Study on wind energy potential for agricultural water pumping system in the middle part of Thailand

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Abstract. A study on wind powered water pumping system aimed for agriculture was carried out in the middle part of Thailand. In this alluvial plain, wind energy potential was determined by making a survey on 21 observation sites. The survey was made in a period of one year, and it has shown that this region locates in a clam climate zone with average wind speeds at about 2 m/s. A wind turbine-water pumping system was installed and evaluated for its performance and efficiency. The result has shown a linear relationship between water discharge capability and the wind speeds. Due to the type of turbine and low wind speed in this region, the system efficiency turned out to be minimal, yet it was practical because the wind power was free. A simple cost analysis from the survey data also has shown that using a wind turbine in this region will be worthwhile when it can be operated for about two decades.

1 Introduction

Among all renewable energy resources, the wind energy is clean and simple to be harvested. It has been used for many centuries, from mainly agricultural applications in the past to the industrial and household usage as in today. A report in 2011 from the Global Wind Energy Council [1] has told that the electricity generated by wind energy in 2010 had increased 35,802 MW which was 22.5% of the total 194,390 MW electricity made by wind energy in the world. Half of these were produced in China where the economy was blooming as well as the need of energy resources. In other countries such as India, Japan, South Korea and Taiwan, the use of wind power was also increasing every year. These made Asia becoming one of the growing regions in wind energy usage with the capacity of 19,022MW in 2010.

Besides harvesting it to produce electricity, wind energy was often gained directly for specific tasks such as irrigations in farming, salt pond, and livestock. Couple decades ago Smulders [2] had presented water pumping system for agriculture using wind energy in developing countries. By designing a wind turbine incorporated with water pump configuration, wind energy can be used efficiently and affordable for cultivation. Several years later Mohsen and Akash [3] studied the possibility of using such systems in different areas of Jordan. The study could pinpoint 11 potential regions for using wind energy irrigation. However the availability of wind energy did not tell that it was worthwhile to be harvested. Al-Suleimani and Rao [4] did the efficiency test for wind turbine-water pump at different levels of wind speeds and the amount of water obtained. For certain region such as Adrar in Algeria, Bouzidi [5] had done a test to show that

water pumping by wind energy was practical and cheaper in comparison to the use of solar cells. Although several researches had confirmed the potential use of wind energy in irrigation, it was important to evaluate the availability of wind energy for any specific region.

Despite all of its advantages, the biggest limitation of wind energy is its inconsistency which is also varied between regions and seasons. However the variation of the wind power is not so crucial in some applications such as agricultural irrigation for certain types of farm. Because some plants and crops do not require frequent irrigation, water pumping via available wind power can be sufficient. In 2007 Saudi Arabia, a team of researchers led by Rehman [7] was able to utilize wind power for irrigation in a remote area using small wind turbines. Another fact about farming is that a good cultivation area usually locates near natural water resources, and should be a suitable living habitat. The location is often in a calm climate region which is not windy, and yet the low speed wind turbine can be used.

This research was carried out with the aim to evaluate the wind power energy for water pumping system in geological lowland region in the middle part of Thailand. This large alluvial plain is surrounded by four main rivers i.e., Chao Phraya, Tha Chin, Mae Klong, and Bang Pakong rivers. It is known as one of the best place for cultivation in South East Asia and locates the largest rice farming area in Thailand. In 2011, a similar work was done at northeast of Thailand. Poonnoi and Tangchaichit have conducted a wind energy survey [6] at high altitude in a period of one year. They found that the average wind speed in that region was 4.0-4.5 m/s

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2 The wind energy survey

This wind energy survey was simple and straight forward. By installing anemometers with data-loggers on the target sites, the wind speeds can be recorded. Due to the large size of target area and the long period of survey, this research turned out to be a tedious work and costly. Fortunately it was supported by the Department of Alternative Energy Development and Efficiency, under the Ministry of Energy, Thailand. With the aim to collect wind energy potential data in the prominent cultivation area of Thailand, the outcome can be useful for the future development in both agriculture and energy conservation.

Fig. 1. The 21 survey sites in the middle part of Thailand

2.1. Locations and data record

The win energy survey was conducted in the middle part of Thailand. There were 21 survey sites that cover 21 provinces where agriculture is the main occupation of the residents. Figure 1 shows the distribution of the observation sites. These locations were selected based on several factors which include district zoning, accessible road, and facilities. Also the availability of nearby water reservoirs was taken into the considerations. After all sites were selected, the wind speed measurement and record equipment were installed in every location.

In each observation site, wind speed and direction of wind were measured using anemometer, Winlog from Rainwise, with the wind speed range between 0-60 m/s and the accuracy within $\pm 2\%$. It was mounted on a tall column and installed at the height of 12 meters. Theoretically the taller wind turbine the more power can be obtained. However large and tall wind turbine tower would require too expensive construction, and in this case, it is not practical. At this height, the wind speed and direction can be observed with insignificant disruption from nearby trees and resident houses. The anemometer can rotate freely for 360 degree, and it was equipped with a digital data-logger with the capability to record with 10 minutes logging intervals for one year on three AA-batteries. The data can be downloaded via USB port into a computer for analysis.

Fig. 2. The sector-wise and Weibull distributions of wind directions and speeds in Chachoengsao observation site.

2.2 Wind power statistic

The measurement of wind speeds and directions were collected for a period of one year from September 2015 to August 2016. This duration began at the end of raining season and was followed by a short period of winter. After several months of summer in the first half of 2016, rains had started, and the data record was stop at the end of that raining season. Although there might be a slight shift of seasons, during the survey in 2015-2016 it was considered a typical climate in that period.

Once the data were collected from all 21 sites, they were analysed into Observed Wind Climate Report (OWC) using a program called WASP version 8.1 which is developed by Riso National Laboratory, Denmark. The software can present data in different forms. The formats used in this research include:

- Weibull distribution of wind speeds in the processed time-series.
- Sector-wise distribution of winds in the processed time-series
- Diurnal variability of wind speed for 24 hours
- Annual variability of wind speed

The Weibull distribution tells the most often wind speed can be observed and the variation of other less often data set. The sector-wise distribution or wind rose diagram tells the distribution of wind frequent directions. Figure 2 has shown an example of both wind rose and Weibull distribution in one year data which belong to the Chachoengsao observation site.

Fig. 3. The example of diurnal variability of wind speed in April 2016 taken from Chachoengsao observation site

In this survey, there were huge amounts of data to be analysed. It was more convenient to average these overwhelm information in order to represent a data set collaborated with a certain domain. For example, the wind speeds for each hour of any day within a month were averaged and represented a wind speed of that particular hour for the entire month. When combining all data from all hours, a diurnal variability chart can be presented as shown in figure 3, an example wind speed in April 2016 from Chachoengsao observation site. This chart can tell the distribution of average wind speed within each day of a month. Still, there were many observation sites, and the data cannot be presented all in here.

To look at the overall wind energy potential for the entire region, Figure 4 presents the statistical mode of wind speeds that were recorded in the duration of one year for the 21 observation sites. It can be seen that the most often wind speeds for all sites were not significantly different. The average most often wind speed for the entire region was 1.93 m/s. This value was considered small but not too much out of our expectation. As mentioned early, most of plentiful cultivation areas usually locate at a calm climate zone. Fortunately low speed wind turbine was practical for the agriculture water pumping application.

Fig. 4. Statistical mode of wind speeds for all observation sites

3 The water pumping system

Because the Based on the wind energy survey data, it was clear that the target region has an average low speed wind throughout the year. Nonetheless the research was to study the potential of using wind power for irrigation in typical cultivation region. At this minimal wind speed, Multi-Blade wind turbine was selected to be installed on a pilot site. There were two main reasons i.e., the Multi-Blade wind turbine is capable of working at low speed wind, and lower cost in comparison to other types of wind turbine. The wind turbine has 30 blades with the diameter 4.2 meters. It was installed at the height of 12 meter same as the anemometer height during the survey. The wind turbine was directly connected with a piston pump via a set of gears, crank shaft, and rods. The piston pump has the diameter at 4.5 inches and the maximum stroke of 7 inches.

Fig. 5. The wind turbine-water pumping system at the pilot site in Ayutthaya province

Using data from the survey, the site in Ayutthaya province was selected to be the pilot site used in testing the wind turbine-water pumping system. At this location, the wind energy survey has shown the record in average value for almost all aspects such as Weibull distribution, and the statistical mode of wind speed. Also Ayutthaya is considered a popular cultivation area with a lot of natural water reservoirs. Figure 5 shows the wind turbine-water pumping system at this location.

The wind turbine at this pilot site was able to run from completely stop at about 2.5 m/s wind speed, and it can maintain the operation with system inertia at the wind speeds between 1.5-2 meters depending on the load. The water pump, which was attached to this wind turbine, was able to operate at the suction head about 6 meters, and discharge head approximately 25 meters. Because the water pump may operate at 24 hours, the system had a water tank with an overflow valve as the reservoir. The pumping system was also equipped with flow meter for telling the amount of water obtained in relation to the wind speed.

To determine the system performance, wind turbine and water pump were considered as one device. All the frictions between these two devices were counted as the system loss. Therefor the input power for the system was the wind power which can be determined by:

$$P_i = \frac{1}{2} \rho A V^3 \quad (1)$$

where ρ is the air density at 1.2 kg/m³, A is the projection area of the wind turbine perpendicular to the turbine spindle axis, and V is the wind speed. For the system output which is the water discharged by the pump, the power can be written as

$$P_o = \frac{\rho_w g H Q * 10^{-3}}{60} \quad (2)$$

where ρ_w is the water density at 1000 kg/m³, g is the acceleration of gravity, H is the head of pump, and Q is

the water flow rate. With both power input and output, the efficiency of the wind turbine-water pumping system can be obtained via:

$$\eta = \frac{\rho_w g H Q \cdot 10^{-3}}{\rho A V^3 \cdot 30} \quad (3)$$

During the experiment, the amounts of water discharged from the pump were recorded in relation to the magnitude of wind speed. This relationship is presented in figure 6, and shown a linear response with the coefficient of determination, $R^2 = 96.9\%$. When applying this relationship to the equation stated above, the variation of system efficiency at different wind speed can be obtained as shown in figure 7. It should be noted that the overall efficiency was very low because the input power was determined by the wind force entering the turbine without deducting the wind momentum that leave the system. It is impossible to absorb all kinetic energy from the wind. Also, because the Multi-Blade turbine was designed to work at low speed, this makes the efficiency better at slower wind speed.

Fig. 6. Relationship between wind speed and pump discharge performance

Fig. 7. The overall efficiency of the wind powered water pumping system at different wind speeds

Although the system efficiency was relatively low, the input energy was free. This system can be made economically worthwhile. By making a simple analysis on the investment and operation cost in comparison to other types of power sources which include electrical motor and diesel engine, the result can be seen in table 1. The estimation was made according to the wind data from the survey. At the average wind speed 2 m/s, the wind turbine can pump water approximately 432,000 liter per month. The initial investment for wind turbine is relatively high, and it costs about 200,000 Bahts for the size used in the pilot test site. Fortunately it requires no fuel, and only small annual maintenance is needed. With the same amount of water pumped, the electrical motor and diesel engine only work for 2 hours per day. The

engine has lowest initial price because it can be operated everywhere. On the other hand, the electric motor can operate by cheaper power source, but the initial cost is relatively higher than the engine due to the electricity may not be available and needed to be established in the rural area. This estimation was made based on today average equipment and energy price. The investment of wind turbine can be returned sooner if the future energy price goes up as it tends to be.

Table 1. Cost comparison of the water pumping system with different power sources

Power sources	Price (Baht)	Fuel cost per hour (Baht)	Total cost 10 years (Baht)	Total cost 20 years (Baht)
Wind turbine	200,000	-	212,000	224,000
Electrical motor (with wiring)	62,000	8	125,400	208,800
Diesel engine	33,000	20	189,000	345,000

4 Conclusion

The wind energy survey in the middle part of Thailand was successfully carried out. The result has shown that this cultivation region has calm climate throughout the year, and the most often wind speed can be observed at about 2 m/s. At this level of low speed wind, Multi-Blade wind turbine was selected and installed at a pilot site. It was tested and able to evaluate the potential of wind powered water pumping system. Based on the turbine performance and the data from the survey, a cost analysis was created, and it has indicated that the use of wind turbine is worthwhile only when it can operate for about two decades.

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