WIND FARM POWER GAIN MAXIMIZATION
VIA COMBINED YAW AND PITCH BASED ACTIVE WAKE CONTROL

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Abstract

The goal of a wind farm control strategy is twofold: first, *maximizing* the wind farm's power production and, secondly, *mitigating* the associated mechanical loads acting on each wind turbine in the farm. Such loads are the result of each turbine's gravitational, inertial, and aerodynamical effects, and also due to the interaction with the wind flow of the neighboring upstream turbines, i.e., the due to the *wake effects*.

In order to maximize the power production and alleviating the loads at wind turbine level, several control schemes have been developed. However, this is not the case at wind farm level; only two active wake control (AWC) methods have been proposed based on axial-induction factor (pitch-based) and wake steering (yaw-based).

In this work, a combined yaw and pitch based (CYP) active wake control strategy for power gain maximization with respect to the greedy configuration is proposed. The performance of the aforementioned strategy is evaluated in terms of power gain increase and it is implemented on a realistic wind farm layout using the steady-state wind farm model FLORIS.

Objectives

- To show the benefits of CYP-based AWC for power gain increase by implementing yaw misalignment and pitch-based axial induction control simultaneously.
- To compare the performance of CYP-based AWC with respect to the yaw-based and pitch based counterparts in terms of power gain maximization.

Method

The CYP-based AWC strategy is implemented on the steady-state wind fam model FLORIS and its *built-in* optimization method for yaw-based and pitch based AWC methods.

A schematic description of the method is shown in the following figure:

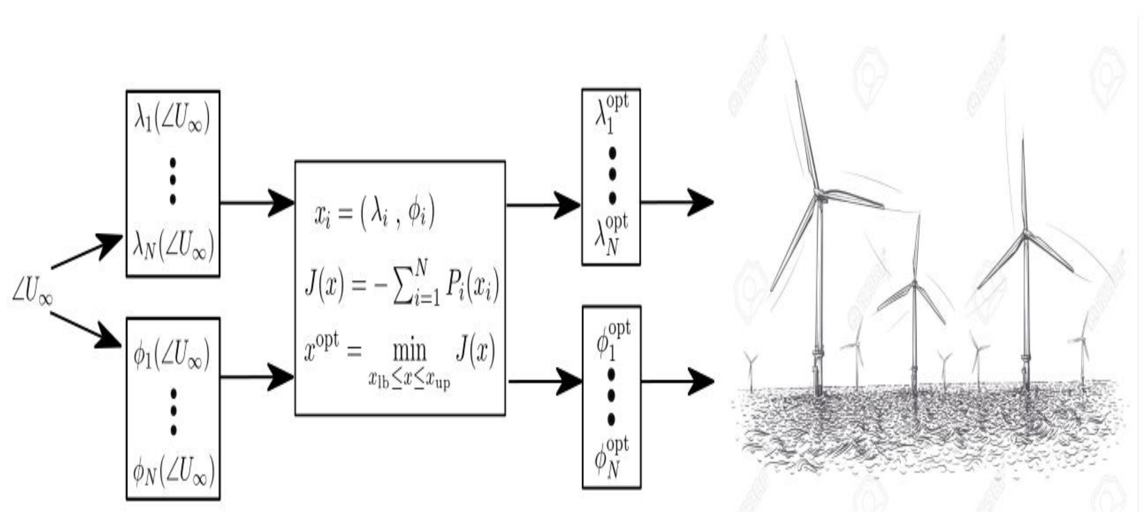


Figure 1: Optimization algorithm block diagram

Given a wind direction, the algorithm takes the corresponding initial values of the yaw and pitch angles of each wind turbine in the farm as input. These are later used in the optimization method for maximizing the power of wind farm. The output of the algorithm are the optimal steady-state yaw and pitch angles of each turbine for the given wind direction.

The study is evaluated on a test array of the of the Sedini wind farm shown in Figure 2. This sub-cluster consist of nine *GE 1.5s* wind turbines with a rotor diameter of 70.5 meters and *1.5MW*.

This sub-cluster is particularly interesting due to the clustered turbines are distributed on a zigzag-like pattern so that there is only partial wake overlapping.

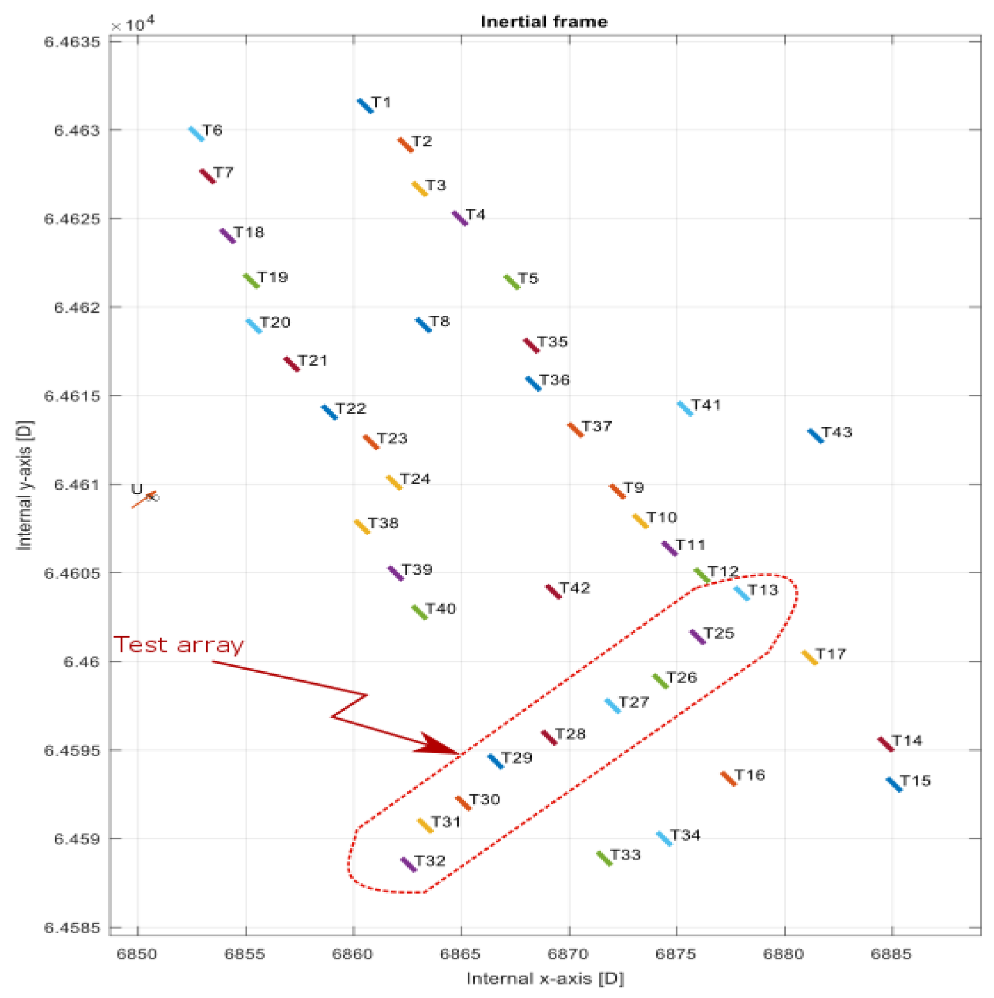
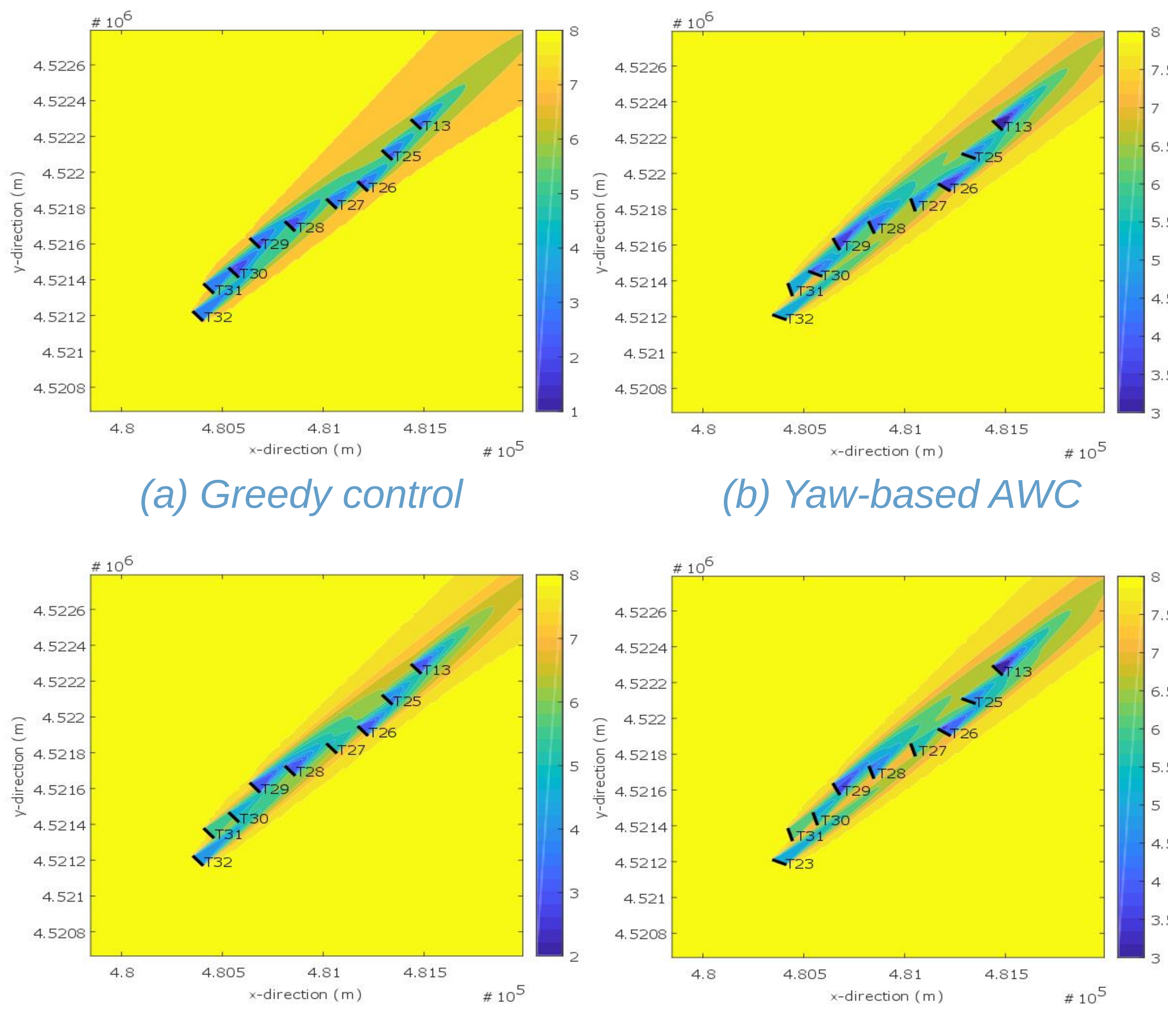


Figure 2: Sedini Wind Farm layout and used test array

Results

The FLORISSE simulation results under greedy control, yaw-based AWC, pitch-based AWC and CYP-based AWC are shown in Figure 3. For this simulation a wind velocity of 8 m/s at 230^o and turbulence intensity (TI) of 0,10 were considered.
It can be seen in Figure 3 that the last downstream wind turbine T13 is kept in greedy control configuration in all wind farm control strategies. This allows turbine T13 to extract the maximum power available of the incoming upstream wind flow.
It is also appreciated that the wake losses are the lowest under CYP-based AWC; while, in wake losses decreasing order, under yaw-based AWC in second place, pitch-based in in third place, and the greedy wind farm control in last place, as expected.



(a) Greedy control (b) Yaw-based AWC

(c) Pitch-based AWC (d) CYP-based AWC

Figure 3: Sedini test array 1 under different control regimes

Now, the CYP-based AWC performance is measured in terms of power gain increase along an interval of wind directions. This is also compared with the yaw-based and pitch-based counterparts.

The yaw angle of each turbine in the test array (upper plot) and the total cluster power gain (lower plot) under yaw-based AWC is shown inf Figure 4. The maximum power production occurs around 230^o with and increase of 17% over the greedy strategy.

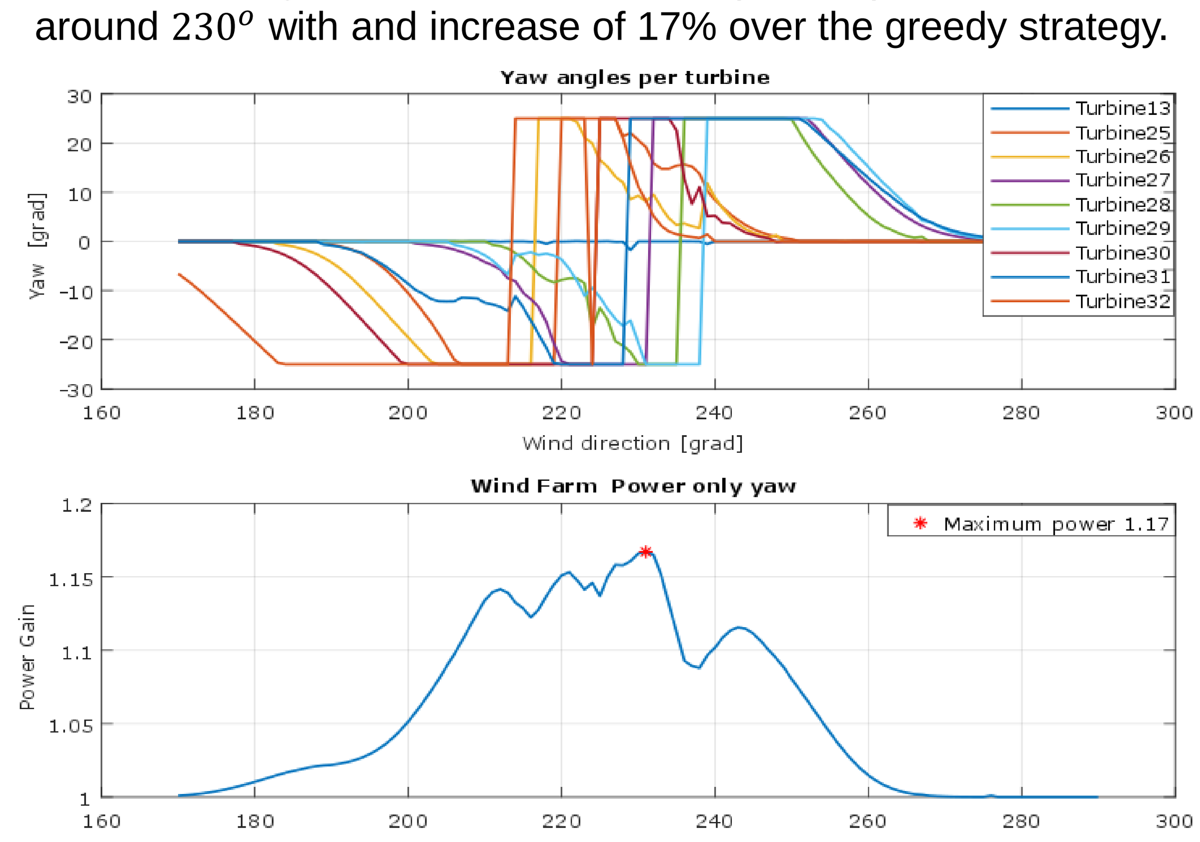


Figure 4: Yaw angles and power gain under yaw-based AWC

Similarly, the performance of the pitch-based AWC strategy is shown in Figure 5. The behavior of the each turbine's pitch angle is presented in the upper plot, while the power gain in the lower one. The power gain increase under this method is of 6% with respect to the greedy strategy, which is scientifically smaller than the yaw-based counterpart.

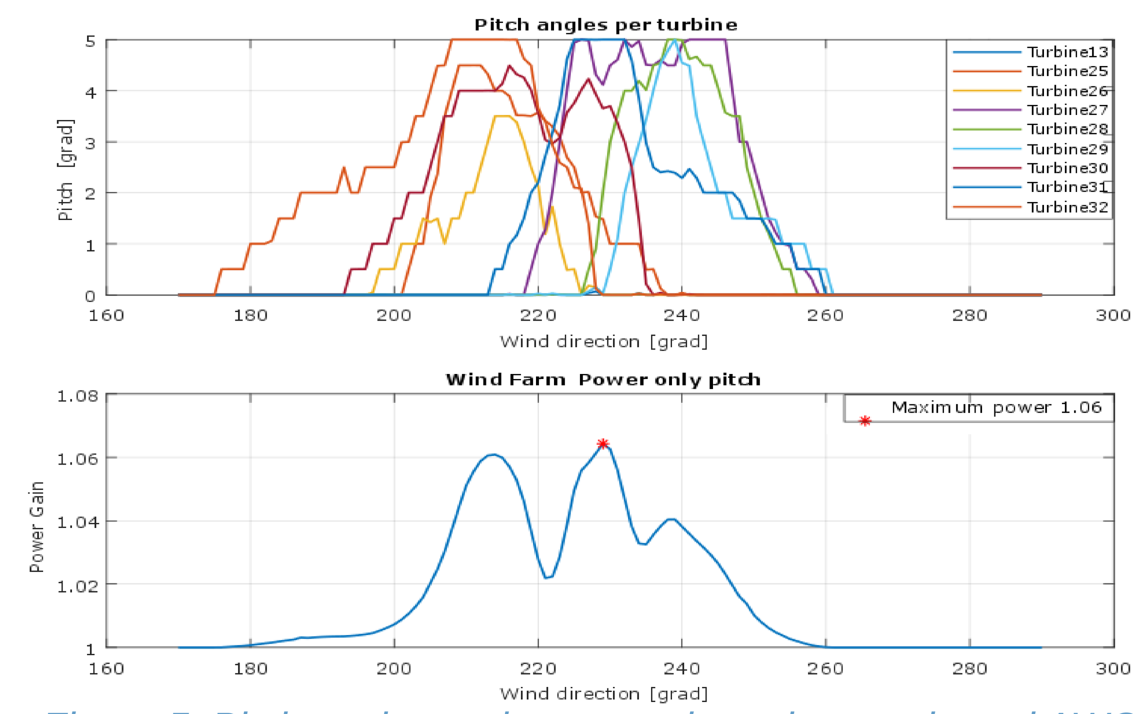


Figure 5: Pitch angles and power gain under yaw-based AWC

Finally, the performance under the CYP-based AWC strategy is presented in Figure 6. The first two plots show the behavior of each turbine's yaw and pitch angles, respectively. The bottom plot contains the power gain performance if the CYP-based strategy and compared with respect to the yaw-based and pitch-based strategies.
It is clear that the power gain increase is maximized with the CYP-based strategy over the other two. This is a direct consequence of the simultaneous operation of yaw misalignment and pitching as it is shown in the figure.

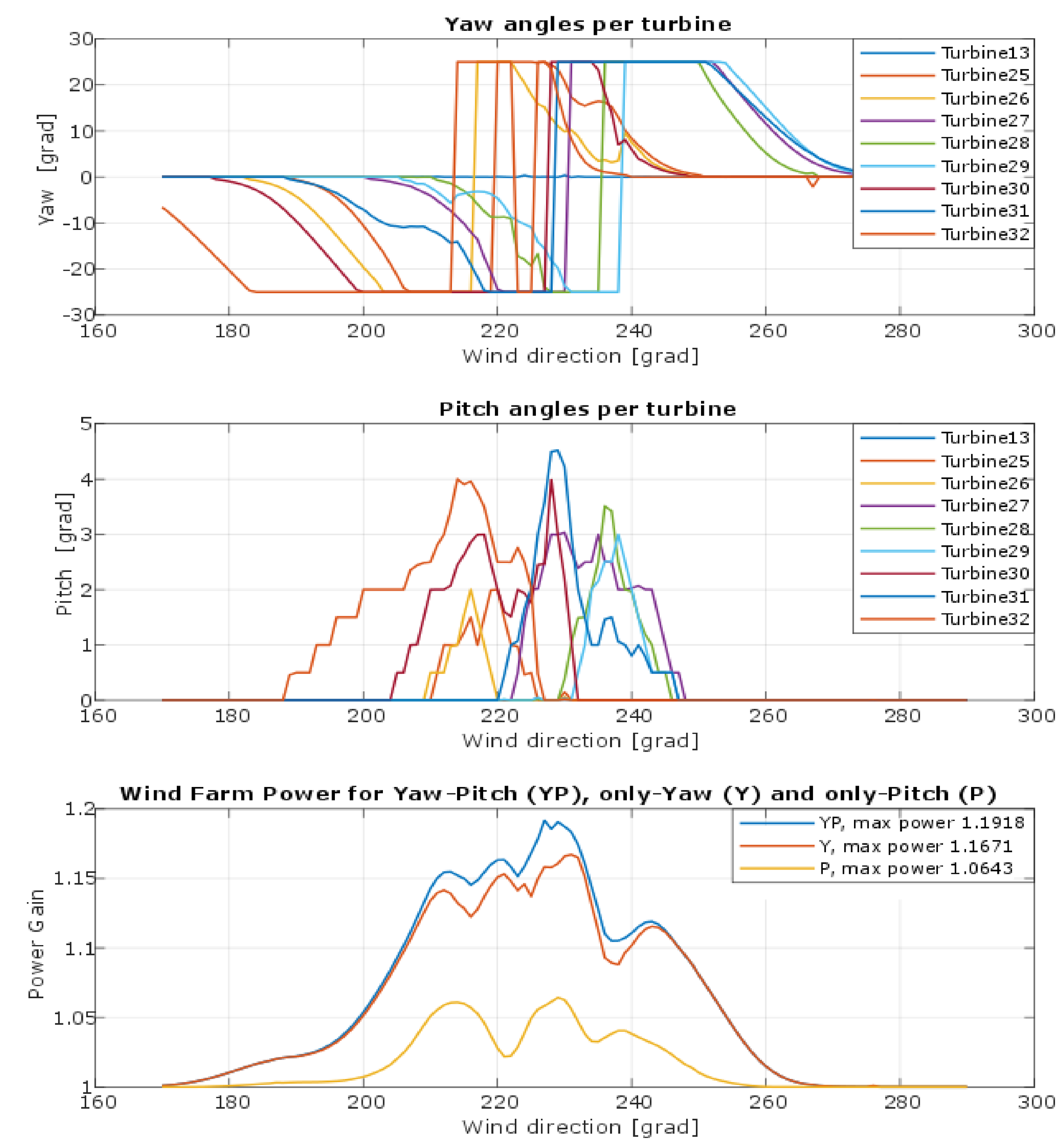


Figure 6: Turbines yaw and pitch angles, and power gain under CYP-based AWC

Conclusions

The CYP-based AWC strategy has been evaluated on a realistic wind farm layout using the steady-state wind farm model FLORIS. The study suggest that the CYP-based AWC strategy can take the benefits of the individual yaw-based and pitch based AWC methods simultaneously. That is, the power gain increase of yaw-based AWC and the potential load mitigation property of the pitch-based method

References

1. Closed-loop Windcon, Deliverable CL-Windcon-D2,5 - Wind Farm Flow control technologies and algorithms, 2019.
2. TUDelft, FLORISSE_M, 2018. URL: https://github.com/TUDelft-DataDrivenControl/FLORISSE_M.