the flow in the casing captured by LES

Objective and planned works:

The objective of this study is to better understand the instabilities of the flow in pump direction, and to be able to identify the main parameters of influence, with the long-term objective to be able to control these phenomena.

To achieve this objective, a first challenge is to assess the relevance of the simulation approaches. Indeed, conventional statistical approaches may fail to predict highly unstable and unsteady flows such as those of the operating regimes concerned. This is because only the mean field of the flow is explicitly simulated, and all of the fluctuations are modelled. To overcome this limitation, large-eddy simulations (LES) can be used. This approach allows to explicitly simulate a larger part of the fluctuations, and to model only the fluctuations developing at the smallest scales. This allows a description of the most dominant hydrodynamic instabilities of the flow. In high performance computing (HPC) context, the development of computational power at the national level now allows to consider such simulations in complex industrial configurations (see Figure 3). With this objective, our research group participates in the development of the YALES2[1] code which is a high performance, multipurpose numerical tool.

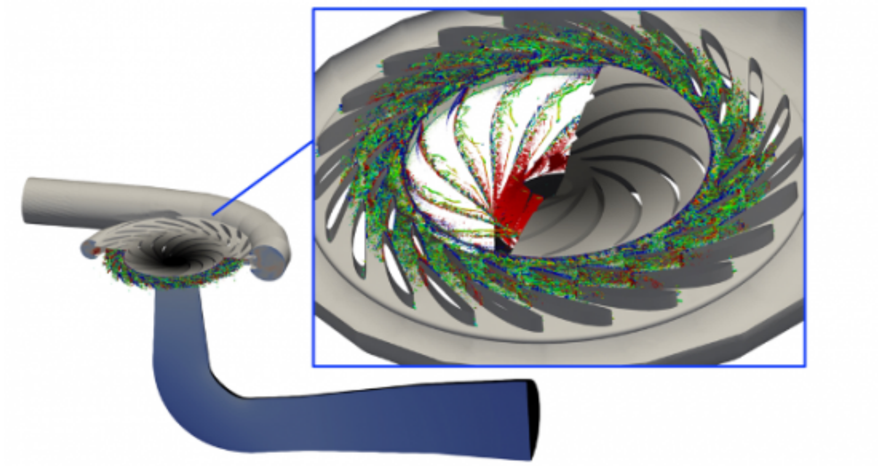
Figure 3 – Illustration of LES of a complete PSP configuration

Two main axes will be investigated in the PhD works:

1) First, starting from the simplified configurations previously mentioned, the goal will be to deepen the analysis of the development of hydrodynamic instabilities, and to identify the parameters of influences. This configuration will then be made more complex, step by step, to make it tend towards a real configuration and thus be able to assess the relevance of the analyzes of the simplified configurations.
2) Second, a real and complete turbine-pump configuration (documented in literature) will be considered in order to assess the relevance of current numerical approaches. This should allow to give an objective inventory of the simulation tools and thus identify the issues for a more precise numerical prediction. This will be the reference case used to assess the new development in YALES2.

[1] www.coria-cfd.fr/index.php/YALES2

3) Third, propose a control strategy to be implemented on the full turbine configuration. This control strategy will be based on a deep understanding of the flow dynamic. Machine learning tools could be also applied to a database constructed with multiple simplified configurations runs.

Further information:

The start is scheduled for October 1, 2022. An early or delayed start may be negotiated.

The candidate must hold an engineering degree and / or a master's degree in fluid mechanics.

Expected skills: Hydraulic machine, Computational Fluid Dynamics, numerical analysis.

Language skills: Writing quality in English, ability to formulate and lead a scientific project

Ability to work in a team

Applications must include a detailed CV; at least two references (people likely to be contacted); a one-page cover letter; a one-page summary of the master’s internship; Master's or engineering school grades (last two years).