UNIVERSITÉ LAVAL

LMFN
www.lmfn.ulaval.ca

Optimization and impact study of hydrokinetic turbine arrays

INTERNATIONAL NETWORK ON
INORE
OFFSHORE RENEWABLE ENERGY
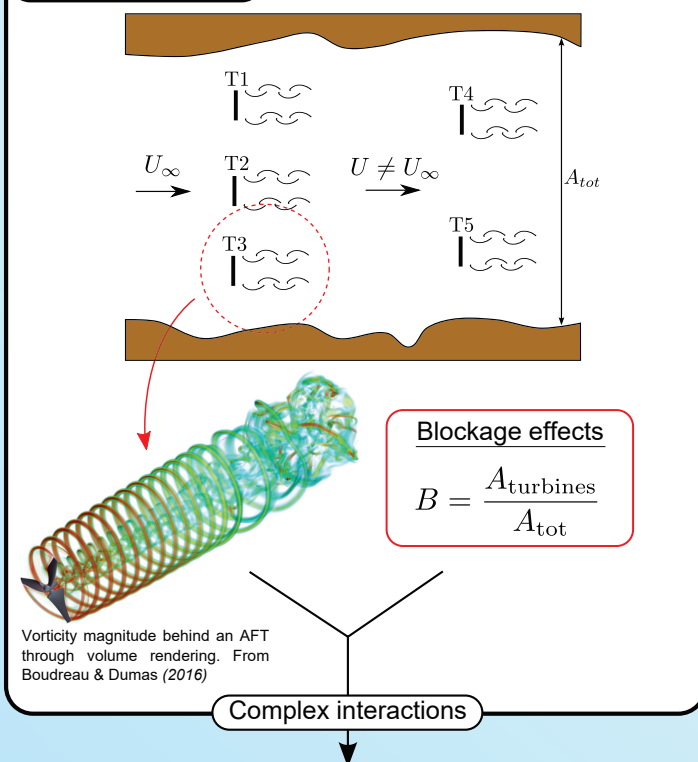
Olivier G. Tremblay and Guy Dumas
CFD Laboratory LMFN, Département de génie mécanique, Université Laval, Québec, Qc, Canada
Contact: olivier.gauvin.2@ulaval.ca

Context

Although we can successfully predict the behavior of a single turbine, few studies have been conducted on the interaction of turbines within an array. **Wake and perturbation effects** are important when considering multiple rows of turbines. Moreover, **blockage effects** can significantly increase the power output of each turbine, but also **modify the undisturbed water level and the available flow velocity**. Thus, several aspects regarding the hydrodynamics of a specific turbine array have to be taken into account when planning and optimizing its deployment.
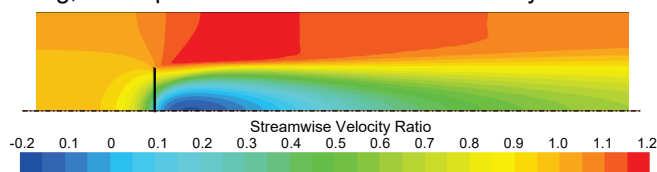
Turbine array

Vorticity magnitude behind an AFT through volume rendering. From Boudreau & Dumas *(2016)*

Blockage effects
$$B = \frac{A_{\text{turbines}}}{A_{\text{tot}}}$$

Complex interactions

Optimization

- Position (x, y, z)
- Operation (e.g. $TSR_{\text{T1}} \neq TSR_{\text{T4}}$)
- Type of turbine (e.g. axial-flow vs cross-flow turbines)
- Number of turbines per row
- Number of rows
- ...

To avoid full CFD of each turbine within the array

Simplified turbine model

Non-uniform momentum sink: aims to reproduce mean drag, mean power and realistic wake recovery.

Streamwise Velocity Ratio
-0.2 0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2
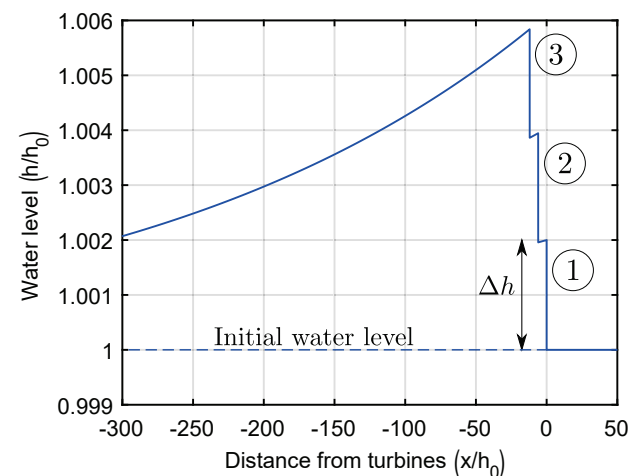
Impact on the river or tidal resource

For example, presence of turbines in a river creates a swelling up (Δh) of the water level upstream, thereby causing a slowdown of the upstream flow.

$$U_\infty < U_0$$
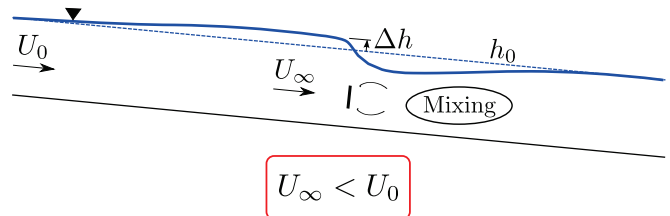
$$\Delta h = \phi \begin{cases} \text{Turbine Drag} \\ \text{Blockage} \\ \text{Froude Number} \end{cases}$$

$\longrightarrow \dfrac{\text{Turbine power}}{\text{Efficiency}}$

The array impact on the resource must be taken into account to predict total power output, especially for upperbound estimates.

Analytical model showing the upstream impact from three small groups of turbines in a river.