A fast wind farm controller for production maximisation

T. Ahmad, P. C. Matthews , B. Kazemtabrizi

Energy Group, School of Engineering and Computing Sciences, Durham University, UK

Abstract

Wind farm controller exploits the benefits of curtailing upstream turbines in a coordinated way for **increasing overall farm production**. A realistic farm controller shall be accurate and computationally efficient. This work presents a realistic farm controller uses a **modified version of the Jensen wake model** [1, 2] and **Particle Swarm Optimisation (PSO)** [3] for maximising farm output. One **onshore (Sole du Moulin Vieux)** and one **offshore (Lillgrund)** wind farm are used as case studies. The power output of case study wind farms was **increased by up to 10%** compared to state of the art greedy control, in certain wind conditions. The optimisation process was completed in **under 15 seconds** for the onshore one-dimensional array of **7 wind turbines** and **50 seconds** for the two-dimensional wind farm made of **48 wind turbines.**

Objectives

1. Modification in the Jensen model for **improved internal wind farm wake prediction**.
2. Developing **curtailment strategies** based on **C_P** and **Yaw angle**.
3. Developing a **dynamic farm controller** with high accuracy and fast processing speed.
4. **Assessment of the presented dynamic farm controller** with simulations from one onshore and one offshore wind farm.

Motivation

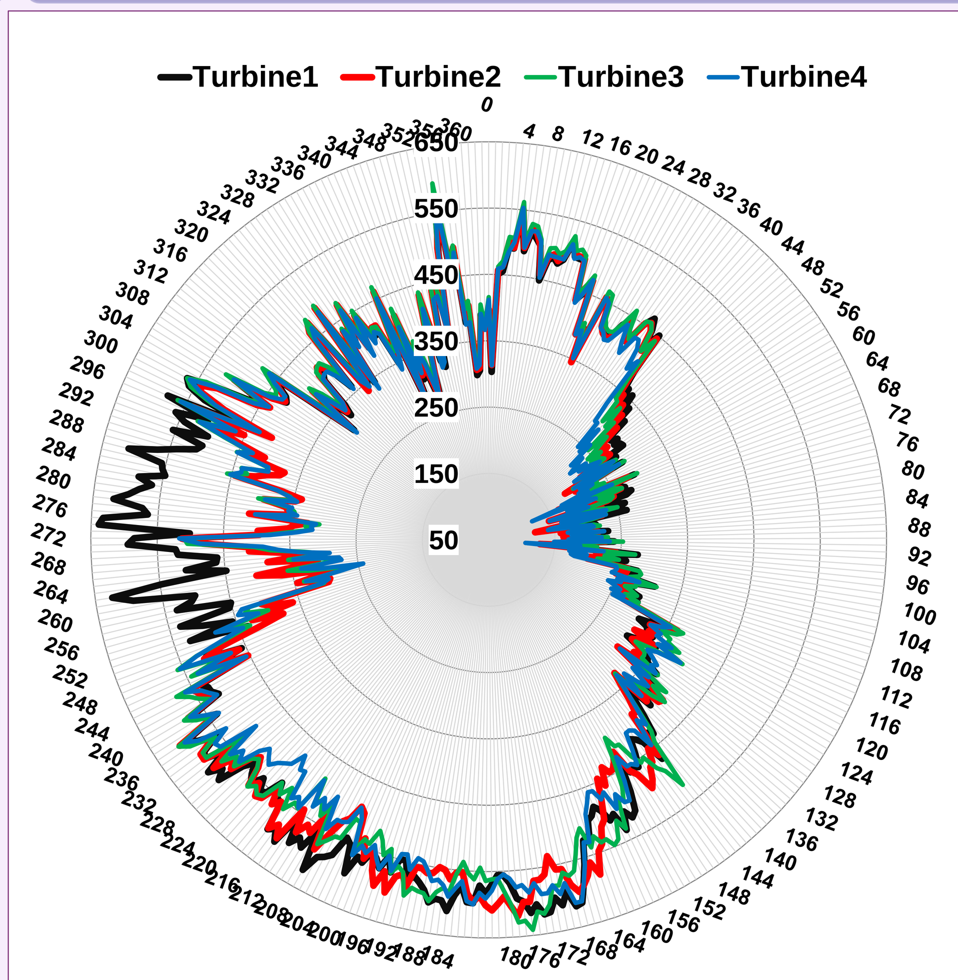

Figure 1a: Average power (kW) in all directions for the first four turbines at 8 ± 0.5 m/s (SMV Wind Farm)

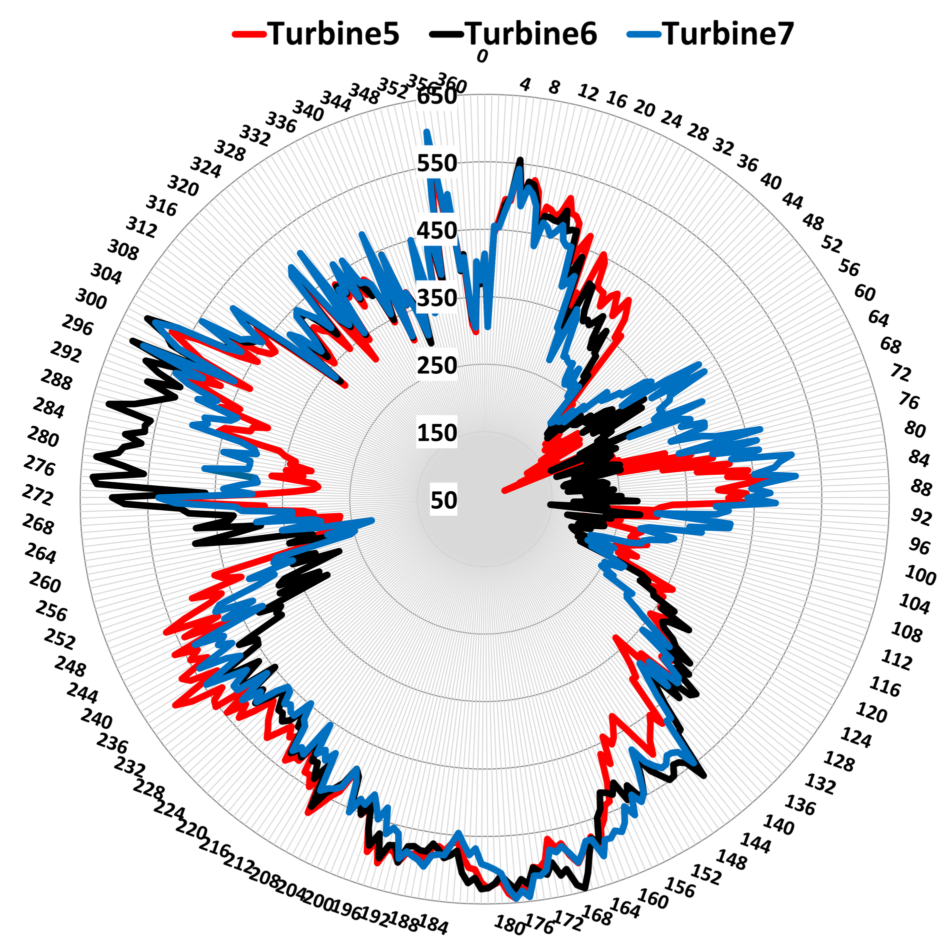

Figure 1b: Average power (kW) in all directions for the last three turbines at 8 ±0.5 m/s (SMV Wind Farm)

Wind Deficit Model

1. Wake expansion up to 10D.
2. Determine which rows and columns can be affected by the wake produced.
3. Find the turbines shadowed by wake producing turbine.
4. Calculate the modified value of **wake decay coefficient ($\boldsymbol{k}$) varies** according to **wake added turbulence** [4].

$$k = 1 / [2\, ln\,(z / z_0)] \qquad (1)$$

$$I_u = \frac{1.0}{ln(z/z_0)} \qquad (2)$$

$$\boldsymbol{k} = I_u/2 \qquad (3)$$

5. Find wind speed deficit [1,2]
6. Multiple wakes [2]

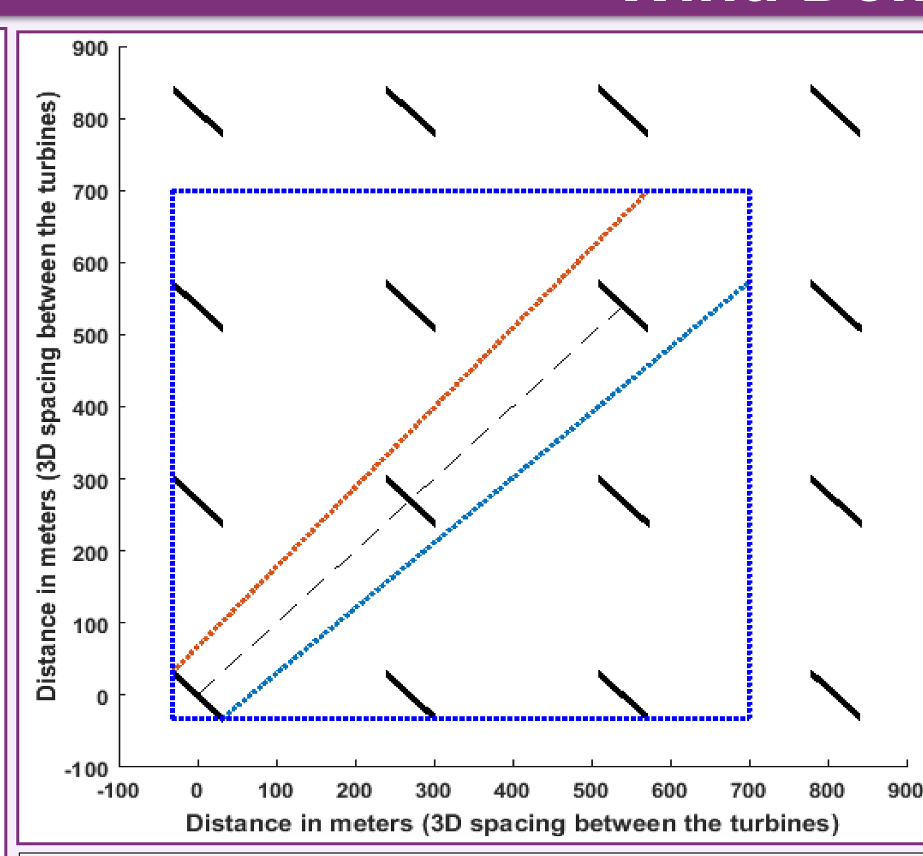

Figure 2a: Step 1 and 2 of Wake Modelling. Determining which turbines are shadowed by an upstream turbine

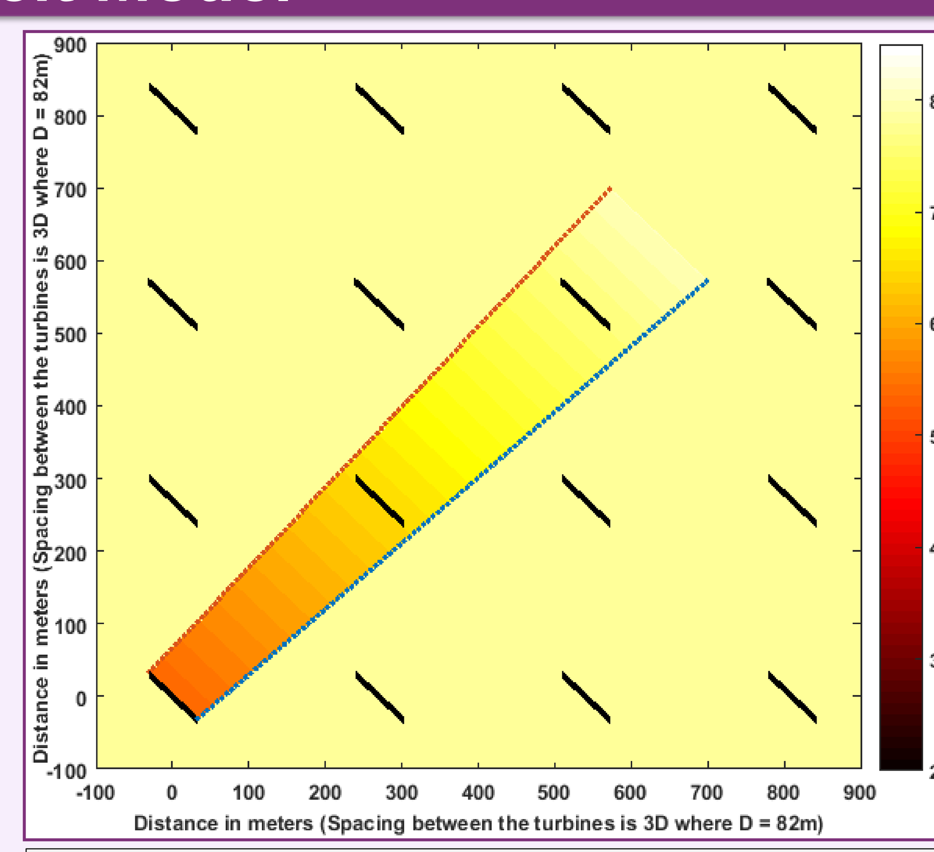

Figure 2a: Step 4 and 5 of Wake Modelling. Wind Speed deficit on shadowed turbines is determined

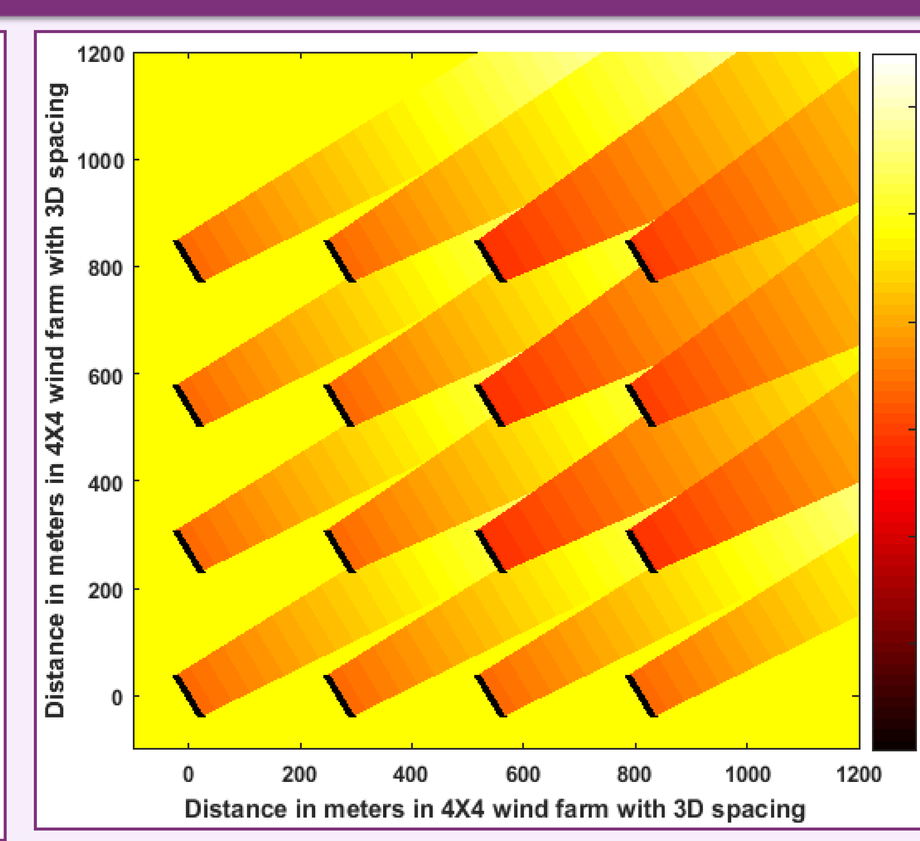

Figure 3a: Step 4, 5 and 6of Wake Modelling. Multiple wake superposition of wakes using new value of *k*

Results

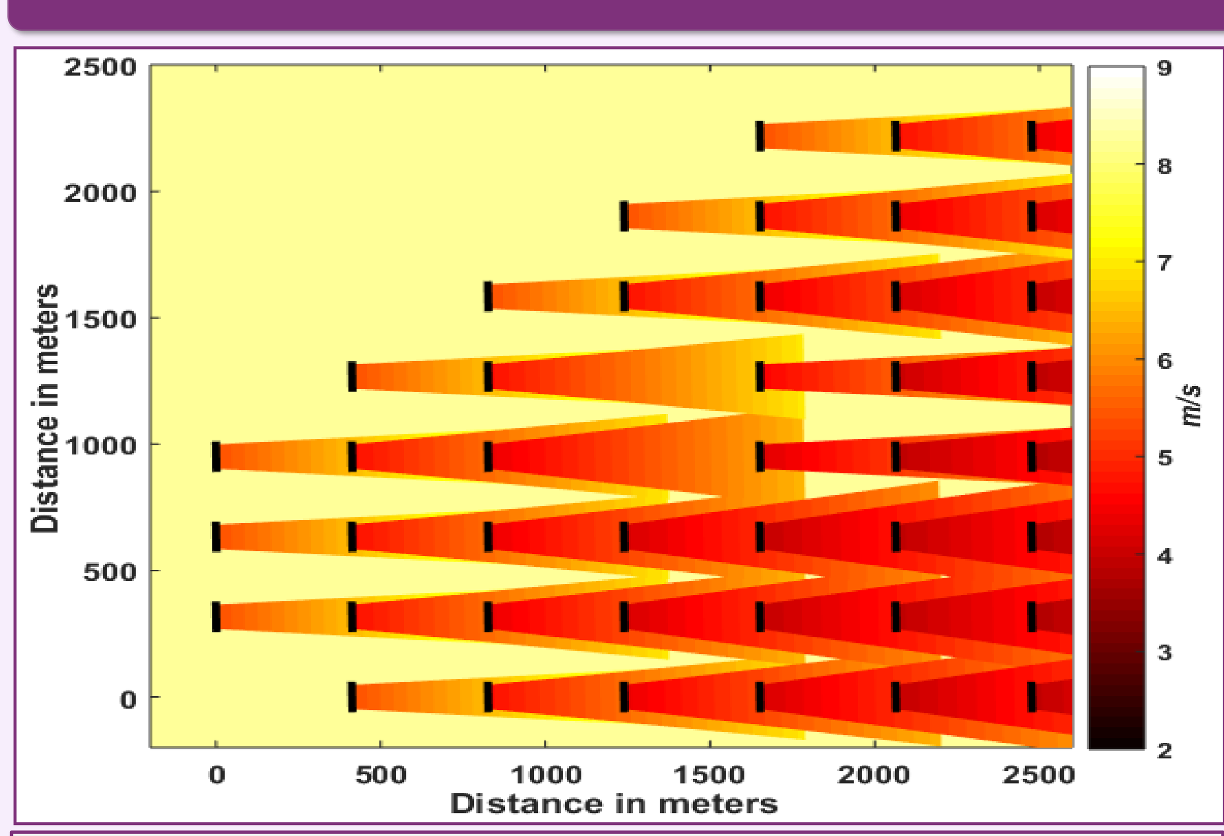

Figure 3a: Conventional Greedy control of Lillgrund wind farm.

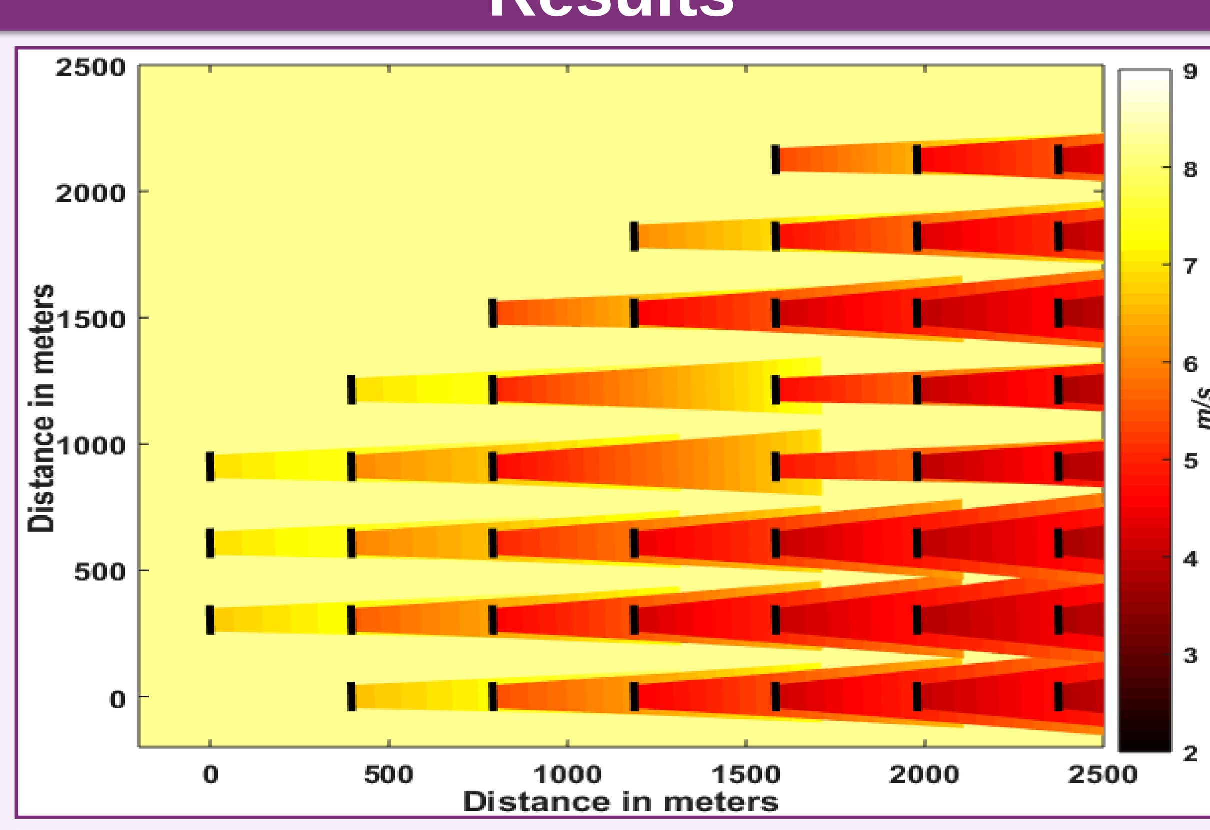

Figure 3b: Cp based optimisation of Lillgrund wind farm.

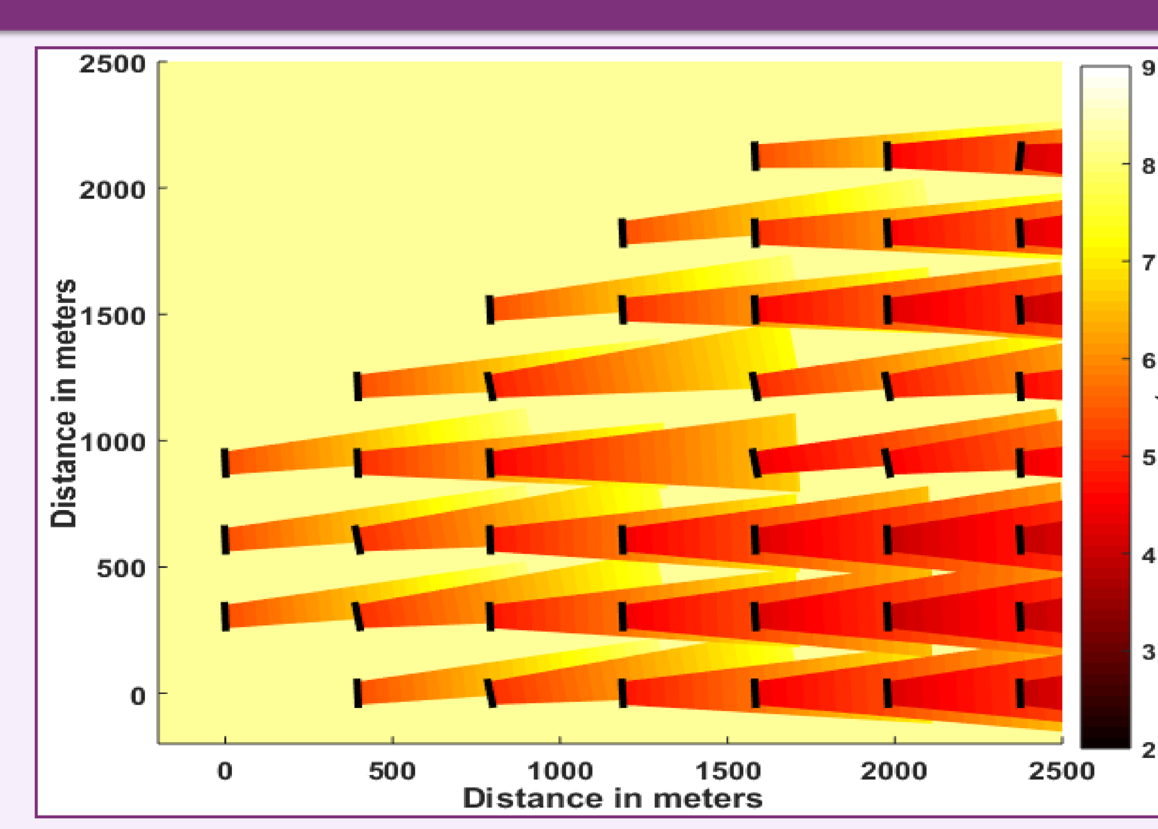

Figure 3c: Yaw based optimisation of Lillgrund wind farm.

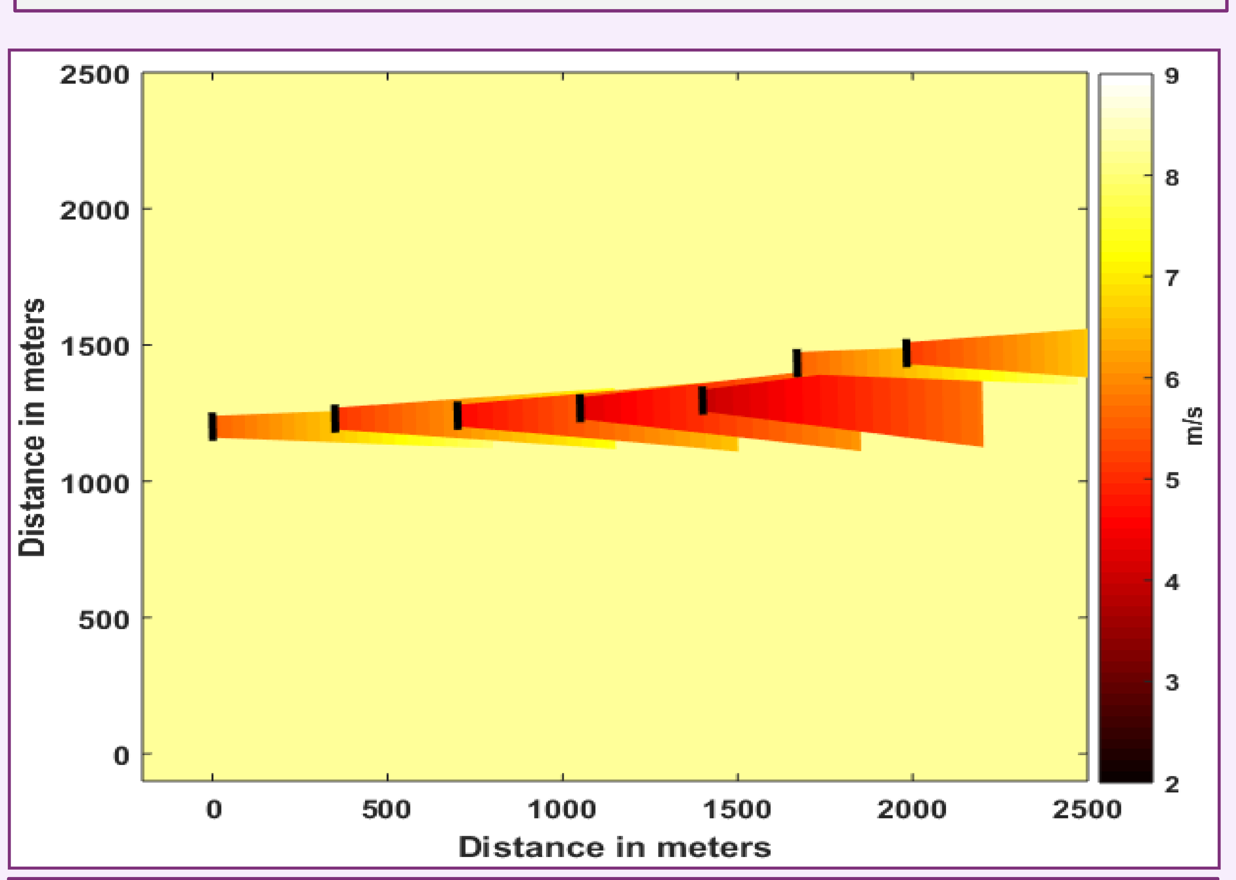

Figure 4a: Conventional Greedy control of SMV wind farm.

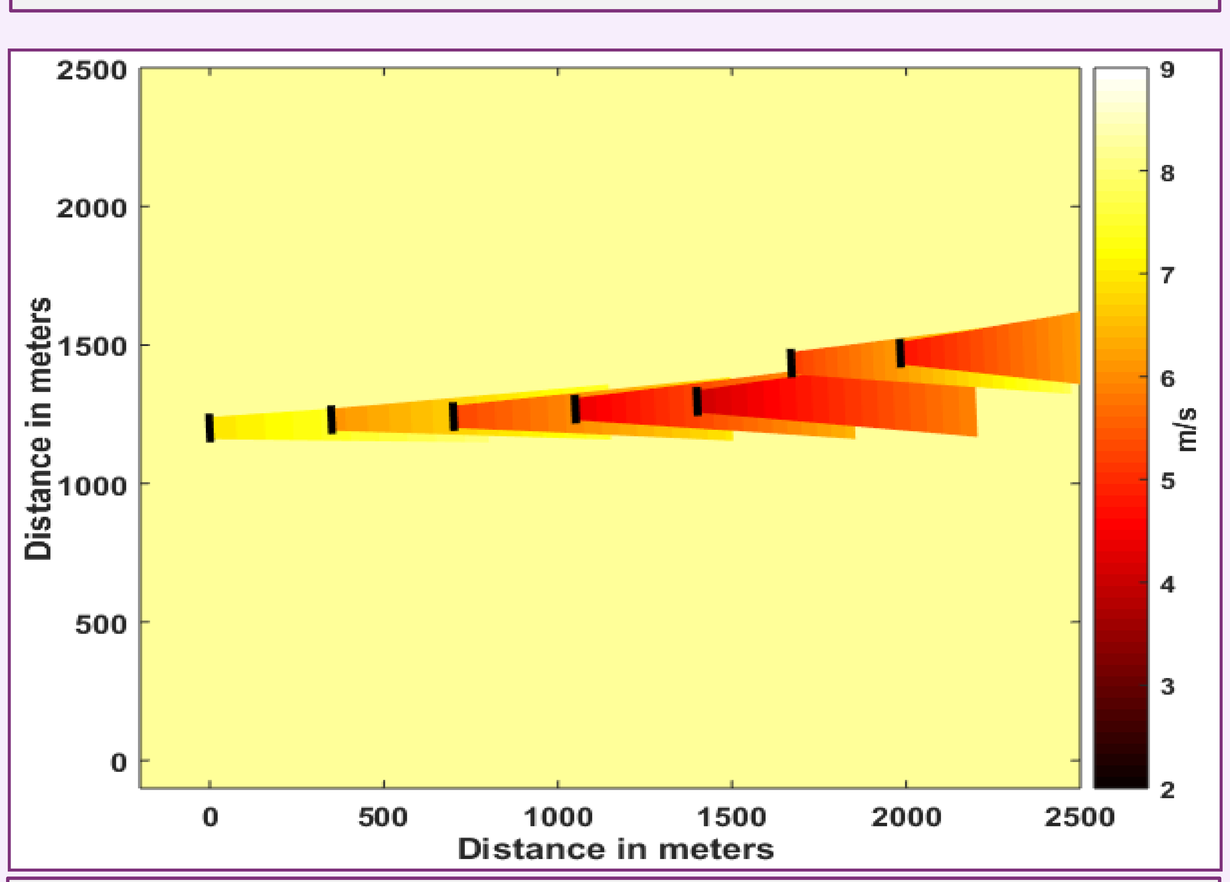

Figure 4b: Cp based optimisation of SMV wind farm.

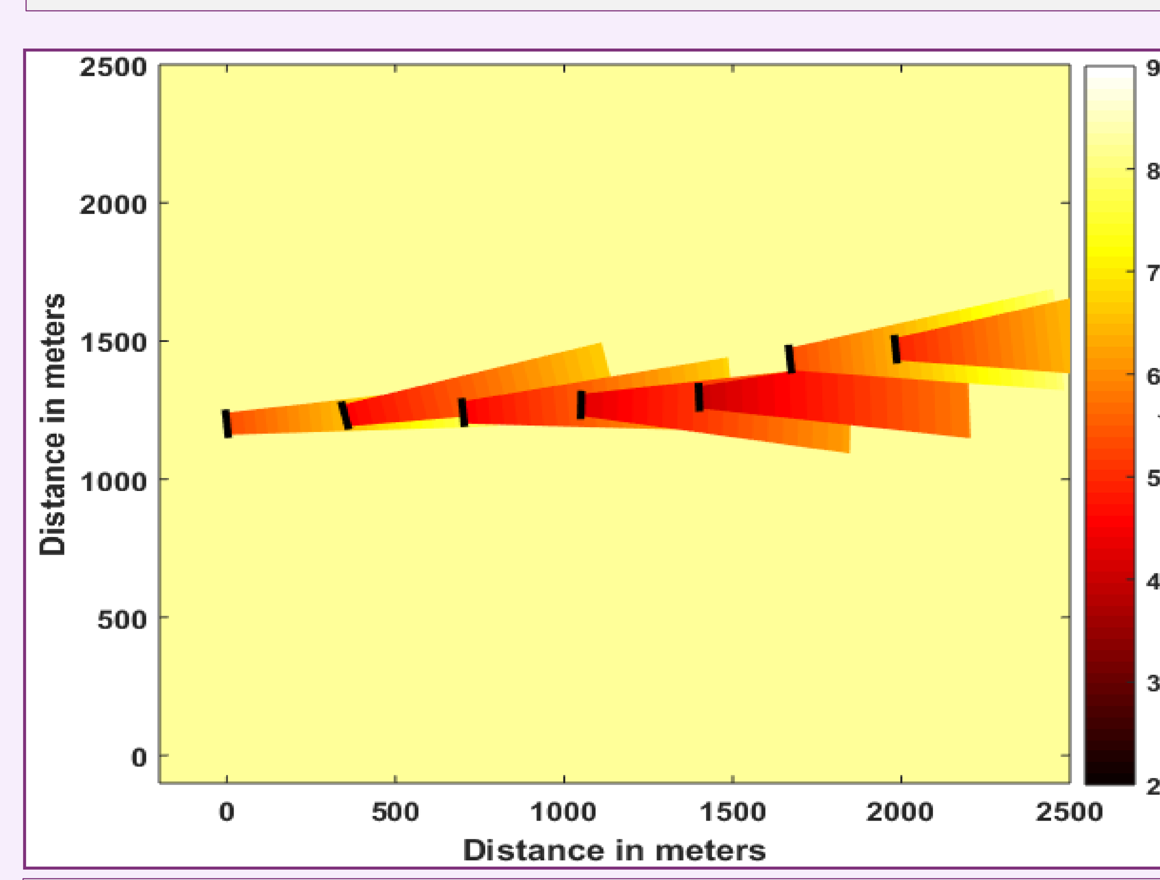

Figure 4c: Yaw based optimisation of SMV wind farm.

Conclusions

- A fast and accurate wind farm controller is presented which combines a modified version of the Jensen model with heuristic techniques (Particle Swarm Optimisation (PSO), Genetic Algorithm and Simulated Annealing)
- Two wind farms (SMV – onshore and Lillgrund – offshore) are used as case studies.
- All the optimisers produces same quality of solution but PSO is the fastest.
- The farm controller can **increase overall output by more than 10%** in certain wind conditions compared to the current state of the art control for **the case study wind farms.** Yaw based optimisation can produce more increase in power as compared to Cp based optimisation
- This **control process for SMV is completed in less than 20 seconds** while optimisation of **Lillgrund completes in 50 seconds** making the proposed **controller suitable for online field use.**

References

1. I. Katic, J. Hojstrup and N. O. Jensen, "A Simple Model for Cluster Efficiency," in *European Wind Energy Association, Conference and Exhibition*, Rome, 1986
2. Jensen, N.O. "A Note on Wind Generator Interaction," Roskilde, Denmark, 1983
3. T. Ahmad, P. C. Matthews and B. Kazemtabrizi, *PSO Based Wind Farm Controller*, in *Eurogen Conference*, Strathclyde, Glasgow, 2015
4. T. Ahmad, N. Girard, B. Kazemtabrizi and P. C. Matthews, *Analysis of two onshore wind farms with a dynamic farm controller*, in EWEA, Paris, France, 2015