FLOWSTAR-Energy Validation
Tjæreborg 60m

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FLOWSTAR-Energy 5.1

1 Introduction

Tjæreborg 60m is a single wind turbine on an onshore test site near to the coast in Denmark. A FLOWSTAR-Energy model of the wind turbine wake was compared with LIDAR measurements of wind speed at a fixed position downwind of the turbine for a range of free stream wind speeds and wind directions.

2 Input data

2.1 Study area

Wake measurements have been recorded over a long period of time (1988 to 1993) at a measurement mast 2D downstream of a 60 m/ 2 MW test turbine at Tjæreborg Enge wind farm in Esbjerg, Denmark. The diameter of the turbine is 61 m; the turbine hub height is 60 m.

The wake data available are measurements of normalised wind speed deficit at hub height for 4 flow cases: 6, 8, 10 and 12 m/s. The wind direction varies by 40 degrees either side of the case where the measurement mast is directly downstream of the turbine.

The thrust coefficient (C_T) data and power curve are available for this turbine; see Figure 1.

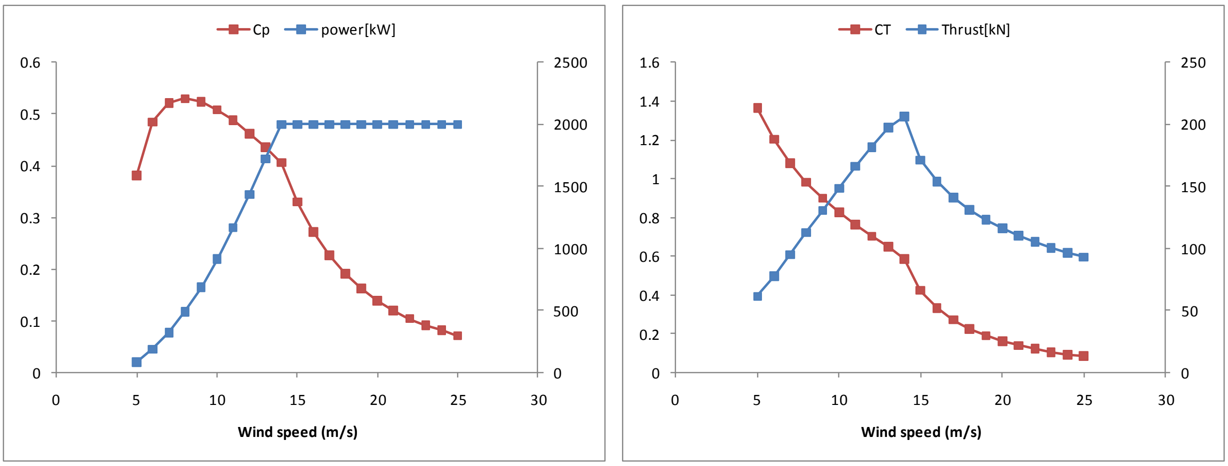

Figure 1- Calculated power (kW), power coefficient C_p, thrust (kN) and thrust coefficient C_T

2.2 Model setup

The inputs to FLOWSTAR-Energy were as follows:

- Onshore site, uniform surface roughness 0.001m
- 4 flow cases: U = 6, 8, 10 and 12 m/s
- For each flow case, wind directions modelled from 230 to 310 degrees inclusive, in 1 degree intervals with no wind direction sector averaging applied
- Boundary layer height 800 m, ground heat flux 0 W/m^2, i.e. neutral conditions
- Single turbine, centre coordinates (0,0)
- Turbine hub height 60 m
- Turbine diameter 61 m
- Power (kW) as a function of hub wind speed (see Figure 1)
- C_T as a function of hub wind speed (see Figure 1)
- Single output receptor directly east of the source, coordinates (122,0)

3 Results

The results presented in Figure 2 are modelled and observed normalised wind speed deficit at the downwind receptor for the four flow cases as a function of wind direction offset, where 0 degrees represents a westerly wind. The results are averaged over the measurement heights 30, 45, 60 and 90 m.

4 Discussion

There is generally good agreement between the modelled and observed wake deficit. However, while the modelled and measured data show broadly the same behaviour, namely that as the wind speed increases the strength of the wake decreases, this behaviour is less marked in the observed data than in the modelled data. The modelled wake has a tendency to be slightly wider than the observed wake in this case.

5 Acknowledgements

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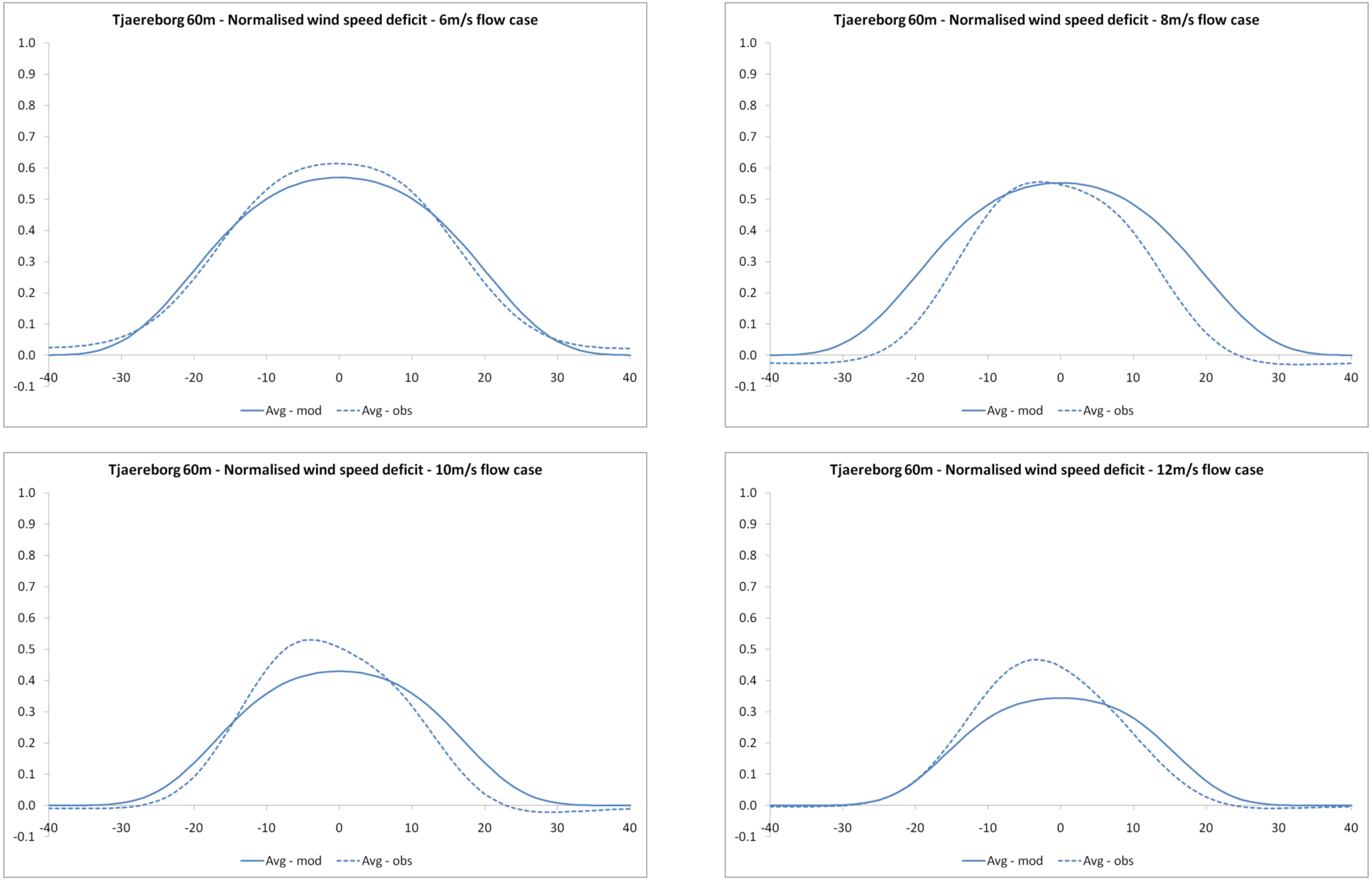

Figure 2 Normalised modelled and observed wind speed deficit at the receptor for the 4 flow cases (6, 8, 10 and 12 m/s) across the range of upstream wind directions, averaged over the 4 measurement heights (30, 45, 60 and 90 m).