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Wind energy potential assessment for the offshore areas of Taiwan west coast and Penghu Archipelago

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ABSTRACT

The average wind speed and wind power density of Taiwan had been evaluated at 10 m, 30 m and 50 m by simulation of mesoscale numerical weather prediction model (MM5). The results showed that wind energy potential of this area is excellent. Taiwan has offered funds to encourage the founding of offshore wind farms in this area. The purpose of this study is to make a high resolution wind energy assessment for the offshore area of Taiwan west coast and Penghu archipelago by using WAsP. The result of this study has been used to the relative financial planning of offshore wind farm projects in Taiwan. The basic inputs of WAsP include wind weather data and terrain data. The wind weather data was from a monitoring station located on a remote island, Tongi, because that all of weather stations in the area of Taiwan west coast are affected by urbanization. SRTM was selected to be used as terrain data and downloaded from CGIAR-CSI for voids problem. The coverage of considered terrain area in this assessment work is about 300 km × 400 km that made some difficulties to run wind energy assessment of the whole area with a high resolution of 100 m. So the interested area of this study is divided into 19 areas for the wind energy assessment and mapping. The assessment results show the Changhua area has best wind energy potential in the area of Taiwan west coast which power density is above 1000 W/m^2 height and the areas of Penghu archipelago are above 1300 W. These results are higher than the expected from NWP. 180 of 3 MW wind turbines were used in the study of micro sitting in the Changhua area.

The type and number of the wind turbines and the layout of the wind farm is similar to the prior study of Taipower Company for demonstrating the reliability of this study. The assessment result of average net annual energy production (AEP) of the wind farm is about 11.3 GWh that is very close to the prior study. The terrain effect is also studied. The average net annual energy production will decrease about 0.7 GWh if the wind turbines were moved eastward 3600 m closer to the coast because of terrain effect. As the same reason, the average net annual energy production would be increased to 11.392 GWh if the wind farm is moved westward 3600 m away from the coast.

1. Introduction

The research and development of renewable energy has been an important issue in our world because of the shortage of energy resource and rapid climate change. Wind energy was paid more attention in many countries because the advantages of cost and low carbon emission. There are more than 100 countries/areas use the power generated by wind turbines. The average increasing rate of wind power installation is about 20% in recent years. 44,799 MW of wind power was installed in the world. The total capacity of wind power installation is above 282 GW that the contribution of wind power exceeds 3% of the world power consuming [1,2].

Most of energy consumed in Taiwan is imported from other countries. Availability of imported energy supplies and fluctuations in international energy prices may strongly affect the energy safety of Taiwan [3]. Renewable energy may benefit Taiwan not only for environmental issues, but also in safety and economic issues. The average wind speed and wind power density of Taiwan at 10 m, 30 m and 50 m had been evaluated by the simulation of mesoscale numerical weather prediction model (MM5) [4] with a grid resolution of 10 km announced in 2001. The result showed that Taiwan has excellent wind energy potential. Taiwan established the first wind farm located in Penghu Archipelago in 2001. After then, the development and application of wind power grow very rapid in Taiwan. There are more than 564 MW of wind power installed in Taiwan by the end of 2012 [2]. 60 MW of wind power is expected to be installed in Taiwan in 2013. Most of the wind turbines were located in the western coast area of Taiwan Island and Penghu

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Archipelago. The population of Taiwan is over 23 million, but the area of Taiwan is only 360 thousands km^2 and most of the area, about 70%, is mountain and sloping field. It is not easily to find a suitable place for establishing wind farm without protest. Therefore, Taiwan government, Bureau of Energy, has offered funds to encourage the founding of offshore wind farms in this area to accelerate the development of wind power application in Taiwan. Taiwan energy bureau has planned to install 1000 wind turbines in the Taiwan area before 2030. The total capacity of wind power will exceed the 4200 MW in future [5,6]. More detailed investigation of wind energy potential and wind condition will increase the benefit of the established wind farm. In this study, the wind energy potential was evaluated at heights of 50 m, 100 m, 150 m and 200 m with a resolution of high 100 m by WAsP in this study.

The purpose of this study is to produce a high resolution wind energy assessment for the potential offshore wind farm area of Taiwan west coast and Penghu archipelago to help the development of Taiwan offshore wind power. There are many tools developed for wind energy assessment. These tools could be divided into 2 categories, potential flow models and CFD models. CFD models may be more accurate for assessing complex terrain area. But they always need large amount of calculation resource and time. So CFD models are not suitable to calculate wind condition of large area [7–12]. Flow model is simpler and can calculate larger area with less time. WAsP(Wind Atlas Analysis and Application Program) was created by DTU (Denmark Technology University) Wind Energy (former Wind Energy Division of Risø National Laboratory, Denmark) by the application of flow model. It has become the wind power industry-standard PC-software for wind energy resource assessment and is also good at siting of wind turbines and wind farms [13].

The interesting area of the west coast area of Taiwan Island and Penghu Archipelago are more than 20,000 km^2 and the whole area of Taiwan Island and Penghu Archipelago is about 1,20,000 km^2. So this study adopted WAsP as a wind energy assessment tool. The basic WAsP inputs include wind weather data, as well as terrain data. The wind weather data was from a monitoring station of a remote island, Tongi, located between the west coast area of Taiwan Island and Penghu Archipelago. The topography data of terrain used in this study is SRTM (Shuttle Radar Terrain Mission) 90 m Digital Elevation Data downloaded from CGIAR-CSI (The Consortium of International Agricultural Research Centers-the Consortium for Spatial Information). The SRTM data was original from NASA which had some voids problem. CGIAR-CSI processed the original SRTM DEMs to fill in these no-data voids. The processes involved the production of vector contours and points, and the re-interpolation of these derived contours back into a raster DEM. These interpolated DEM values are then used to fill in the voids within the SRTM data. CGIAR-CSI had done the quality assessment by the Comparisons with digital elevation models generated from cartographic data [14]. The roughness of terrain data was drawn according to satellite image from google earth.

One of the challenge in this study is the coverage of considered terrain area in this assessment work is about 300 km × 400 km that made some difficulties to run WAsP for wind energy assessment of the whole area with a 100 m of resolution. So the interested area of this study is divided into 19 areas for the wind energy assessment and mapping. The assessment result shows the Changhua area of Taiwan west coast is above 1000 W/m^2 height and the areas of Penghu archipelago are above 1300 W. These results are higher than the expected from NWP. 180 of 3 MW wind turbines were used in the study of micro sitting in the Changhua area. The Annual Energy Production of these 180 wind turbines are above 2000 GWh very close to other evaluation results funded by Taipower company.

2. Description of evaluation method and relation inputs

WAsP was adopted as the wind energy assessment tool in this study. As mentioned above, WAsP is an industry-standard PC-software for wind resource assessment. The error of the evaluation result of WAsP usually is lower than 10%. However, that should have good inputs. Wind weather data and terrain data are the essential inputs of WAsP. The weather data should be treated by WACA (WAsP Climate Analyst) to get long term statistic results of wind weather and climate. The terrain data should be treated by WAsP Map Editor for producing a map file as an input of WAsP.

It is not easy to find a good weather monitoring station in Taiwan because of rapid urbanization. The wind weather data was from a monitoring station of a remote island, Tongi, located between the west coast area of Taiwan Island and Penghu Archipelago. Tongi is a remote island located between the west coast area of Taiwan Island and Penghu Archipelago. It doesn't have urbanization problem. Tongi is a pretty small island. The roughness condition of Tongi is similar to offshore condition. The wind rose chart and weibull distribution chart in Fig. 1 were produced from 10 years (from 2001 to 2010) wind weather data of Tongi monitoring station treated by WACA. WACA can generate a omwc file for running WAsP after the treatment.

SRTM is original from U.S. NASA. CGIAR-CSI corrected the void problem of SRTM. So this study use the digital elevation data downloaded from CGIAR-CSI. The data from CGIAR is grid data. Some GIS software could transfer this grid data into DXF file for the input of WAsP Map Editor. The satellite images of Google Earth were inputted into WAsP Map Editor for drawing the roughness map. The roughness of terrain data was drawn according to satellite image from google earth. The coverage of considered terrain area in this assessment work is about 300 km × 400 km that made some difficulties to run wind energy assessment of the whole area for a high resolution of 100 m. So we plan to divide the interested area of this study into 19 areas for the wind energy assessment and mapping. These areas include Hsinchu, Miaoli, Taichung(1), Taichung(2), Changhua(1), Changhua(2), Changhua(3), Yuanlin(1), Yuanlin(2), Chiayi, Tainan, Tongi Island, Penghu(1), Penghu(2), Penghu(3), Penghu(4), Penghu(5), Penghu(6), Penghu(7). The more detailed locations of these 19 areas were shown in Fig. 2.

The wind turbines are bigger and bigger and the hub heights are higher and higher in the world recently because of the economic factors and technology development. So this study planned to calculate the wind resource at 50 m, 80 m, 100 m, 150 m and 200 m. The wind turbine used in this study is a 3 MW wind turbine which is provided by WAsP. This wind turbine is also used in other wind energy assessments funded by TaiPower Company. That is good to check the assessment result of this study.

This study designed a wind farm of 180 wind turbines, shown in Fig. 3, which referenced the layout of prior Taipower company assessment. However the wind farms are not at the exactly same place.

This study also try to move the wind farm toward and outward the coast 3600 m for understand the influence of land by the different distance between wind farm and the land.

3. Result and discussion

The wind energy potential assessment results of WAsP at different heights for the 19 areas were listed in Table 1 (The average wind speed assessment results) and Table 2 (The average power density assessment results). Both of the average wind speed and the average power density are increased with height.

It is obvious that the areas of Penghu archipelago have better wind energy resource. The average wind speeds of the areas of