How can we Improve Underwater Turbines with Hydrodynamic-Exploiting Control?

STUDENTS: Ari Athair (Presenting), Abigale Snortland and Dr. Isabel Scherl

Introduction

Cross-Flow vs Axial-Flow Turbines
- Lower individual efficiency, higher per unit area
- Construcive interference
- Insensitive to flow direction
- Lower optimal rotation rate

Why Variable Speed Control?
- Controlling angle of attack and hydrodynamics with fixed geometry
- Improves understanding of beneficial flow phenomenon
- Simple control scheme

Control Parameter Sweep

Percent Change in Turbine Efficiency
- Max efficiency improvement 15%
- Low sensitivity to changes in \( A_{\omega} \)
- Higher sensitivity to changes in \( \phi \)
- Narrow region of beneficial kinematics, more combinations produce poor performance
- It is possible to decrease loading while still improving performance!

Phase Averaged Analysis

Motor/Generator

Methods

- Alice C. Tyler Flume test facility at Harris Hydraulics Lab
- Forces and moments measured with 6-axis load cells mounted at top and bottom of turbine
- Sweep of control parameters fixing \( \omega_0 = 21 \text{ rad/s} \) the optimal value for our turbine
- Particle Image Velocimetry (PIV) for key cases to explore near blade hydrodynamics
- Metrics of Interest:
  - Power producing efficiency, \( \eta \)
  - Ratio of average \( \eta \) to max in plane force, \( C_{\text{Force}} \)

Control Parameter Sweep

- Data being used for CFD validation by collaborators at the University of Wisconsin
- Analysis of work repeated with the addition a cambered profile blades to assess impacts on hydrodynamics and performance
- Optimal \( \eta/\max(C_{\text{Force}}) \) shows slightly worse shedding than constant case

Future Work and Acknowledgments

Data being used for CFD validation by collaborators at the University of Wisconsin
- Analysis of work repeated with the addition a cambered profile blades to assess impacts on hydrodynamics and performance
- Interpretation of results through the lens of Coriolis effects and virtual forces present in a rotational frame

References:

Project supported by the naval facilities engineering systems command (NAVFAC) and the U.S. Department of Energy TEAMER Program