Wind Farm Power Maximization through Wake Steering Optimization (Onshore or Offshore)

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Sector: Renewables

Why chose **ORTO** for this application?

The impact of wind turbine wake on downstream turbines is highly non-linear and difficult to model. Wind speed and direction can also change rapidly, causing the optimum operating points also to change rapidly. The optima will also be unconstrained. Traditional model-based RTO technologies are not suited to such applications.

ORTO however is model free, continually adapting as conditions vary. ORTO can therefore track movements in the optimum operating point. Total power is thus continually being maximized, as prevailing weather conditions change.

ORTO agents are autonomous and highly scalable. They can be removed or added as needed, at any time, allowing for greater scheme flexibility. Wake steering optimization can therefore be applied incrementally across the wind farm over time, if desired.

Business Objective

A standalone wind turbine should be kept at 90^{O} to the wind direction to maximise power generated. However, when placed in a wind farm, the resulting air turbulence caused by the rotating blades can adversely impact the power generated by downstream wind turbines. It may be advantageous to sacrifice some power generated by upstream wind turbines, by adjusting its yaw away from 90^{O}, to reduce their impact on the downstream turbines, to maximise the total power generated by the wind farm. This is commonly referred to as wake steering optimization.

Typical Optimization Objective Function

Maximize total normalised power generated by an upstream and downstream wind turbine pair. Repeat for all pairs across the whole wind farm. Pairings will change as wind direction changes e.g., by $>90^{O}$.

By manipulating, within a permitted range:

- Bias on yaw angle, on the upstream turbine.

Subject to suitable constraint limits on:

- Power output on each turbine.
- Mechanical integrity measurements e.g., stress, strain, vibration, on each turbine.

Solution

For an NxM matrix of wind turbines, NxM agents are required, each adjusting yaw angle bias on its respective wind turbine. The bias is applied to the yaw angle regulatory controller setpoint i.e., $SP = 90^{0} \pm bias$. Wake steering optimization can be used in conjunction with single wind turbine optimization, which adjusts tip speed ratio and blade pitch to maximize power (see variable speed wind turbine use case).

Benefits

Typically, a 2-6% increase in power generated is possible, as wind speed varies between the cut-in and rated speeds. Due to a reduction in turbulence effects, the operating life of the wind farm can also be prolonged.