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Analyzing the Economy of Off-shore Wind Energy using GIS Technique

Asifujiang Abudureyimu[a*], Yoshiki Hayashi[b], Ken Nagasaka[b,]

[a]*Department of Electronics and Information Engineering Tokyo University of Agriculture and Technology, Japan*
[b]*Department of Electrical and Electronics Engineering Tokyo University of Agriculture and Technology, Japan*

Abstract

Wind energy has emerged as the most attractive solution to the world's energy challenges. The possibility of locating wind turbines in the sea bed has opened up a new frontier for wind power, especially in the countries of northern Europe, where the availability of relatively shallow coastal waters has combined with the need to find space for much larger projects than are possible on land.
In this paper begins with an exploration of the importance of wind power in today's energy-hungry in Japan. In this paper looks at the basics of the off-shore wind power industry, how a wind turbine works, analyzing and understanding the technologies involved in harvesting off-shore wind power, economical analysis of off-shore wind power, and much more. Economics, issues and barriers, regulatory incentives, tax incentives, and other such factors related to off-shore wind energy also explored in-depth in this paper. As our calculation results show, the generation cost is within 10 to 17 Japanese Yen/kWh and construction cost is within 139,445 Japanese Yen/kW to 240,366 Japanese Yen/kW which revealed the applicability of off-shore wind power in Japan.

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Keywords: GIS; Off-shore; Wind Energy; Economic; Generation cost

1. Introduction

Off-shore wind energy has been drawing interest recently. This research is focusing on the potential analysis of off-shore wind energy surrounding entire Japan coast using GIS technology. Base on the economy and environment assessment, this research is evaluating the current situation and forecasting on

* Corresponding author. Tel.:+81-42-388-7481; fax: +81-42-388-7481.
E-mail address: aspjiang@gmail.com.

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future of wind energy technology in Japan. In order to reduce the green-house gas emission, also due to recent nuclear power problems in Japan, renewable energy (such as wind energy, solar energy, fuel cell…) is considered to gradually substitute the primary energy resources (such as coal, oil...).

In Japan, most of the off-shore wind resource potential in many areas, where is available in water deeper than 30 m. In contrast, all of the European off-shore wind turbines installed to date are fixed-bottom substructures, and have mostly been installed in water shallower than 20 m by driving monopoles into the seabed or by relying on conventional concrete gravity bases. These technologies are not economically feasible in deeper water. Instead, space frame substructures, including tripods, quad pods, or lattice frames (e.g. jackets), will be required to maintain the strength and stiffness requirements at the lowest possible cost. At some depth, however, floating support platforms will be the most economical.

In this paper, off-shore wind power is the centre of our focus. Based on GIS technique, off-shore wind turbines in the surrounding of Japanese coast-line are considered. In the study, 2000kW rated off-shore wind turbines are considered for further installation. Accumulated production of wind power had reached 2,185,938kW by the end of 2010[1]. The production of wind power in 2010 didn't exceed the half of the target value (3,000,000kW) the target and just accounted for 1.6% of the total global production.

To achieve the deployment levels described in the 20% wind report, many technical and economic challenges must be faced. Many coastal areas in the Japan have large electricity demand but have limited access to a high-quality land-based wind resource, and these areas are typically limited in their access to interstate grid transmission. Off-shore wind resources have the potential to be a significant domestic renewable energy source for coastal electricity loads.

As previously mentioned, the database was developed using Geographic Information Systems (GIS) techniques, allowing for spatial correlation of these characteristics.

2. Analysis Method and GIS Database Structure

In this study, by using the GIS ArcInfo and calculation of various scenarios, we overlapped all the wind velocity data, which are based on geographical data and meteorological model, by the GIS ArcInfo, where is the abundance calculated by various scenarios.

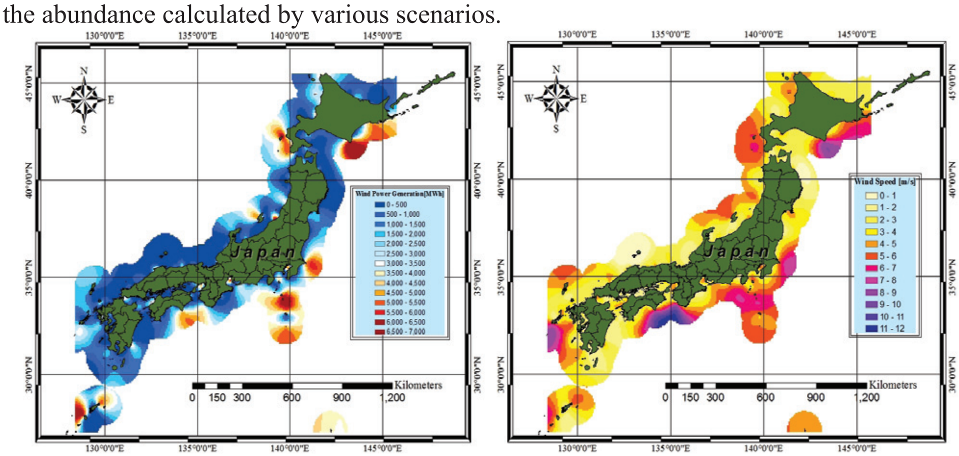

Fig. 1. (a) Wind power generation; (b) Wind speed of Japan

A GIS database was chosen to house the off-shore resource data because the datasets have a significant spatial component. All of the component datasets are spatially referenced to the same spatial base allowing rapid indexing of the different datasets to each other. A database user may compare information from different datasets in the same geographic location. The GIS database also allows portions of a dataset to be quickly updated as new information becomes available. The database is sufficiently flexible to allow new elements such as environmental exclusion areas and shipping lanes/navigation zones, for example, to be included in future versions. The horizontal resolution of the database grid cells is 100 m by 100 m. The database extends out from the shoreline to 50 nm and includes major bays and inlets.

The database contains wind resource information in two types of fields[2]. The first make the wind power map in the 70 m height above the surface layer in all Japan (Fig.1.a). The second is make the annual average wind speed at 70 m above the surface layer (Fig.1.b), the approximate hub-height of many current-day off-shore wind turbines. The primary method used to present the off-shore wind resource data are maps that categorize the resource by annual average wind speed at 70 meters (m) above the surface. The resource maps extend from the shoreline out to 50 Kilometer (km) off-shore.

3. Economic Analysis of Wind Power and Discussion

3.1. Present Investment Costs of Off-shore Wind Power

Wind power is developing rapidly on both European and global levels. Over the past 15 years, the global installed capacity of wind power increased from around 2.5 GW in 1992 to just over 94 GW at the end of 2007, an average annual growth of more than 25 per cent[3]. Owing to ongoing improvements in turbine efficiency and higher fuel prices, wind power is becoming economically competitive with conventional power production, and at sites with high wind speeds on land, wind power is considered to be fully commercial.

Off-shore wind energy development promises to be a significant domestic renewable energy source, especially for coastal energy loads with limited access to interstate grid transmission. The definition of the magnitude and distribution of this resource required the development of a standard and flexible database. Developed using Geographic Information System (GIS) techniques, the database includes off-shore wind resource characteristics such as wind speed, water depth, and distance from shore. It combines the resource characteristics with state administrative areas and quantifies the resource for several scenarios. In the future, the database may be expanded to include other important characteristics such as wave power density, extreme wind and wave, ocean currents, and a number of other parameters important to the design of off-shore wind turbines.

In recent years, three major trends have dominated the development of grid-connected wind turbines:

- Turbines have become larger and taller – the average size of turbines sold on the market has increased substantially;
- The efficiency of turbine production has increased steadily;
- In general, the investment costs per kW have decreased, although there has been a deviation from this trend in recent years.

Off-shore wind only accounts for a small amount of the total installed wind power capacity in the world – approximately 1 per cent. The development of off-shore wind has mainly been in northern European counties, around the North Sea and the Baltic Sea, where about 20 projects have been implemented. At the end of 2007, almost 1 100 MW of capacity was located off-shore. 2008 saw 366 MW of off-shore wind capacity installed in the EU, taking the total installed capacity to 1 471 MW in nine Member States, compared to the five countries having operating wind farms in 2007[4].

Off-shore wind is still around 50 per cent more expensive than onshore wind. However, due to the expected benefits of more wind and the lower visual impact of the larger turbines, several countries now have very ambitious goals concerning off-shore wind.

3.2. Calculation of power generation cost

Economics of wind power, electricity production costs are evaluated. In general, the generation cost is calculated in annual energy production divided by annual recurring costs. The annual operating costs consist of variable costs and fixed costs and operation and maintenance expenses, the method of calculating the fixed costs, and the payback method, there is a method of determining the average interest rate as the sum of depreciation and the like. The following method describes how to calculate payback[5].

$$G_{\cos t} = \frac{C_{\cos t} \times A_{er} + O_{\cos t}}{A} \tag{1}$$

$G_{\cos t}$: Generation cost (Yen/ kWh)

$C_{\cos t}$: Construction cost

A_{er} : Annual expense ratio

$O_{\cos t}$: Operation and maintenance cost

A : Annual generation amount

$$A_{er} = \frac{r}{1-(1+r)^{-n}} \tag{2}$$

r : Interest rate

n : Service life

We estimated the data and get the distances away from the coastal areas by GIS.

We calculated the wind power potentials on the supposition that off-shore wind turbines with a rated output of 2000kW were installed with interval of 100m apart from each other in each coast. In addition, we assumed the windmill off-shore wind turbines to run in 6m/s wind velocity for 3000 hours per year when calculating the yearly wind power potentials[6]. We created a distribution of annual electricity production cost (Fig.2).

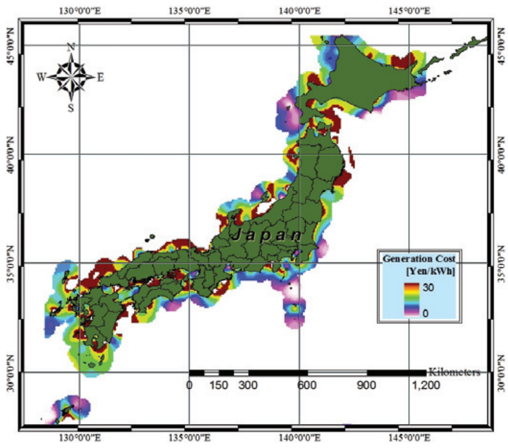

Fig. 2. Wind power generation cost of Japan

Table 1. Off-shore Wind Power generation cost in Japan

Candidate wind turbine installation sites	Annual average wind speed at 70m-high [m/s]	Power generation [kWh]	Candidate coastal areas at 20km offshore [km2]	Expected installation [unit]	Generation cost min [Yen/ kWh]	Generation cost max [Yen/ kWh]	Installation cost min [Yen/ kW]	Installation cost max [Yen/ kW]
Erimo Misaki	8	2,305,800	1,201	11,206	6	11	88,288	152,185
Kushiro	7	1,615,200	2,533	23,644	9	15	126,036	217,253
Yagishiri	6	1,060,000	188	1,759	14	23	192,050	331,045
Yoneoka	6	1,424,300	737	6,877	10	17	142,929	246,372
Okushiri	8	2,245,400	1,184	11,047	6	11	90,662	156,279
Aikawa	6	1,506,100	516	4,813	10	16	135,166	232,991
Choshi	6	1,582,500	1,121	10,458	9	16	128,640	221,743
Haneda	7	1,721,100	61	572	8	14	118,281	203,886
OoshimaKitanoya	6	1,166,700	276	2,574	12	21	174,487	300,770
Miyake Tsubota	7	1,816,300	1,643	15,336	8	14	112,081	193,199
Miyakezima	6	1,357,500	587	5,476	11	18	149,962	258,496
Koudushima	6	1,037,500	836	7,807	14	24	196,215	338,224
MisakiMuroto	6	1,288,600	696	6,498	11	19	157,980	272,317
Total	(AVE=6.5)	20,126,900	11,579	108,067	(AVE=10)	(AVE=17)	(AVE= 139,445)	(AVE= 240,366)

As the result of this study, we have determined that 108,067 off-shore wind turbine units in the investigated areas outcomes average generation cost is within 10 to 17 Japanese Yen/kWh and construction cost is within 139,445 Japanese Yen/kW to 240,366 Japanese Yen/kW which revealed the applicability of off-shore wind power in Japan. (Table 1).

4. Conclusion

The costs of off-shore capacity have increased in recent years, We have get the wind speed 6 m/s or more of the coastline, the average cost of electricity is about generation cost is within 10 to 17 Japanese Yen/kWh and construction cost is within 139,445 Japanese Yen/kW to 240,366 Japanese Yen/kW. And the higher wind speed the lower the cost of power generation, and we can get a more accurate set of possible wind turbine area and in the implementation of the construction of wind turbines, the more effectively achieve the economic assessment for off-shore construction of wind turbines make more precise and more effective economic base of Japan.

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