eXSeek™ Wind Farm Optimization

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Offshore 2022 WINDPOWER
OCTOBER 18-19 | PROVIDENCE, RI

MOTIVATION

Wake effects cause

- Turbine power losses up to 40%.
- Increased fatigue loads.

eXSeek™

Log-of-Power Extremum Seeking Control (LP-ESC) for wake steering

- Dynamic, model-free feedback control framework.
- Real-time gradient-based algorithm to maximize Region II power.

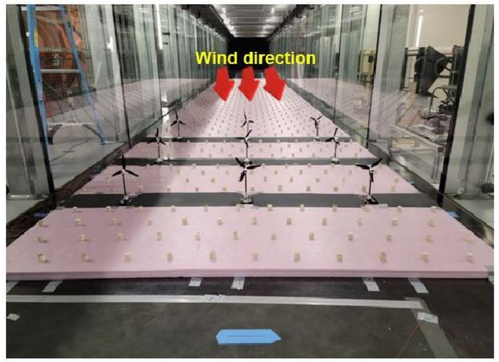
LP-ESC for Aging Turbines

- LP-ESC can be used to tune control parameters/set-points in off-design conditions due to degradation of blade aerodynamic performance (icing, bugs, erosion, etc.).

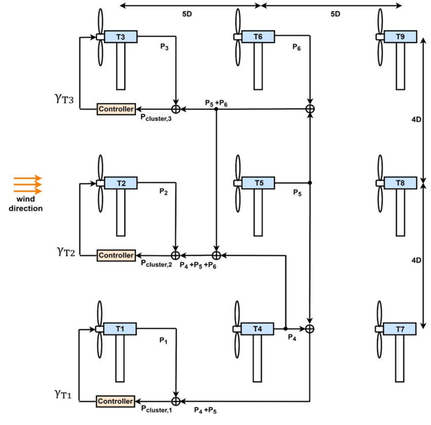
LP-ESC is not sensitive to wind speed variations and (essentially) model free [1,2]

METHODS

Cluster-based Yaw Control – Experimental set up[3]

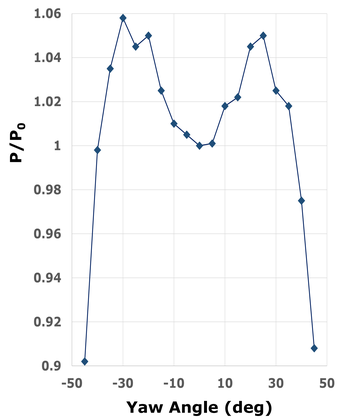


- **Rotor diameter: 0.2 m**
- **Turbine parameters:** $C_P \approx 0.35, C_T \approx 0.8$
- **Test at 7 m/s mean wind speed with 9% turbulence intensity.**
- **Yaw controller at base of turbine**



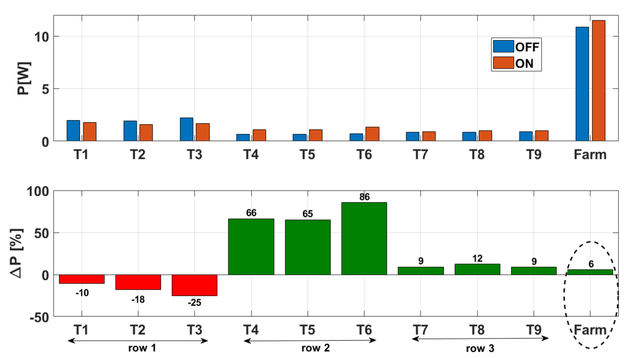
RESULTS[3]

Static Map



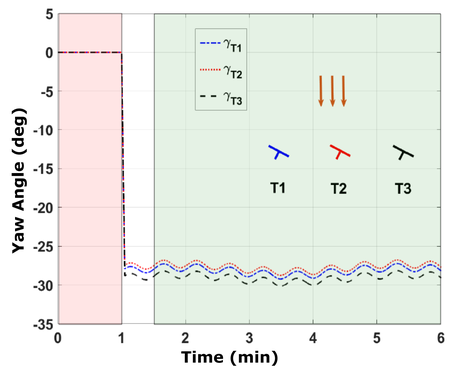
Wind plant power static map: upstream row with yaw angles ganged together at γ_{row1}

Converged Power



Turbine average power after yaw angle convergence (from 1.5 min to 6 min). Total farm power increases about 6%, as predicted from the static map.

Rapid Convergence



Upstream turbines reach optimal yaw angles in 2.8 sec starting from no misaligned conditions.

CONCLUSIONS

- eXSeek™ provides a robust, model-free dynamic control approach to wake-steering.
- Requires only SCADA data, no additional sensors.
- Verified by wind tunnel tests and high-fidelity simulations, ready to be piloted on a wind farm.
- Improvements to LP-ESC include accelerated convergence[4].

REFERENCES

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[2] Ciri, U., S. Leonardi, M.A. Rotea (2019), "Evaluation of log-of-power extremum seeking control for wind turbines using large eddy simulations," Vol. 22, Issue 7. https://doi.org/10.1002/we.233
[3] Kumar D., M.A. Rotea, E.J. Aju, Y. Jin (2022), "Wind plant power maximization via extremum seeking yaw control: a wind tunnel experiment," (in review)
[4] Kumar, D. & M.A. Rotea (2022). Wind turbine power maximization using log-power proportional-integral extremum seeking. Energies, 15(3), 1004. https://doi.org/10.3390/en15031004

ACKNOWLEDGEMENTS

This work was supported in part by the National Science Foundation, the University of Texas at Dallas, and by the WindSTAR I/UCRC.

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