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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Due to the clean, renewable and sustainable characteristics, the generation of wind energy around the world grows rapidly. This rapid development of wind energy and the associated high uncertainties and fluctuations in power generation present a big challenge for both wind power generators and electric grids in many countries, especially Japan where the topography condition is very complex. An effective way to solve these problems is providing accurate and reliable wind power predictions in advance to properly adjust the integration of wind power into existing electrical systems. However, to our best knowledge there is very limited report in literature on any practice to establish a comprehensive forecasting system for wind farm sites in Japan.

Therefore, the purpose of this thesis is to develop a wind power forecasting system for a wind farm of interest in Awaji island of Japan as an effort to facilitate the short-term wind power forecast in Japan area. Considering the specific situation in Japan, we have combined meso-scale WRF (Weather Research and Forecasting) model, power curve (approximated by a 10^{th}-order polynomial), Kalman filter, data assimilation and the micro-scale OpenFOAM (Open source Field Operation and Manipulation) model together to build a novel and integrated forecasting system for wind energy prediction under complex terrain conditions.

We firstly evaluated the forecasting ability of the WRF and power curve model separately as the basic components of the integrated forecasting system. It is noted that the WRF model has been tuned to adapt the wind farm in Japan. Compared with the observed data of both wind speed and power, it is found that the two components are able to provide reasonably reliable forecasting results in the target site which has complex geographic environment very typical in Japan. However, significant errors and uncertainties were also observed in this preliminary system, for example the systematic overestimation of the wind power.

In order to improve the accuracy and reliability of wind power prediction, we have integrated Kalman filter, data assimilation and a micro-scale CFD (computational fluid dynamics) model (OpenFOAM model) as new modules in the system to reduce the errors and uncertainties. The performance of those three modules has been validated with the observed data. With Kalman filter,

the raw wind prediction can be substantially improved. The 15-turbine averaged improvements of ME (mean error), RMSE (root mean square error) and CC (correlation coefficient) are 97%, 22% and 10% respectively. Meanwhile, the Kalman filter also demonstrates a promising capability of reducing the uncertainties in the power curve model. More specifically, Kalman filter could significantly improve the raw model prediction of power by 92%, 33% and 15% in ME, RMSE and CC respectively. The validation results of data assimilation also indicate that the WRF model forecasts can be markedly improved after assimilating nacelle wind data, with the relative improvements of 34%, 24% and 9% in ME, RMSE and IA (index of agreement) respectively. It is noted that the data assimilation module can handle part of random errors which cannot be eliminated by Kalman filter module, and integrating both Kalman filter and data assimilation with WRF model can obtain the best performance. The resolution (500-m of horizontal direction) of the current forecasting system is too coarse to capture the detailed flow information caused by the complex terrain in the atmospheric boundary layer. Thus, the micro-scale OpenFOAM model has been coupled with the WRF system to build a multi-scale forecasting system for short-term prediction of hub-height wind under forcing of local geographic conditions. The ability of this multi-scale system for simulating wind flow the complex terrain is firstly validated with an arbitrary case. It is found that this system can capture reasonable distribution of the velocity and turbulent kinetic energy at the atmospheric boundary layer compared with other researchers' work. Moreover, this multi-scale forecasting system also shows remarkable advantages against the single meso-scale WRF component through validations with a 8-day series of observed data (192 cases).

In summary, a novel integrated forecasting system has been developed by combining the meso-scale WRF model, power cure model, Kalman filter, data assimilation and the micro-scale OpenFOAM model in this study. Its performance has been validated with the real-case observed data from the Awaji wind farm in Japan. Part of this system has been installed and used as routine tool for operational prediction.