Influence of Near-blade Hydrodynamics on Cross-flow Turbine Performance

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Motivation

- Cross-flow turbine power production changes with tip-speed ratio as a consequence of blade kinematics.
- Compare phase-averaged performance with phase specific blade hydrodynamics captured with 2-D planar Particle Image Velocimetry for two different tip speed ratios representing two different operating conditions.

Performance Results

- Blade performance is isolated by subtracting the support performance (measured separately) from the complete turbine performance.
- λ=1.1 is representative of under-speed power shedding operation.
- λ=1.9 is representative of maximum power generation.

Take Aways:
- λ=1.1 has a shallow and extended minimum performance trough and a limited period of maximum power production.
- λ=1.9 has a limited but strong period of minimum performance and an extended and significant maximum performance peak.
- Phase shift and amplification of maximum performance with increase in λ because lower λ cases reach dynamic stall earlier in rotation (see PIV results).
- Dynamic stall characteristics do not clearly explain the amplification of the minimum performance peak at higher λ, suggesting an influence from the downstream blade.

Background

• Time Averaged Performance
  - Close to minimum power: λ=1.9
  - Under-speed power shedding: λ=1.1

• Phase Averaged Performance
  - λ=1.1
  - λ=1.9
  - λ=2.7

Particle Image Velocimetry (PIV) Results

Conclusions

- The duration, severity and phase of flow reversal and detachment on the blades appear to be critical to overall turbine performance.
- Phase of maximum performance does not correspond to that where the leading-edge vortex is the strongest.

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