Small Wind Power Potential in Six Cities at Gifu Prefecture, Japan

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Abstract. Wind energy is one of the economic renewable sources and a valuable supplement to conventional energy sources. Small wind power generator can be used for substitution of conventional energy source. The main objective of the present study is to estimate small wind power potential using wind speed data. The result shows, the highest maximum wind power potential was found in Gifu city it was 4.77 watt. However, the total wind power potential at 2016-2017 the highest is 50365.62 Kwh in Gero city and the lowest was found in Gujo city with only 884.32 Kwh. The potential for wind power was strongly influenced by the geological condition and seasonal change. The high the potential of small wind power found in March-May, this time changes the season from winter to spring or spring. Gero city, Gifu city, and Takayama city have the potential to install small wind power generator, but not recommended for Gujo city and Nakatsugawa city.

1.Introduction

Nowadays, Global climate change was treated the human kinds and environment such as extreme weather condition, unpredictable of the dry season in the tropical country [1,2]. One factor promotes the global climate change is increasing the air pollution and greenhouse gases effect caused by massive burning the fossil fuel for the source of energy [3]. One strategy to decrease the effects of Global climate change is converting fossil fuel (non-renewable) to renewable energy. According to the global environmental problem, trends towards sustainable energy and green power sources such as solar, wind, biomass, and geothermal energy were largely increased. Wind energy is one of the economic renewable sources and a valuable supplement to conventional energy sources. The wind technology was gradually improved since the early 1970s. By the end of the 1990s, wind energy has emerged as one of the most important renewable energy resources [4-10].

The world established wind power is 24,322 MW in 2001, it has increased to 237,016 MW at the end of 2011 [11]. China is one of the largest installed wind generators, the record shows that the global total installed wind generation capacity has exceeded 310 GW. and in China, the current installed wind farm capacity is approximately 91.42 GW with a growth rate of 21.4% in 2013 [12]. In Turkey, the available wind power was increase time by time, where was 801 MW by the end of the year 2009. This capacity reached 1329 MW at the end of 2010. This capacity became 2041.35 MW at the end of July 2012 [13].

In Japan, after Fukushima nuclear power accident, power generation by nuclear rapidly decreased from 25% almost reach to the zero. The other hand, trends of renewable energy increase year by year. Large hydropower is the highest renewable energy was used in Japan around 7.1%, while only 0.5% for wind power energy [14]. Wind energy installation started increasing in late 1998 with capital subsidies. The first boost came with the green certificate program in 2000. Although the installation in 2002...
dropped with the anticipation of the Renewable Portfolio Standards (RPS) system introduced in 2003, the combination of RPS and capital subsidies supported an annual installation of about 250 MW between 2003 and 2010. However, Japan missed its wind energy target of 3 GW in 2010. Because of the halt of the NEDO capital subsidies to wind projects in FY 2010 due to the anticipated FIT (Feed-in Tariff) introduction, wind energy installation decreased by 20% between 2010 and 2011. However, after Fukushima nuclear power accident the wind power be one choice as a source of energy. Currently, the government only focus on big size the of wind power generation, which is in this size natural phenomenon such as Storm, Lightning strikes, Turbulence, Icing can break down the wind power generation [15].

The information about the potential of small wind power in Japan is limited especially in Gifu prefecture. Small wind power energy may have high potential to substitute the source or energy in household level, because the size is small, not take a large area to compare to photovoltaic (solar panel), and easy to install. The objective of this research is to estimate the potential of small wind power energy in six cities in Gifu Prefecture.

2. Research Method

The research was conducted in Gifu prefecture in August 2018. Wind speed data was provided by the Japan Meteorological Agency (JMA) based on Automatic Weather Station measurements, the location of the Automatic Weather Station (AWS) was provided in table 1. The data uses are wind speed data from 1 January 2016-31 December 2017. The characteristic of the measurement location can be seen in figure 1. The model of small wind power generation is ENGELEC the detail information in table 2.

| Name of Station | Longitude | Latitude  | Altitude (m) |
|-----------------|-----------|-----------|--------------|
| Takayama        | 137º 15.2’ E | 36º 09.3’ N | 560          |
| Gero (Hagiwara) | 137º 12.4’ E | 35º 53.3’ N | 426          |
| Gujo (Hachiman) | 136º 58.7’ E | 35º 45.4’ N | 250          |
| Nakatsugawa     | 137º 29.2’ E | 35º 36.6’ N | 378          |
| Gifu            | 136º 45.7’ E | 35º 24.0’ N | 12.7         |
| Ogaki           | 136º 37.2’ E | 35º 20.8’ N | 6            |

Table 2 The characteristic of small wind power generation model

| Characteristic of wind power generator | ENGELEC |
|----------------------------------------|---------|
| Brand name                             | ENGELEC |
| Model number                           | EN-300W-S |
| Type                                   | Wind power generator |
| Rate power                             | 300 W   |
| Max power                              | 310 W   |
| Rated voltage                          | 12/24V  |
| Start-up wind speed                    | 2m/s    |
| Rated wind speed                       | 13m/s   |
| Survival wind speed                    | 50m/s   |
| Wind wheel diameter                    | 1.35m   |
| Blades number                          | 3/5pcs  |
| Blade material                         | Nylon fiber |
The calculate the power converted from the wind into rotational energy in the turbine using the equation:

\[ P_{\text{avail}} = \frac{1}{2} \rho A V^3 C_p \]

Where, \( P_{\text{avail}} \): energy (Watt), \( \rho \): air density (kg/m\(^3\)), \( A \): swept area of the blade (m\(^3\)), \( V \): wind speed (m/s), \( C_p \): power coefficient (0.5) based on Betz’ law.

3. Result and Discussion

The results show, in table 3, Gujo city and Nakatsugawa city have 98% and 94.43% wind speed under 2m respectively. Gero city and Gifu city have enough wind speed to promote wind power generator around 57.92% and 53.88% respectively. Takayama, Gujo, Nakatsugawa and Ogaki city in 2016-2017 does not have wind speed more than 10m/s and only under 1% in Gero city and Gifu city, this data explains no extreme wind speed in all cities. Wind speed under 2m/s cannot be converted to be energy by the generator.
Table 3 Classification of the wind speed

| Wind speed | Takayama | Gero | Gujo | Nakatsugawa | Gifu | Ogaki |
|------------|----------|------|------|-------------|------|-------|
| <2 m/s     | 71       | 41.99| 98   | 94.43       | 46.02| 63.49 |
| 2-10 m/s   | 29       | 57.92| 2    | 5.57        | 53.88| 36.51 |
| > 10 m/s   | 0        | 0.09 | 0    | 0           | 0.1  | 0     |

Figure 2 Monthly energy potential from six cities

Figure 3 Effect of seasonal change on energy potential from six cities

From figure 2, it can be seen, the higher monthly energy potential was found in Gero city and next in Gifu City with the potential energy between 1500-3000Kwh. Ogaki city and Takayama city have the middle potential for wind power energy between 500-1500Kwh, but Gujo city and Nakatsugawa city has the lowest potential of wind power energy with monthly energy under 500Kwh. From figure 3, it can be clearly seen that the potential energy of wind power generation was influenced by seasonal changes. It can see the peak of the potential energy was found at the end of winter season or period the changing from winter season to the spring season. In table 4, explain the highest annual potential at 2016-2017 was found in Gero city (50365.62 Kwh) and the lowest in Gujo city (884.32 Kwh).

Table 4 Annual wind power energy potential

|         | Takayama | Gero   | Gujo   | Nakatsugawa | Gifu   | Ogaki  |
|---------|----------|--------|--------|-------------|--------|--------|
| Annual  |          |        |        |             |        |        |
| 2016    | 11489.3  | 25282.77| 445.36 | 1506.94     | 22576.28| 13693.54|
| 2017    | 10239.83 | 25082.85| 438.96 | 1833.04     | 22401.44| 13351.58|
| Total   | 21729.13 | 50365.62| 884.32 | 3339.98     | 44977.72| 27045.12|
The potential energy of six cities in Gifu prefecture was varied. The highest was found in Gero city and the lowest was found in Gujo city. The varied of the potential was depending on the speed of the wind, but in this research, the source of the wind was still difficult to be analyzed. Gujo city and Nakatsugawa is the lowest potential of energy, this may cause by measured area it was too close to the forest, where the stand of a tree can reduce the speed of the wind. Moreover, the potential energy also was influenced by seasonal changes, in figure 2 and figure 3, the potential energy was increasing from December (starting of winter), and reach the maximum in March (end of winter or period the change from winter to spring). This phenomenon was relating to air density or mass of air, where decreasing the air temperature will increase air density, so based on the theory and the calculation increasing the density of air will increase the energy potential. And in spring (March-April-May), migratory cyclones and anticyclones that alternately move eastward prevail across Japan. Temperature increases (decreases) in front (back) of cyclonic systems due to warm southerly (cold northerly) flow. Because of the movement cyclones and anticyclones across Japan, that will increase the frequency and the speed of the wind. Low temperature and increase the frequency and the speed of wind can promote the potential energy reaches the maximum.

Wind power energy continue to increase worldwide, with a total installed capacity of 238 GW by the end of 2011, which meets about 3% of the global electricity demand, and an expected capacity of 500 GW by 2015 In Europe, wind power generation is expected to contribute to EU’s 2020 targets for reduction of carbon dioxide emissions by more than 30% and to supply at least 14%–16% of Europe's electricity. The highest percentage found in Denmark (28%), a country that has recently set the ambitious target to produce 50% of its electricity from wind turbines by the end of 2020 [16–18]. In 2010 in China already install more than 40000MW, In India around 15000MW [13], but in Japan in 2010 only 2475 MW [15]. The installation of wind power generation in Japan still low compared to China and India. The policy of the government has a big influence on the installation of wind power generation. In the future, the strategies to increase wind power energy is needed to decrease using fossil fuel as energy sources.

4. Conclusion
The conclusion of this research is that small wind power generation have high potential to substitute the conventional energy in household level. The highest maximum wind power potential was found in Gifu city it was 4.77 watt. However, the total wind power potential at 2016-2017 the highest is 50365.62 Kwh in Gero city and the lowest was found in Gujo city with only 884.32 Kwh. The potential for wind power was strongly influenced by the geological condition and seasonal change. The high the potential of small wind power found in March-May, this time changes the season from winter to spring or spring. Gero city, Gifu city, and Takayama city have the potential to install small wind power generator, but not recommended for Gujo city and Nakatsugawa city.

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