Wind Farm Layout Optimization over Complex Terrain

オマ, モハメド, アリ, モハメド, イブラヒム

https://doi.org/10.15017/4059955

出版情報：Kyushu University, 2019, 博士（学術）, 課程博士
バージョン：
権利関係：

（様式３）Form 3

氏　　名　：オマ　モハメド　アリ　モハメド　イブラヒム

Name　　Omar Mohamed Ali Mohamed Ibrahim

Title　　Wind Farm Layout Optimization over Complex Terrain

論 文 名　：（複雑地形におけるウィンドファーム配置最適化）

区　　分　：甲 (Kou)

論　文　内　容　の　要　旨

Thesis Summary

Over the last decade, more onshore wind farms were constructed over or near to complex terrain such as: hills and mountains. Complex terrain can affect wind flow, wind turbine performance, and power output. This thesis examined the flow over a steep two-dimensional hill as well as the performance of a turbine located over the same hill. A good agreement between Experimental and Numerical simulations was achieved for the average vertical wind speed profiles. These results displayed the impact of the steep hill on air flow.

Moment acting on turbine was lowest upstream of the hill, and highest at the top of the hill. This is due to the higher wind speed at the top of the hill compared to upstream wind speed. A good agreement between wind tunnel test and CFD results was achieved for the wind turbine power coefficient by using the Transition SST model. The Transition SST model yielded better results than the SST k-omega turbulence model specifically at high tip speed ratios.

In this thesis, an engineering wake model, that considers acceleration on a two-dimensional hill, was developed based on the momentum theory. The model consists of the wake width and wake wind speed. The equation to calculate the rotor thrust, which is calculated by the wake wind speed profiles, was also formulated.

In this thesis, a wind-tunnel test was conducted to investigate wake development over a two-dimensional hill in simple flow conditions, where a uniform approach-flow with turbulence intensity less than 0.5 % was used. Conducting the wind-tunnel test in such simple flow conditions was necessary for this study in order to investigate the effect of the hill on wake development and evaluate the new wake model without the influence of the ABL, ground roughness, or turbulence.

Wake width was about 0.29D at the top of the hill (location 5), and about 1.09D at location 9 downstream of the hill. This means that the hill has caused the wake to accelerate and shrink upstream of the hill, and to decelerate and expand downstream of the hill.

The wake model was compared with the wind-tunnel test, and the results obtained by using the wake model were close to the wind-tunnel test results. The wake model was able to estimate the wake shrinkage in an accelerating two-dimensional wind field, and the percentage difference between the measured and estimated wake width at locations 3, 4, and 5 was 13.3%, 23.6%, and 48.9% respectively. The measured wake width at the top of the hill was lower than the estimated value (by the wake model), this could be because the wake center at the top of the hill was moved downwards due to the hill effect; this wake center movement must be confirmed with further studies.

Further numerical studies will be important to evaluate the new wake model at distances farther than 3D away from the rotor, as it was difficult to do so in the wind-tunnel due to the size limitation of the test section. In the wind-tunnel test, the hill surface was smooth as it was made of ABS resin, however, the surface

roughness may affect wind speed profiles over the hill. Consequently, the effect of the surface roughness on wake development must be considered in the future studies.

Further experimental and numerical studies where the approach-flow represents real atmospheric conditions (where the ABL is reproduced) are required to investigate wake development over the hill in conditions that wind turbine experience in the field. Finally, further modifications to the wake model are necessary to include the effect of turbulence and ground roughness on wake development over the hill, and to extend the wake model to decelerating wind field (downstream of the hill).