Wind Analysis in Operation phases: Identifying and Unlocking Optimization Capacities

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Introduction:
Huge potential for optimization of wind operations

Optimization potential in wind industry: **4-8%**

= 10,000 € / MW of additional revenue each year in France
Introduction:
Full knowledge of inputs is key to performance assessment

- Wind turbine operators are currently not able to precisely know the wind conditions "seen" by their turbines; nacelle anemometers are just giving rough estimations. In that sense, turbines can be seen as "visually impaired".

- Because turbine performance is defined by the relation between inputs and outputs, operators therefore do not have the possibility to easily and quickly assess the performances of wind turbines.

- Wind industry is one of the only industry in the energy sector where the "fuel" resource is left that much unknown.
Introduction:
Full knowledge of inputs is key to performance assessment
Nacelle anemometry or met mast: no satisfactory measurements of the wind conditions "seen" by the turbine

- Why are wind turbines "visually impaired"? Because their wind measurement equipment (nacelle anemometers) is located at the rear of the nacelle, where the wind flow is heavily disturbed by the rotation of the blades.

- Also, a lot of approximations are made in the commissioning of the equipment, in the application of the nacelle transfer function and in the stability of the air flow conditions around the nacelle.

- Fortunately, new technologies (nacelle-based lidar, iSpin) are now available on the market, in order to precisely measure the "fuel" of the wind turbine.

=> These technologies enable many valuable applications for wind turbines in operation
Nacelle anemometry or met mast: no satisfactory measurements of the wind conditions "seen" by the turbine
Correcting yaw misalignment leads to about 2% more annual energy production

• First application: correction of yaw misalignment => because the nacelle anemometer is only roughly estimating the wind direction, knowing the ”true” wind direction can help the operator to properly ”realign” the turbine in the wind.

• Correcting yaw misalignment just means bringing the red curve as close as possible to 0 on the following figure. This leads directly to additional AEP for the turbine.

• The relation between misalignment angle and additional AEP is given in the following table.

• ROMO’s experience shows that app. 60% of the turbines on the market are significantly misaligned (>4°), for a potential AEP gain of around 2%.

• In Germany, ROMO’s corrected yaw misalignment on a 19-turbines wind farm, leading to 275.000€ additional revenues each year (= +8% AEP).
Correcting yaw misalignment leads to about 2% more annual energy production.
Correcting yaw misalignment reduces overloads on the turbine, hence bringing a better aging on the long term

- An indirect consequence of yaw misalignment is mechanical overload on the turbines, leading to faster aging and to higher risks of failures of major components.

- It is very hard to estimate additional AEP when reducing turbine overloads => ROMO still requested Garrad Hassan to run a material fatigue assessment (both on glass fiber and iron).

- On the following figure, it can be seen that at 10° yaw misalignment, the turbine would undergo a 6% overload on the blade root (glass fiber, blue curve). This 6% overload is actually reducing the design lifetime from 20 years to 12 years.

- This is just a statistical analysis, however confirmed by the field experience of many operators (redundant gearbox replacements, fallen blades or rotor).
Correcting yaw misalignment reduces overloads on the turbine, hence bringing a better aging on the long term.
With fuel perfectly known, wind farms can be seen as a global asset to optimize

- Second application: optimization of operational strategy
- If inputs and outputs are fully known, it becomes possible to quantify the impacts of turbines on each other.
- This makes it possible to maximize the global AEP of the farm, instead of just maximizing the AEP of each individual turbine.
- In the following figure, the turbulence intensity was measured in all wind directions on a wind turbine in Germany: it can be seen that everytime turbine K3 was downwind of a neighboring turbine, the turbulence intensity limit set by the IEC norm (18% for class A) was exceeded.
- Same conclusion with inflow angle, where the IEC limit (8°) is frequently exceeded on this Croatian example (figure on the right).
With fuel perfectly known, wind farms can be seen as a global asset to optimize.
With fuel perfectly known, performances and optimizations are quick and easy to assess

- Third application: performance assessment

- If inputs and outputs are fully known, it becomes possible to easily and quickly assess the performances of wind turbines and compare them to the expectations.

- Also, it is possible to easily quantify the impact on AEP of any optimization measure installed on the turbines (yaw realignment, installation of vortex generators, correction of rotor inbalances, cleaning the blades, blade erosion, ...)

- Feel free to join our new LinkedIn group "Optimisation of Wind Turbine Operations", where many experts from all around the world are sharing ideas and best practices on how to maximize AEP of wind turbines.
With fuel perfectly known, performances and optimizations are quick and easy to assess.

Power Curve Optimization to Yaw Error Correction
Calculations according to IEC-61400-12-1

Join our LinkedIn Group: Optimisation of Wind Turbine Operations

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All wind turbines fully optimized in France

= one month of electrical consumption in Paris