Array Dynamics of a Pair of Co-Rotating Cross-Flow Turbines

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**Motivation and Methods**

Individual cross-flow turbines are often less efficient than axial-flow turbines, but may have superior array efficiency. Experiments with two cross-flow turbines performed at the Bamfield Marine Science Center (BMSC)

- Stationary turbine
- Mobile, cantilevered turbine
- Motorized 2-axis gantry

**Control Optimization**

We optimize array efficiency at each geometric location using Nelder-Mead (downhill simplex) strategy

- Smart simplex initialization and termination from results of neighboring turbine locations
- 55 hour runtime compared to 310 hours using brute force parameter sweeps

**Caveat:** possible to find local optimum control, rather than global optimum

**Control Strategy**

Optimized parameters: TSR Control

Optimized parameters: Coordinated Control

**Optimized Parameters:**

- TSR Control
  - Turbine 1 TSR
  - Turbine 2 TSR

- Coordinated Control
  - Coordinated TSR

**TSR Control Mode**

Tip-speed Ratio (TSR) is optimized for each turbine separately

\[ \lambda = \frac{\omega R}{U} \]

Control Parameters: \( \lambda_1, \lambda_2 \)

Optimize individual turbine to maximize array power rather than individual turbine performance

**Coordinated Control Mode**

Equal TSRS and phase difference, \( \phi \), of both turbines are optimized

\[ \phi = \phi_1 - \phi_2, \text{Co-Rotation} \]

**Performance Metrics**

Coefficient of Performance, \( C_p \)

\[ C_p = \frac{\omega U^2 R^2}{T} \]

Normalized array performance where stars denote turbine performance in isolation,

\[ C_{p,X} : C_{p,1} + C_{p,2} = \frac{C_{p,X}}{C_{p,1}} + \frac{C_{p,X}}{C_{p,2}} \]

**Conclusions**

1. With geometric and control optimization, array power output can be greater than 1.2x the sum of the turbines operating in isolation.
2. Optimal array TSRS often match the optimal isolated turbine’s TSR
3. Next steps will be to test a three turbine array with similar geometric and control optimization schemes

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\[ \text{Nelder, John A., and Roger Mead. } \text{*A simplex method for function minimization.* } \text{The computer journal 7.4 (1965): 308-313.} \]