Separate analysis of wind speed and direction for Mersing, Malaysia

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ABSTRACT – This research is conducted purposely to study the effect of wind speed and wind direction in generating wind power. Although the scope is extensive, but this paper will only discuss on the density probability distribution, numerical and graphical presentation of both. A Weibull and finite mixture model of von Mises distribution is used in this paper to represent data of Mersing (Malaysia). The suitability of the distributions was examined by the coefficient determination of R^2. The analysis reveals that the selected models fit with the data.

1. INTRODUCTION

The nature of wind with variant wind speed and direction leads to a broad spectrum of wind research. The importance of wind speed behaviour has widely studied by researchers all over the world including Malaysia.

While research in wind direction is far behind compare to wind speed. The nature of it circular data has limits the interest of investigation. This type of data cannot be treated as an ordinary (linear) data. Despite normal distribution for a linear data, von Mises or a Circular Normal (CN) distribution is the model of choice for circular data in most applied problems [1].

This paper will only discuss on von Mises distribution or Finite mixture von Mises to be exact. This chosen is basically depend on the nature of data which is circular with multi modal that best explain with this type of probability distribution [2-4].

2. METHODOLOGY

2.1 Weibull distribution

The probability density function (pdf) for Weibull is presented in equation (1):

$$h(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{(k-1)} e^{-\left(\frac{v}{c}\right)^k} \quad for\ 0 < v < \infty \quad (1)$$

Where:

k= shape parameter; c= scale parameter;
v= wind speed

The Weibull shape and scale parameters are estimated using Maximum Likelihood method which is given by:

$$k = \left[\frac{\sum_{i=1}^{n} v_i{}^k ln(v_i)}{\sum_{i=1}^{n} v_i{}^k} - \frac{\sum_{i=1}^{n} ln(v_i)}{n}\right]^{-1} \quad (2)$$

Where:

v_i= wind speed in time step, *I;*
n= number of data points

The value of k is evaluates by using an iterative technique. In this study the Newton Raphson method [5] has been used. The scale parameter, c is obtained by:

$$c = \left[\frac{1}{n}\sum_{i=1}^{n} v_i{}^k\right]^{1/k} \quad (3)$$

2.2 Finite mixture von Mises (mvM)

$$f_\theta(\theta) = \sum_{j=1}^{H} \frac{\omega_j}{2\pi I_0(\kappa_j)} \exp(\kappa_j \cos(\theta - \mu_j)) \quad (4)$$

For;

$$0 \le \theta < 2\pi,\quad 0 \le \mu_j < 2\pi,\quad \kappa_j \ge 0,$$

$$0 \le \omega_j < 1 \quad \text{for } j = 1,2,......H \quad \text{and} \sum_{j=1}^{H} \omega_j = 1$$

$$I_0(\kappa_j) = \frac{1}{\sqrt{2\pi}} \int_0^{2\pi} \exp(\kappa_j \cos\theta) d\theta$$

$$= \sum_{\kappa=0}^{\infty} \frac{1}{(\kappa!)^2} \left(\frac{\kappa_j}{2}\right)^{2\theta}$$

3. RESULTS AND DISCUSSION

For this study, appropriate distributions have been determined by fitting Weibull probability distribution. Parameter estimations is verifying by using maximum likelihood method. The maximum likelihood estimator (MLE) for the parameters of each can be determined numerically by using Newton Raphson method. Table 1 below shows the result on parameter estimation for Weibull and Gama distribution. These parameter estimation values are then being used in the respective probability distribution function.

Table 1 Estimation parameter.

Year	Weibull distribution Shape parameter k	Scale parameter c
2007	2.10758	3.05830
2008	2.09565	3.29368
2009	2.16443	3.19343
2010	2.14770	2.95556
2011	2.08609	3.24657
2012	2.06077	2.91111
2013	2.08768	3.10305

For the wind direction analysis, the appropriate distribution will best explain the prevailing wind direction in such area. This study chooses finite mixture von Mises distribution to explain its wind direction regime. The parameter estimates for the finite mixture von Mises distribution (H=1,2…8) at Mersing station is first to be calculated. This parameter estimates are important in model fitting.

This study uses R^2 correlation coefficient as the numerical evaluation and determined that the best number of component that represents Mersing data is H=6. By using the parameter estimates, estimation for density probability function of finite mixture von Mises (H=6) model is then derived as:

$$
\begin{aligned}
f_\theta(\theta) = {} & \frac{0.276666}{2\pi I_0(12.25072\ )} \exp\left(12.25072\ \cos(\theta - \mu_1)\right) + \\
& \frac{0.065021}{2\pi I_0(14.95576\ )} \exp\left(14.95576\ \cos(\theta - \mu_2)\right) + \\
& \frac{0.046866}{2\pi I_0(10.62431\ )} \exp\left(10.62431\ \cos(\theta - \mu_3)\right) + \\
& \frac{0.317662}{2\pi I_0(19.55538\ )} \exp\left(19.55538\ \cos(\theta - \mu_4)\right) + \\
& \frac{0.16176}{2\pi I_0(14.04048\ )} \exp\left(14.04048\ \cos(\theta - \mu_2)\right) + \\
& \frac{0.132026}{2\pi I_0(14.95576\ )} \exp\left(14.95576\ \cos(\theta - \mu_2)\right)
\end{aligned}
$$

With the parameter of mean directions:

$$
\begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{bmatrix}^T = \begin{bmatrix} 0.90195 & 0.431841 \\ -0.21838 & 0.975863 \\ -0.87079 & 0.491656 \\ -0.66725 & -0.74484 \\ -0.09333 & -0.99564 \\ 0.931101 & -0.36476 \end{bmatrix}^T
$$

The parameter of mean directions refer to mean for circular data in rectangular coordinates:

$$X^T = [\cos\theta \quad \sin\theta]$$

This result reveals that density probability function of finite mixture von Mises (H=6) is the best model that represent the wind direction data for Mersing.

4. CONCLUSION

In this study, Weibull and finite mixture von Mises with H=6 are used to be the best models that represent wind speed and direction data for Mersing. With more than 99% in its R^2 coefficient test, variation in the data can be explained by the selected model. This study gives the idea of how wind speed and direction are typically distributed. Results from this study might be significant for advance studies of wind energy potential in Mersing.

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