Experimental Study of the Effects of Turbulence and Large Coherent Structures on Hydrokinetic Turbines

V.S. Neary¹, L.P. Chamorro², C. Hill², B. Gunawan¹, F. Sotiropoulos²

¹Energy-Water-Ecosystems Engineering, Wind and Water Power Technologies, Environmental Science Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
²St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN, USA

Background
- Flow induced vibrations (FIV) can reduce hydrokinetic turbine performance and cause fatigue and potentially failure of stationary and moving machine components. Sources of FIV considered here include those induced extraneously by turbulence of the approach flow, both by the random fluctuations of velocity and pressure of small scale turbulence buffeting the turbine and large energetic coherent structures generated by large bluff bodies upstream of the turbine, e.g. piers, commonly found in river and tidal channels.

Methods
- Dynamometer measurements of torque, rpm and power
- Velocity measurements with 3 synchronized acoustic Doppler velocimeters (ADV) sampling at 200 Hz

Results – Profiles of Velocity and Turbulence
- Incoming flow characteristics
- Flow characteristics in the SAFL main channel

Results – Spectra Plots
- Pre-multiplied spectra of turbine power: undisturbed flow (black plot); disturbed flow with a cylinder located upstream of the turbine (red plot).
  (Cylinder diameter d=0.115m, located 7.5d upstream of the turbine)

Conclusion and future research needs
- Flow instabilities and coherent structures generated by bluff bodies in rivers and tidal channels significantly perturb the inflow to turbines
- Unsteady response of the turbine is clearly affected with the scales imposed by the disturbance. Large and very large scale motions on the flow are not affected and, then, do not alter the transient response of the turbine.
- Future research would be greatly enhanced through use of advanced eddy resolving numerical models like the LES simulation below

Study Objectives
- Simultaneous and high resolution measurements of 3-component flow velocity and turbine power (torque, rpm)
- Assess possible resonances between dominant frequencies of turbulence and natural frequencies of the rotating turbine, blades and stationary tower.

Unperturbed instantaneous turbulent inflow to turbine

Conceptual layout with schematic of perturbed turbulent inflow approaching turbine

Example of the measurement grid around the turbine

Experimental setup: turbine, cylinder and 3 ADV’s.

Point of Contact
Vincent S. Neary, Ph.D., P. E.
Email: nearyvs@ornl.gov
http://www.esd.ornl.gov/WindWaterPower/

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Flow characteristics in natural rivers.
From Nezu and Nakagawa (1986).

Flow characteristics in the SAFL main channel

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\begin{align*}
\sqrt{\overline{u'^2}}/u_c &= 2.30 \exp(-z/D) \\
\sqrt{\overline{v'^2}}/u_c &= 1.63 \exp(-z/D) \\
\sqrt{\overline{w'^2}}/u_c &= 1.27 \exp(-z/D)
\end{align*}
\]

Flow characteristics in natural rivers.