The Importance of CFD for assessing met mast position for complex terrain site (lessons learned from a failure case)

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1. Introduction

Windfarm planning requires a good grasp of the site wind resource. In most cases, met masts are installed to get real measurement data. So how do you go about deciding the mast positions? Needless to say, data gathered will be used for calculating production, assessing turbulence level, wind turbine selection, and wind turbine positions. These are all critical tasks.

Ideally, the more masts we install the better. However, mast installation at every single turbine position is not economically viable. Under such circumstances, it is highly important to locate the masts at optimal positions.

Landowner's permission, forest protection, and transportation often impose severe restrictions on selecting mast positions. With complex terrain, there is always the potential that the chosen spot experiences high turbulence. Turbulence level may be so high that the wind data is not representative of the site.

In order to prevent that, CFD can be employed to check and confirm if the position in consideration is exposed to high turbulence or not. In this paper, the importance and the necessity of CFD is illustrated through studying a failure case.

2. Site and Mast Description

The site area and position of the mast is shown in Fig.1 The site is a ridge roughly running in an East-West direction, and the surrounding terrain is highly complex. Mast position is installed at a spot with elevation of 970m. The mast stands at 60m height with two anemometers at 57.5m level.

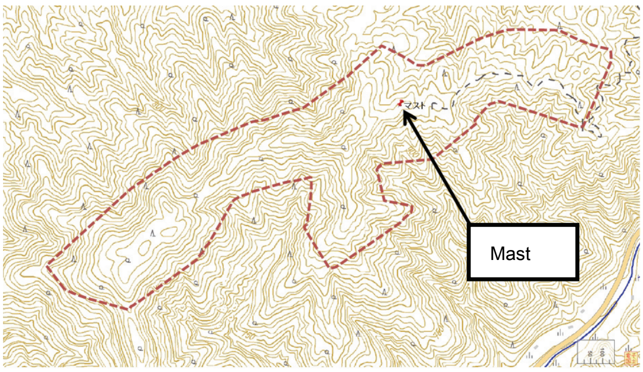

Figure 1 - Site and Mast Location
(Height Contours in 10m)

3. Analysis of Mast Data

Using one full year of 10 minute average data, an annual wind rose is plotted as shown in Fig.2. The main wind direction is WNW (280 to 310 degree) during winter. And the secondary wind direction is SSE to S (160 to 180 degree), which blows mainly during the summer seasons.

It should be pointed out that while wind speed data above 10m/s is clearly present for the secondary direction, it is not present in the main wind direction.

As a result, the average monthly wind speed during winter months is low, as shown in Figure 3. The annual average wind speed is at 4.9m/s.

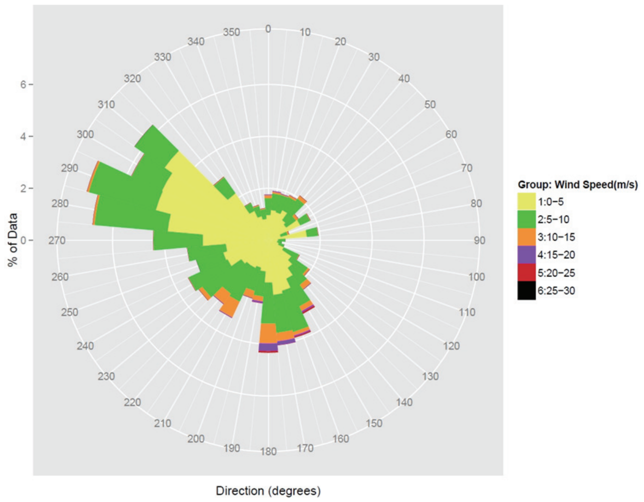

Figure 2 - Annual Wind Rose at 57.5m Height Level

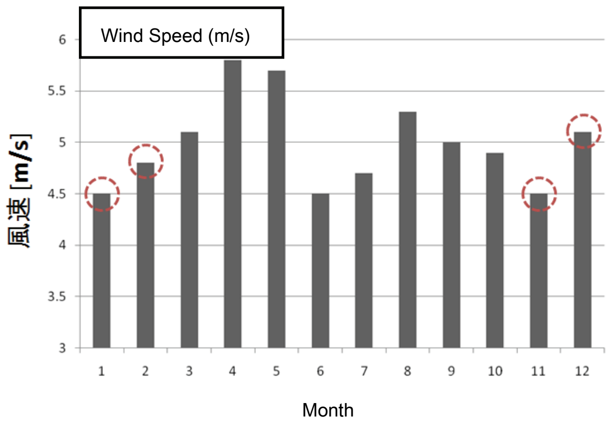

Figure 3 - Monthly Average Wind Speed at 57.5m Height

The turbulence intensity data is presented in Figure 4 for both directions. Compared with the graph on the left, the right graph (wind direction 290 degrees) shows exceptionally high turbulence intensity, with most data points exceeding the IEC standards (2nd Editions) by a large margin. In sharp contrast, the turbulence intensity in the secondary direction mostly falls below the IEC standard. The higher the turbulence intensity, the higher the wind speed fluctuation. So it is confirmed that large wind speed fluctuation exists in the main wind direction.

The wind speed and turbulence intensity time series is shown in Fig.5 for a chosen period of 3 hours, during which the wind direction varies between 270 and 292 degrees. Turbulence intensity varies from 0.34 to 0.52.

Wind speed at its lowest level is at about 1m/s. The difference between maximum and minimum wind speed is large, ranging from 13.6m/s to 21.9m/s. Within a ten-minute period, a 20m/s or above wind speed difference is considered to be a very large fluctuation. comes from the wind, this suggests the terrain surrounding turbine position T7 is creating excessive turbulence which leads to these failures.

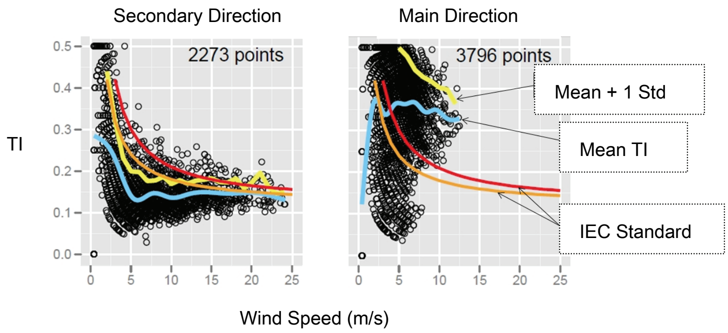

Figure 4 - Turbulence Intensity at 57.5m Height

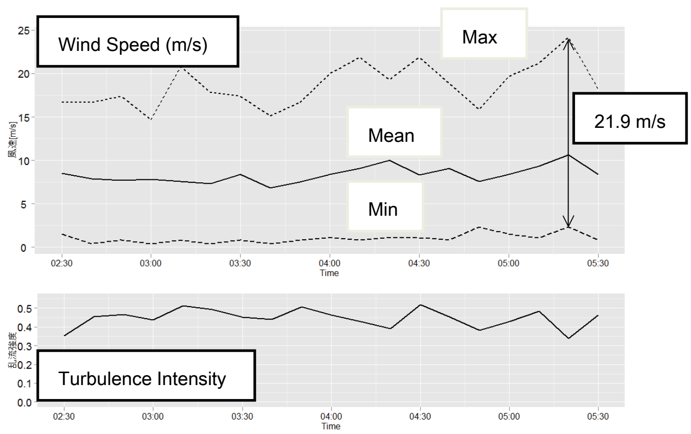

Figure 5 - Time Series from Mast Data
(Top: Wind Speed, Bottom: Turbulence Intensity)

4. CFD

CFD is carried out to investigate the turbulent structure. RIAM-COMPACT with its unsteady LES turbulence model is chosen to simulate the flow pattern. Figure 6 shows the CFD model. For the calculation domains: 3.4km along the main wind direction (x), 3.3 km for the perpendicular direction (y) and for the vertical direction (y) 2.3km. For both x and y directions, a uniform grid spacing of 10m, and for z direction, a non-uniform grid spacing with smallest grid size at 1m is applied. The mesh size is 340(x) X 340(y) X 50(z), a total of 5.75 million grid points. CFD wind direction is set to 290 degrees with inflow wind speed set at 10m/s.

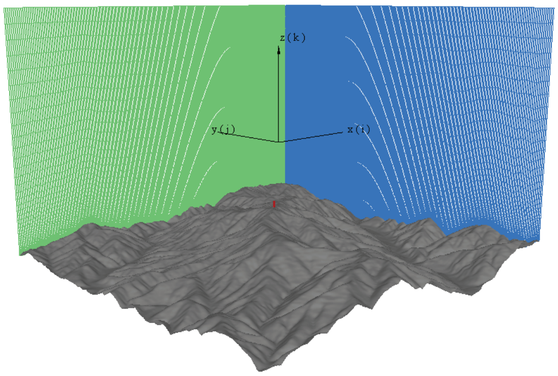

Figure 6 - CFD Model

Figure 7 shows an instantaneous result of the simulation. Flow separation occurs at the ridge located upstream of the mast. Vortex recirculation flows are seen to pass through the mast. More than half of the mast height is engulfed in this turbulent recirculation zone.

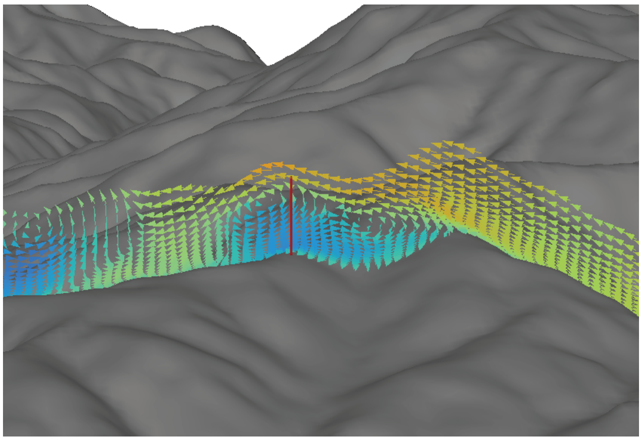

Figure 7 - CFD Result - Vector Plane at Mast (Instantaneous Result)

The location of the flow separation is shown in the map (Figure 8). It is about 140m from the mast, and the elevation difference between the separation zone and the mast position is only 10m. It is very obvious that this terrain feature brings about the onset of turbulence.

A time series from CFD at 58m is plotted and is shown in Figure 9. Large wind speed fluctuations can be observed with wind speed difference at 14.7m/s and turbulence intensity at 0.32. The simulation result is in broad agreement with measured results shown in Figure 5.

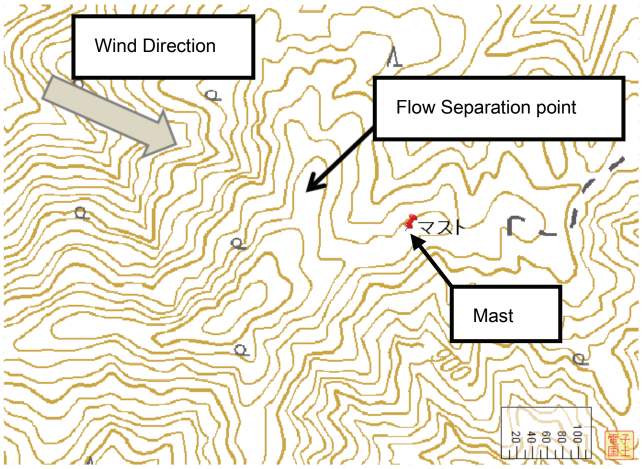

Figure 8 - Mast and Flow Separation Point

5. Summary

Appropriate and suitable wind measurement is a pre-requisite for the success of wind energy projects. To achieve that, mast position is critical, in particular for complex terrain sites. Terrain upstream of the mast can bring an onset of turbulence; therefore the possibility of the mast experiencing excessive turbulence should be assessed before mast installation. In the failure case described here, flow separation results in extremely high turbulence intensity and significant lowering of average wind speed. The flow pattern reproduced by the CFD identifies the mast as located in a recirculation turbulent zone. Numerical results obtained from CFD also display similar high level of turbulence intensity. Therefore, it can be concluded that CFD can be used for planning mast positions.

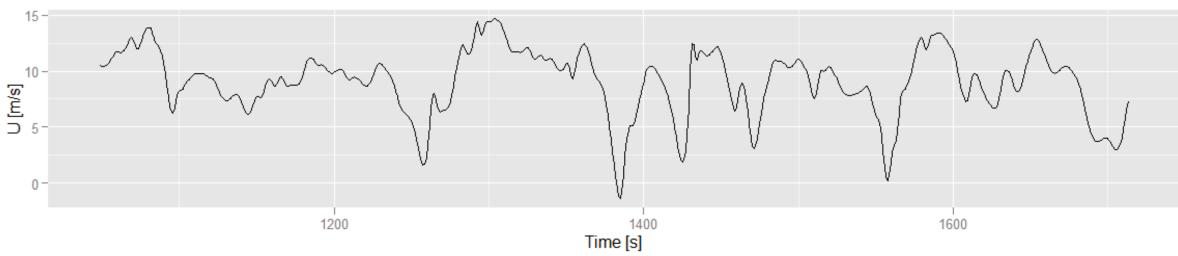

Figure 9 - CFD Result - Horizontal Wind Speed Component Time Series at 60m level