Coordinated motion of a dual drivetrain for a contra-rotating reversible pump-turbine in a hydropower storage system

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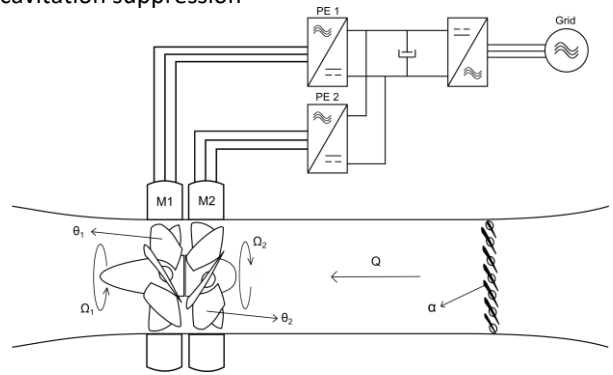
Goal

The aim of this research is to find, design and validate the drivetrain architecture, electric machines and control system that provides coordinated motion of a contra-rotating reversible pump-turbine in a hydro power storage system. This research is part of the European Horizon 2020 ALPHEUS project.

Motivation

ALPHEUS: **A**ugmenting grid stability through **L**ow-head **P**umped **H**ydro **E**nergy **U**tilization and **S**torage

Reversible pump-turbine with contra-rotating propellers → Swirl reduction → Improved efficiency, stability and cavitation suppression



Grid state provides power setpoint P^*. Machine side control must ensure to reach setpoint fast and efficient.

5 degrees of freedom in control system:

- Inlet vane angle α (influence on water flow Q)
- Machine torques T_{m1}, T_{m2}
- Pitch angles θ_1, θ_2

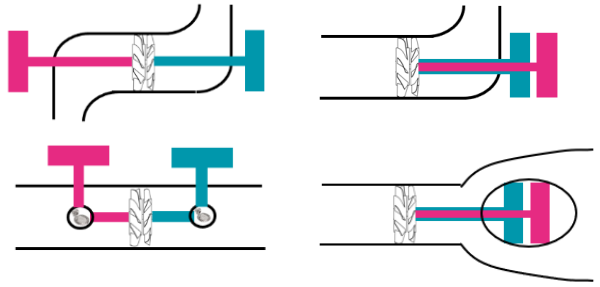
Physical linkage of turbines through water flow. Load torque T_r on propeller i:

$$T_{ri} = f(Q, \Omega_1, \Omega_2, \theta_1, \theta_2)$$

Approach

Drivetrain architecture

Different Power Take-Off (PTO) concepts are compared w.r.t. bearing, sealing, electric machine dimensional restrictions, cooling and impact on flow.



Electric machines

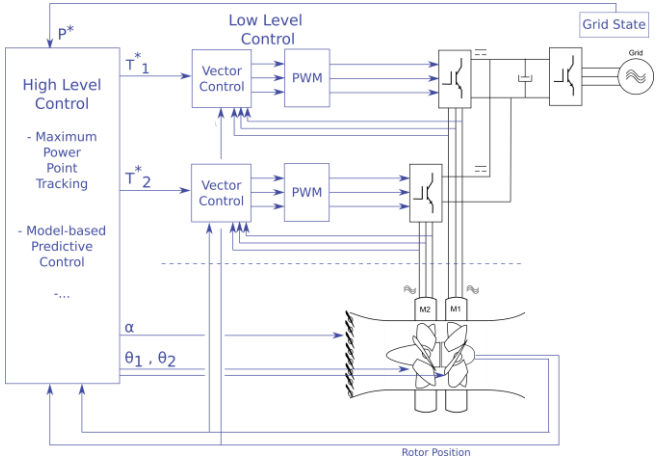
Low speed & high torque → Direct drive

High pole number axial-flux PMSM YASA topology:

- High power density
- No yoke, reduces iron losses
- High efficiency

Machine side control

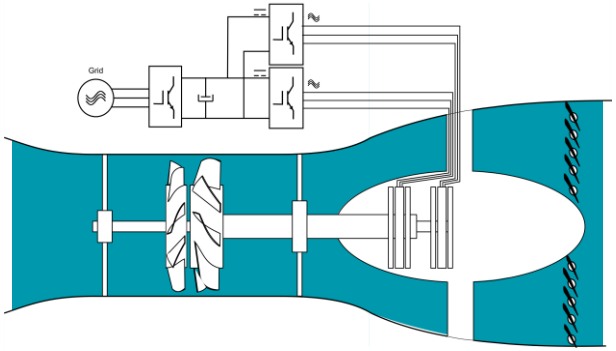
Power setpoint P^* → High level control → Torque setpoints T^* → Low-level control



Results

Drivetrain architecture

Coaxial shafts with opposite motion with electric machines in dry bulb chamber



Electric machines

Parametric sizing tool for dimensioning, preliminary design and scaling of the AF-PMSM

Machine side control

1. Maximum Power Point Tracking-based algorithm with basic characteristics and water flow model.
2. Model-based predictive control algorithm based on blade element method model

Key take-aways

A coaxial shaft drivetrain architecture was chosen to provide energy transmission. The machines will be placed inside a bulb. An AF-PMSM with YASA topology will be designed to drive the low-speed reversible pump-turbine. The high level control has 5 DOFs and will initially consist of an MPPT-based algorithm. In the future this will be extended to an MPC control system based on a BEM-model.

Further reading

- alpheus-h2020.eu/
- biblio.ugent.be/publication/8680470