Objective

Francis turbines working in off design operating conditions may experience the formation of a vortex rope at the runner outlet. In full load condition a pulsating vortex rope develops from the hub of the runner to the center axis of the draft tube in the bulk flow. This phenomenon may compromise the stability of the machine operation, since it is a major source of pressure fluctuation in the hydraulic system.

In order to better understand and some day prevent this issue, improvements on the model used for the stability analysis are required. The main objective is to characterize the unstable flow in the cone of the draft tube on a reduced scale model of a Francis turbine operating at full load. In particular, the evolution of the axial and tangential velocity components is analysed by means of a Laser Doppler Anemometry. Combined with the measurement of the instantaneous vortex rope volume and the pressure fluctuation, the discharge variation at the two horizontal positions is computed.

Investigation

The contour of the vortex rope is detected by applying an algorithm based on thresholding and Laplacian of Gaussian filtering to all the frames recorded with a high speed camera. Then the volume is computed under the hypothesis of axis-symmetry.

The velocity components are investigated at several radial location at level position 1 and 2.

Results

The relation between discharge, rope volume and velocity components is established by taking the pressure signal as a reference in phase averaging. This illustrates how the vortex rope pulsation influences the flow at the outlet of the runner.

Mean and standard deviation of the velocity components and pressure coefficient as a function of the vortex rope pulsation phase. At position 1 the \( C_m \) component presents a periodic behaviour with respect to the \( C_p \) signal which is flattened out downstream at position 2. The \( C_u \) component, at both positions, increases and decreases with different delays compared to the \( C_p \) signal.

Discharge and rope vortex volume as a function of the vortex rope pulsation phase. At position 1 the discharge experiences a fluctuation that seems to vanish downstream at position 2.