Mapping of Wind Energy Potential using Weibull Distribution

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Abstract – A feasibility study of wind energy potential in Peninsula Malaysia was carried out. The purposes of this research are to determine the average of wind power that can produced during 2 major monsoon season namely northeast and southwest monsoons. Subsequently the results will display in mapping using method of kriging. Initially, the wind speed data was recorded daily for the year 2009 in unit of meter per second. The data was fit with well-known Weibull distribution and the distribution’s parameters were calculated. Next, the wind power was determined using wind power density function. The contour map shows that, Peninsula Malaysia had weak wind energy potential throughout the year 2009. There was slightly different in wind power estimated for monsoon season whereby northeast monsoon expected to produce higher wind power estimated compared to southwest monsoon especially along the area of east coast Malaysia.

Key-Words: - Wind energy potential, Wind distribution, Weibull distribution, Wind mapping.

1 Introduction

As the world modernize, the usage of conventional resources getting higher and higher. These scenarios will cause the natural resources decreased eventually. People will spent a lot amount of money to get the resources because it very costly. Furthermore, the usage of conventional resources will lead to harmful pollution. Research should be done to find a way out of this crisis by searching new safe and long lasting energy (alternative energy) such as solar energy, wind energy, biogas, hydro energy, etc. There are many research conducted worldwide to study about wind potential, for instance, in India, the electricity generation using windmill reached 202MW at 30.06.2010 and cumulative total dateis 12,009MW to be supplied to the interior, the industry and the economy in terms of increase space and work areas (Mahendra & Mool 2010). While in Algeria, wind studies conducted in Tindouf area show that the average wind velocity is good at around 5.8 m / s. Wind density generated for the wind velocity using Weibull distribution is 250W/m² (Himri et al. 2010).
Malaysia has two major monsoons; winds northeast monsoon and the southwest monsoon winds. Southwest monsoon winds formed in the month of May to September. The prevailing wind blows in this season with speeds not exceeding 15 knots. A northeast monsoon wind was formed in November to March. The prevailing wind in this season is from the east or northeast with winds speed range of 10 to 20 knots. East coast states of Peninsular Malaysia are more affected than other areas where wind speeds exceed 30 knots (Azami et al. 2009).

2 Research Methodology

Weibull distribution is commonly used because it gives the best fit to the observed data. Estimation of Weibull distribution parameters for monthly and annual wind velocity is also done in each area in India. The parameters estimated with annually wind velocity help in identifying the potential areas of wind, while the parameters of the monthly wind speed was very useful in estimating the size of the wind energy conversion system (Mahendra & Mool 2010).

2.1 Weibull distribution

It can be defined by the probability density function that has 2 parameters, the scale parameter \( c \) and the shape parameter \( k \) as shown below:

\[
f(v) = \frac{k}{c} \left( \frac{v}{c} \right)^{k-1} \exp \left[ -\left( \frac{v}{c} \right)^k \right]
\]

(1)

While the cumulative distribution function for Weibull distribution is:

\[
F(v) = 1 - \exp \left[ -\left( \frac{v}{c} \right)^k \right]
\]

(2)

\[
p_n = F(v) = 1 - \exp \left( -\left( \frac{v}{c} \right)^k \right)
\]

(3)

By taking \( \ln \) and simplify the equation yield:

\[
\ln[-\ln(1 - p_n)] = kl\ln v - klnc
\]

(4)

Comparing with equation of straight line: \( y = ax + b \), yield \( y = \ln[-\ln(1 - p_n)] \), \( x = \ln v \), \( a = k \), and \( b = -k \ln c \).

2.2 Predicting wind power

The wind power density function is

\[
P = \frac{1}{2} \rho v^3
\]

(5)

with \( P \) = wind power (W/m\(^2\)), \( \rho \) = air density (1.16 kg m\(^{-3}\)). The expected value of \( V^3 \) is calculated by:

\[
E(V^3) = c^3 \Gamma(1 + \frac{3}{k})(1 - \frac{s}{100})
\]

(6)

where \( \Gamma \) is a gamma function and \( s \) is the percentage of calm wind frequency.

2.3 Mapping the Wind Power

Kriging is a geostatistical technique to interpolate the value of a random field at an unobserved location from observations of its value at nearby locations. Kriging belongs to the family of linear least squares estimation algorithms. The aim of kriging is to estimate the value of an unknown real-valued function, \( f \), at a point, \( x^* \), given the values of the function at some other points, \( x_1, x_2, \ldots, x_n \). A kriging estimator is said to be linear because the predicted value, \( f(x^*) \), is a linear combination that may be written as

\[
\hat{f}(x^*) = \sum_{i=1}^{n} \lambda_i f(x_i)
\]

(7)

The weights \( \lambda_i \) are solutions of a system of linear equations which is obtained by assuming that \( f \) is a sample-path of a random process \( F(x) \), and that the error of prediction is to be minimized in some sense.

\[
\epsilon(x) = F(x) - \sum_{i=1}^{n} \lambda_i f(x_i)
\]

(8)

For instance, the so-called simple kriging assumption is that the mean and the covariance of \( F(x) \) are known and then, the kriging predictor is the one that minimizes the variance of the prediction error. From the geological point of view for this case study, the practice of kriging is based on assuming continued extreme wind speed between measured values. Assuming prior knowledge encapsulates how wind co-occurs as a function of space. Then, given an ordered set of measured grades, interpolation by kriging predicts extreme wind speed at unobserved points (Sapuan et al. 2011).

3 Results

3.1 Result of Wind Power

The expected wind power results are displayed in table below:

<table>
<thead>
<tr>
<th>Station</th>
<th>Southwest Monsoon</th>
<th>Northeast Monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayan Lepas</td>
<td>3.55</td>
<td>7.1236</td>
</tr>
</tbody>
</table>
### 3.2 Wind Power Map

From the Surfer Software, we can make generalization of wind power in any area around Peninsula Malaysia. Figure 1 and 2 is the result for wind power in southwest and northeast monsoon. The dark color represents higher wind power and vice versa.

<table>
<thead>
<tr>
<th>Location</th>
<th>SWM</th>
<th>NEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alor Setar</td>
<td>2.5546</td>
<td>6.1564</td>
</tr>
<tr>
<td>Chuping</td>
<td>0.699</td>
<td>2.7188</td>
</tr>
<tr>
<td>Kota Bharu</td>
<td>12.3495</td>
<td>14.772</td>
</tr>
<tr>
<td>Kuala Terengganu</td>
<td>2.8774</td>
<td>7.8612</td>
</tr>
<tr>
<td>Ipoh</td>
<td>2.9178</td>
<td>2.8916</td>
</tr>
<tr>
<td>Cameron</td>
<td>3.751</td>
<td>6.8808</td>
</tr>
<tr>
<td>Subang</td>
<td>3.3642</td>
<td>1.9676</td>
</tr>
<tr>
<td>Kuantan</td>
<td>2.6842</td>
<td>2.9982</td>
</tr>
<tr>
<td>Melaka</td>
<td>2.5994</td>
<td>10.312</td>
</tr>
<tr>
<td>Mersing</td>
<td>10.2354</td>
<td>17.7604</td>
</tr>
<tr>
<td>Senai</td>
<td>1.623</td>
<td>4.8188</td>
</tr>
</tbody>
</table>

Fig. 1: Southwest expected wind power map in Peninsula Malaysia 2009.

Fig. 2: Northeast expected wind power map in Peninsula Malaysia 2009.

### 4 Conclusion

The research shows that wind energy resource in Peninsula Malaysia is not suitable enough to build the wind turbine for wind farm. It is clearly explained from the contour map, the total areas of Peninsula Malaysia seem to have low wind power estimated and the wind behavior was influenced by 2-major monsoon that is northeast and southwest. The contour maps explain that during northeast season, the wind power expected to have higher potential compared to southwest season. This is due to the fact that during monsoon season, there was a strong movement of cold air from the north and makes the wind velocity goes higher when reach at the east coast region. Although the research tells that there was low wind energy potential in Peninsula Malaysia, look up from the other point of view, the places located at east coast Malaysia like Kota Bharu, Kuala Terengganu and Mersing are persistent to have higher wind velocity during the northeast season.

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### References


