Analysis of the influence of the ground topography on the flow properties and the performance of small wind turbines by CFD simulation

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Wind conditions near a building surface are very different from the general wind conditions in the region, due to both the influence of neighbouring structures and the effects of the building itself. In short, the wind speed and turbulence intensity in built environments are affected to a large extent by the ground topography and the shape of the buildings. Thus, different CFD simulations of two low-rise buildings located in the Lichtenegg Energy Research Park are developed to model the annual wind flow over the topography and the buildings to help analyse the distribution of the flow over the wind turbines and around buildings.

Problem and motivation

The target of a micro roof-mounted wind turbine is to obtain the optimum annual amount of energy. Achieving this will involve a detailed analysis of factors such as the direction of the mean wind speed, the topography, the interaction of the building with the wind flow and the level of turbulence the turbine is exposed to. To that end, numerical modelling of the wind flow above the building roof and its surrounding area plays an important role. However, it is seen that studies generally ignore topographies and their combined effects with buildings, regardless of their important role in the airflow, often being more influential than the buildings and trees located in the area.

Research objectives and approach

This work attempts to analyse not only the influence of the ground topography but also the effect of the roof shape on the flow properties and the performance of small wind turbines.

Methodology

The current work is developed in two stages employing CFD simulations. One of the buildings is a flat roof building and the other one is a gabled roof building, in both simulations. In the first stage (Case 1), the buildings are analysed without taking into account the topography of their location. This means that the simulation is developed in a flat terrain. However, the second scenario (Case 2) represent both buildings set along the real topography of their location.

Through this method, it can be observed which roof shape has a major influence on the flow properties and if it is greater than the effect of the topography for the considered location.

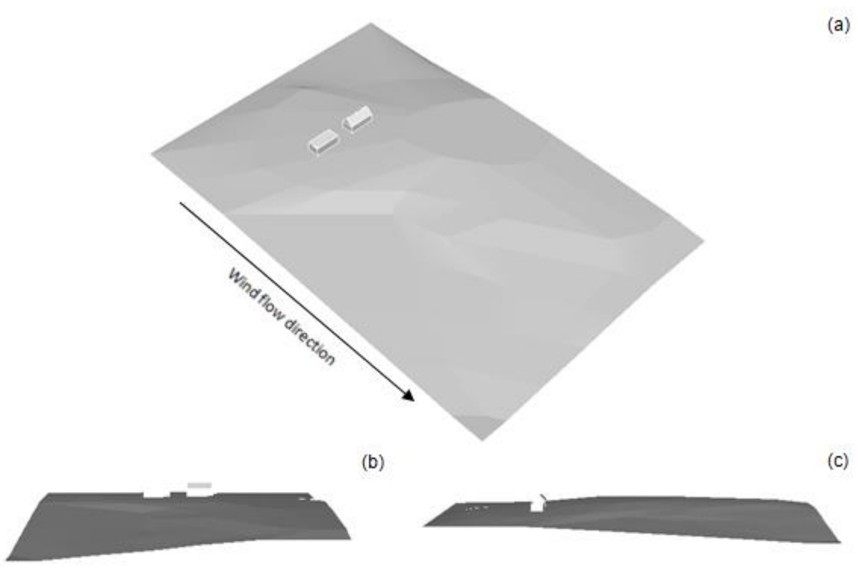

Figure 1 - Different views of the modelled domain in the case of real topography: top view (a), view from the outlet boundary (b) and view in the direction of the wind flow (c)

Results and conclusions

General flow patterns such as the velocity and turbulent kinetic energy seem to be irrespective of the topography of the location. Nevertheless, the investigation of the case with the topography showed a 6.5 % on average higher acceleration of the velocity in the flow direction around the buildings and a 16.5 % on average reduction of the turbulent kinetic energy in this zone. Moreover, the wind power utilization is enhanced as the wind power density (WPD) increases under the given simulation conditions.

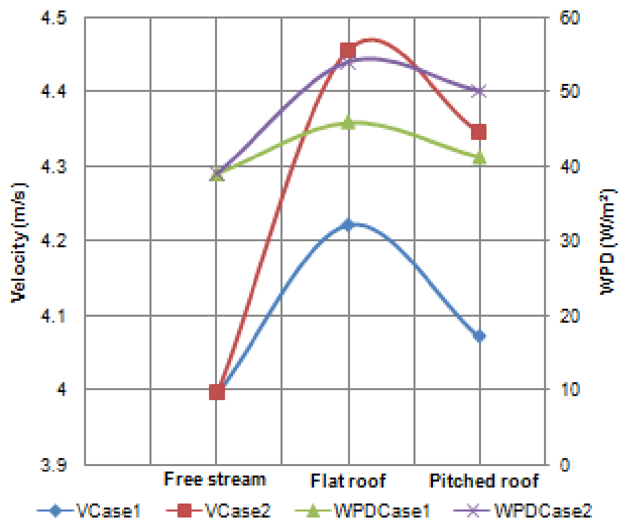

Figure 2 - Comparisons between the standard input and the wind speed and wind power density at the height of the rotor of the SWT

On the other hand, all roof shapes showed an accelerating effect. However, it was found that the wind above flat roof has not only a 3.5 % higher concentration effect compared to the pitched roof but also a 26.5 % lower turbulent kinetic energy. Additionally, it has also been noticed that the turbulent kinetic energy, as well as the turbulence intensity (TI), decreases more rapidly over the flat roof.

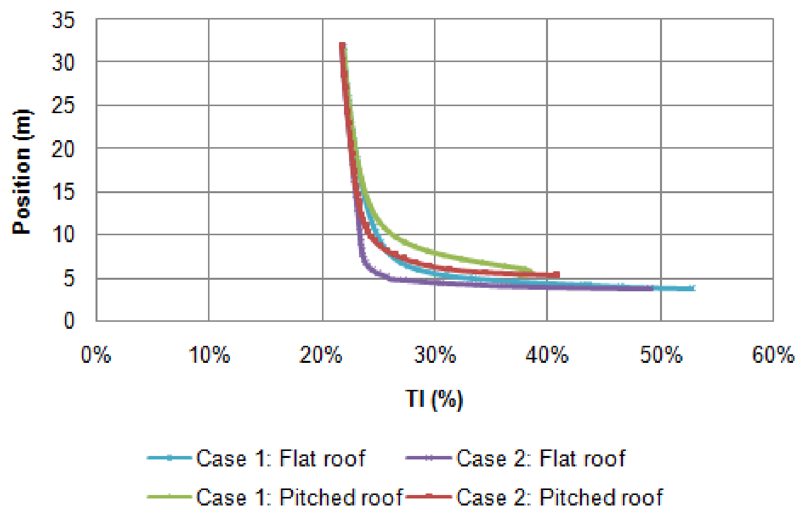

Figure 3 - Comparison between the turbulence intensity profiles above the centre of the different roofs in the different case studies

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STADT der Zukunft

Das Projekt „SmallWindPower@Home“ (FFG-Nummer: 854638) wird im Rahmen der 3. Ausschreibung des Programms „Stadt der Zukunft““ des Bundesministeriums für Verkehr, Innovation und Technologiegefördert.

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