An Assessment of the Available Offshore Wind Energy Potential Using Mesoscale Model and Geographic Information System

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SUMMARY: Offshore wind climate along the coast of Kanto area was investigated by a mesoscale model and wind energy potential considering economical and social criteria was estimated by Geographical Information System (GIS). The prediction accuracy of the annual mean wind speed by the mesoscale model was 4.8%. The estimated wind climate shows that offshore Choshi, the annual mean wind speed is significantly higher than other area. Without considering any economical or social criteria, the total potential along the coast of Kanto area is 287TWh/year, which is almost equal to the annual supply of Tokyo Electric Power Company. If only the bottom mounted foundation is used, the potential varies from 0.21TWh/year to 7.98TWh/year depending on the scenario. On the other hand, when floating foundation is taken into consideration, the potential is 100.59TWh/year even for the most conservative scenario.
Keywords: Offshore Wind Energy, Mesoscale Weather Model, Geographic Information System.

INTRODUCTION

A large portion of wind energy potential in Japan is located at rural area, where demand is low and the grids are weak. On the other hand, in the supply area of Tokyo Electric Power Company (TEPCO), which is the biggest utility in Japan and supplies electricity 282TWh per year, onshore wind resource is limited although there is no limitation for the grid integration of wind energy. Thus, if offshore energy potential around the supply area of TEPCO is estimated, certainly it will help the penetration of wind energy in Japan.

This study, first propose a offshore wind climate assessment method by mesoscale meteorological model and verify it by measurement. Then to consider the economical and social criteria, 18 scenarios are proposed and the available wind energy potential is estimated for each scenario by using geographical information system (GIS).

WIND CLIMATE ASSESSMENT BY A MESOSCALE MODEL

In this study, in order to investigate the wind climate and its spatial distribution in the offshore of TEPCO supply area, numerical simulation by a mesoscale meteorological model was carried out for the year 2000. As a mesoscale model, RAMS (Regional Atmospheric Modeling System)[1] was used in this study. RAMS is based on non-hydrostatic Reynolds-averaged primitive equations. The governing equations contain the conservation of mass, momentum, heat and water. The parameterization of the turbulent kinetic energy is based on Mellor and Yamada level 2.5 scheme and the parameterization of convection, radiation, soil and vegetation is also included in the model.

Two level nested grids were used to simulate the offshore wind climate. A grid with horizontal resolution of 8km was set to cover the Kanto Region (Eastern Japan). Inside this grid, two different grids with horizontal resolution of 2km were located to cover the offshore area around TEPCO supply area.

Simulated wind speed was verified at the Choshi meteorological station. The estimated annual mean wind speed shows good agreement with the measurement and the prediction error was 4.8%.

Annual mean wind speed differs considerably depending on the location even offshore. Generally wind speed decreases as the distance from the shore decreases. However, at some areas wind speed is considerably lower than the other area. At the offing of Choshi, the annual mean wind speed reaches 7.5m/s although at the northern area annual mean wind speed is much lower.

THE AVAILABLE WIND ENERGY POTENTIAL FOR SCENARIOS

In this study, area within 50km from the coastline in the supply area of TEPCO was chosen and the wind energy potential was calculated. However, some areas are not suitable for the exploitation of wind energy due to social or economical reasons. To consider those restrictions, some scenarios were assumed and available potential was estimated for each scenarios.

First criterion is the water depth. Water depth is strongly related to the type of the foundation. In this study, two scenarios were considered regarding the water depth. In the first scenario, only bottom mounted foundation can be used and the water depth is less than 20m. The second scenario assumes to use floating foundation, in which case, the area with water depth less than 500m can be used.

Second, prohibited area is considered. In the first scenario there is no prohibited area for the construction of wind farms, i.e. all the area can be used for the exploitation of wind energy. In the second scenario, national parks, ports, and areas with fishery rights cannot be used for the exploitation of wind energy. Third scenario is the most conservative scenario and in addition to the second scenario, area within 10km from the coastline is excluded due to landscape reason.

Finally, economical criterion was considered. In this study, three scenarios are considered regarding the capacity factor. In the most optimistic scenario, the minimum capacity factor is 25% and in the most conservative scenario, it becomes 35%.

Considering all the combination of these scenarios, 18 scenarios are assumed. Table 1 shows the installed capacity annual available potential and the ratio of the potential to the annual demand of TEPCO for each scenario. The spatial distribution of the available potential for each scenario is shown in Fig. 1.

Table 1. Potential wind energy for each scenario

Scenario	Installed Capacity (10,000kW)	Potential Wind Energy (TWh/year)	Quantitative Ratio (%)
B0-25	399	11.51	3.99
B0-30	261	7.98	2.76
B0-35	56	1.84	0.64
B1-25	157	4.71	1.63
B1-30	130	3.98	1.38
B1-35	35	1.16	0.40
B2-25	6	0.21	0.07
B2-30	6	0.21	0.07
B2-35	6	0.21	0.07
F0-25	4,643	150.42	52.10
F0-30	3,978	133.42	46.21
F0-35	2,651	93.53	32.40
F1-25	3,915	129.14	44.73
F1-30	3,503	118.55	41.06
F1-35	2,480	87.76	30.40
F2-25	3,205	107.56	37.26
F2-30	2,934	100.59	34.84
F2-35	2,262	80.40	27.85

If only the bottom mounted foundations are used, the available potential is strongly dependent on the availability of the area near the coastline. For example, assuming the capacity factor is more than 30%, if no social restrictions are considered (Scenario B0-30, Fig 1(a)), the available potential is 7.98TWh/year corresponding to the 2.76% of the annual demand of TEPCO. When the social criterion is considered, the available potential decreases to 0.21TWh/year for the most conservative scenario.

If floating foundation can be used, the available potential increases significantly. Assuming the capacity factor is more than 30%, even in most conservative social scenarios, 12,255 wind turbines can be constructed in the area of 6,622km2 and the available potential is 100.59TWh/year, which corresponds to 35% of the annual demand of TEPCO.

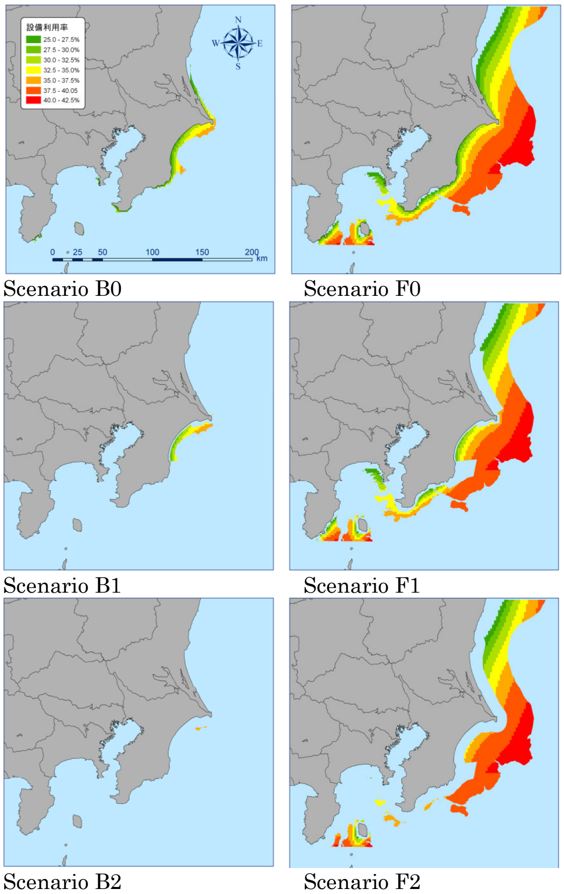

Figure 1. Spatial distribution of wind energy potential for each scenario

CONCLUSIONS

In this study, offshore wind energy potential in the supply area of Tokyo Electric Power Company (TEPCO) was investigated considering social and economical criteria by using mesoscale model and geographical information system (GIS). Following results were obtained.

1. Predicted wind climate by mesoscale model shows good agreement with measurement. The prediction error of annual mean wind speed at Choshi Meteorological Station was 4.8%.
2. Theoretical potential within 50km from the coastline in the supply area of TEPCO is 287TWh/year which is almost equal to the annual demand.
3. If only the bottom mounted foundation can be used, the available potential is limited to 0.21 to 11.51TWh/year depending on the scenario.
4. If floating foundation can be used, the available potential significantly increases and even for the most conservative scenario, the available potential is 80.4TWh/year.

References

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