STATISTICAL ASSESSMENT OF WIND ENERGY POTENTIAL CASE STUDY: BANSONGKORN STATION, THAILAND

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Abstract- Thailand is facing an energy crisis for a decade because of inadequate power generation capacity compared with its demand. In order to secure the energy future, renewable energy is the most promising for strategic planning. Wind energy is the most well–known renewable energy due to the awareness of clean and environmental friendly resources. In this study, the assessment of wind energy potential is approached by means of statistical methods. Probability distributions are employed in order to estimate wind speed values. The study analyzes wind speed data from Bansongkorn station in Thailand. Five distributions are fitted to the monthly average wind speed. The best distribution is selected based on the coefficient of determination ($R^2$). The results indicate that the best performance can be obtained by lognormal distribution, which the accurate determination of probability distribution of wind speed values is significant to evaluating wind energy potential of a region.

Index Terms- wind energy potential, wind speed, probability distribution, Thailand

I. INTRODUCTION

Energy, particularly for electricity, is essential to social and economic development in Thailand. In the past decade, electricity consumption has increased on average at 5,700 GWh/year [1]. Thailand Load Forecasting Center illustrates that the demand grows doubling from its existing value in 2021. For power generation, installed energy capacity is dependent on natural gas resources that accounted for 66.76% of the total electricity generation (177,580.47 GWh) in 2015 [2]. Consequently, the rapid growth in the electricity demand is likely to result in inadequate resources for electricity supply.

From the limitations of conventional energy (natural gas) as discussed above, renewable energy becomes the most promising for the future strategic energy planning. Many researchers have investigated the renewable energy potential that is crucial for proper allocation of available resources. Up to now, Thailand’s installed renewable energy capacity has reached 4,485 MW, accounting for 10.1% of total power capacity [3]. Wind energy is one of the most well–known renewable energy due to the awareness of clean and environmental friendly resources. The availability of wind resources is limitless that makes wind energy as an alternative of domestic energy resources in many countries [4].

In statistical assessment of wind energy potential, many researchers have tried to fit different distribution to wind speed values for the accurate estimation. N. Masseran derived a wind power density model and its statistical properties particularly from the Weibull, Gamma, and Inverse Gamma density functions [5]. G. Li and J. Shi combined Bayesian model averaging and Markov Chain Monte Carlo sampling methods to derive wind speed distribution [6]. Z.R. Shu, Q.S. Li, and P.W. Chan applied Weibull distribution function to estimate the Weibull parameters which use to facilitate the evaluation of offshore wind energy potential [7].

This study aims to find the best probability distribution to monthly average wind speed of Bansongkorn station in Thailand. The accurate determination of probability distribution of wind speed values is significant to evaluating wind energy potential of this region.

II. WIND SPEED DATA: CASE STUDY BANSONKORN STATION

For the assessment of wind energy potential, the wind speed is measured at meteorological station, namely Bansongkorn weather station. Basongkorn station (14°48’27.8", 101°54’22.6") is located at flat area in Northeast of Thailand. An anemometer is placed at a height of 238 m above the mean sea level, with a ground level of 40 m. In the study, monthly average wind speed values belonging to Bansongkorn station has been analysed. The data was recorded from the year 2005 to 2011 at a height of 40 m are presented in Table I [3].

<table>
<thead>
<tr>
<th>TABLE I. MONTHLY AVERAGE WIND SPEED VALUES FROM 2005 TO 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVERAGE WIND SPEED (m/s)</strong></td>
</tr>
<tr>
<td>Year Month</td>
</tr>
<tr>
<td>JAN.</td>
</tr>
<tr>
<td>FEB.</td>
</tr>
<tr>
<td>MAR.</td>
</tr>
<tr>
<td>APR.</td>
</tr>
<tr>
<td>MAY.</td>
</tr>
<tr>
<td>JUN.</td>
</tr>
<tr>
<td>JUL.</td>
</tr>
<tr>
<td>AUG.</td>
</tr>
<tr>
<td>SEP.</td>
</tr>
</tbody>
</table>
A. Normal distribution
The normal distribution depends on two parameters (mean and standard deviation). The average wind speed can be generated using an independent sequence of random numbers. The probability density function of normal distribution is given by (3):

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left( \frac{x-\mu}{\sigma} \right)^2 \right] \]  

where: \( x \) is the monthly average wind speed, \( \mu \) the average of the monthly wind speed data, and \( \sigma \) is the standard deviation of monthly data of wind speed.

B. Lognormal distribution
The Lognormal distribution is a continuous probability distribution of a random variable whose logarithm is normally distributed. The random variable which is log-normally distributed takes only positive real values. The probability density function of lognormal distribution is given by (4):

\[ f(x) = \frac{1}{x \sigma \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left( \frac{\ln x-\mu}{\sigma} \right)^2 \right] \]  

C. Exponential distribution
The exponential distribution describes the time between events in a Poisson process which events occur continuously and dependently at a constant average rate. The probability density function of exponential distribution is given by (5):

\[ f(x) = \frac{1}{\theta} \exp\left(-\frac{x}{\theta}\right) \]  

where: \( \theta \) is the scale parameter of the distribution.

D. Minimum extreme value distribution
The minimum extreme value distribution is limiting distributions of the minimum of a large number of unbounded identically distributed random variables. The probability density function of minimum extreme value distribution is given by (6):

\[ f(x) = \frac{1}{\theta} \exp\left(-\frac{x-u}{\theta}\right) \exp\left(-\exp\left(-\frac{x-u}{\theta}\right)\right) \]  

where: \( \theta \) is the scale parameter of the distribution, and \( u \) is the location parameter.

E. Weibull distribution
The Weibull distribution is a special case of generalized Gamma distribution. The probability density function of Weibull distribution is given by (7):

\[ f(x) = \frac{m}{\theta} \left( \frac{t}{\theta} \right)^{m-1} \exp\left[-\left( \frac{t}{\theta} \right)^m \right] \]  

where: \( t \) is the frequency of occurrence of wind speed, \( \theta \) the scale parameter of the distribution, and \( m \) the shape parameter.

### III. STATISTICAL METHODS

Wind speed data in time-series format is arranged in the probability distribution to model wind and wind potential evaluation. Five different probability distributions – normal, lognormal, exponential, minimum extreme value, and Weibull distribution are considered as the probability density function in this study [8]. With the best fit to the distribution, linear transformation is applied on probability density function for evaluating average wind speed based on the coefficient of determination (R²) [9], which the linear equation model is as in (1).

\[ y = ax + b \]  

where:

\[ a = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad b = \bar{y} - a\bar{x} \]  

, and the coefficient of determination is calculated as in (2)

\[ R^2 = \left( \frac{\sum_{i=1}^{n}(x_i y_i) - \bar{x} \cdot \bar{y}}{\sqrt{\left( \frac{1}{n} \sum_{i=1}^{n} x_i^2 \right) \left( \frac{1}{n} \sum_{i=1}^{n} y_i^2 - \bar{y}^2 \right)}} \right)^2 \]  

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TABLE II. WIND SPEED PROBABILITY DISTRIBUTION

<table>
<thead>
<tr>
<th>Probability Distribution</th>
<th>Coefficient a</th>
<th>Coefficient b</th>
<th>Coefficient of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1.6997</td>
<td>-4.5925</td>
<td>0.9465</td>
</tr>
<tr>
<td>Lognormal</td>
<td>4.8009</td>
<td>-4.6787</td>
<td>0.9829</td>
</tr>
<tr>
<td>Exponential</td>
<td>-1.6137</td>
<td>3.3888</td>
<td>0.9414</td>
</tr>
<tr>
<td>Minimum extreme value</td>
<td>2.0101</td>
<td>-5.9865</td>
<td>0.8489</td>
</tr>
<tr>
<td>Weibull</td>
<td>5.8445</td>
<td>-6.2509</td>
<td>0.9311</td>
</tr>
</tbody>
</table>

Based on the coefficient of determination, the lognormal distribution constitutes the most accepted for wind speed. The average wind speed at Bansongkorn station derived from linear transformation that applying on probability density function with 2.71 m/s, is calculated as in (8).

$$\mu = \gamma_{0} \exp\left(\frac{\omega^2}{2}\right)$$

where:

$$\gamma_{0} = \exp\left(-\frac{b}{a}\right), \quad \omega = \frac{1}{\omega}$$

CONCLUSION

This study discusses the statistical assessment of the wind speed density function. The transformation method has been proposed for deriving a theoretical density function of wind speed that based on normal, lognormal, exponential, minimum extreme value, and Weibull probability density functions. From the results, the lognormal distribution is found the best fit of the probability density function. The average monthly wind speed for Bansongkorn station is 2.71 m/s which is suitable for standalone and small scale wind power generation.

REFERENCES


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