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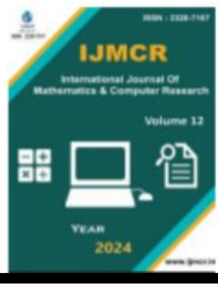

The Comparison Some Models Daily Wind Speed Data in Pekanbaru City Using Two, Three and Four Parameters Gamma Distributions

M. Rafly Ramaesa Putra[1], Rado Yendra[2], Ari Pani Desvina[3], Rahmadeni[4], Muhammad Marizal[5]

[1,2,3,4,5]Department of Mathematics, Faculty of Science and Technology, Universitas Islam Negeri Sultan Syarif Kasim Riau.

ARTICLE INFO	ABSTRACT
Published Online: **12 June 2024** Corresponding Author: **M. Rafly Ramaesa Putra**	Accurate wind speed modeling is critical in estimating wind energy potential for harnessing wind power effectively. One of the bases for assessment of wind energy potential for a specified region is the probability distribution of wind speed, therefore wind speed data is needed to produce statistical modeling, especially in determining the best probability distribution. For this purpose, several modified distributions will be used and tested to determine the best model to describe wind speed in Pekanbaru. Six continuous probability density function such as Two Parameters Gamma (GM), Three Parameters Slashed Quasi-Gamma (SQG), Three Parameters Quasi Gamma (QG), Three Parameters Generalized Gamma (GG), Four Parameters Poly Weighted Exponentiated Gamma (PWEG) and Four Parameters Exponentiated Gamma Exponential (EGE) distributions were fitted for these tasks using the maximum likelihood technique. To determine the model's fit to the daily wind speed data, several goodness-of-fit tests were applied, including the graphical methos test (pdf plot) and numerical criteria method test (AIC). The QG and GG distributions are found to be the best-fitted probability distribution based on goodness-of-fit tests for the daily wind speed data at the Pekanbaru station.

KEYWORDS: Gamma, Slashed Quasi-Gamma, Quasi Gamma, Generalized Gamma, Poly Weighted Exponentiated Gamma, Exponentiated Gamma Exponential, Wind Speed

I. INTRODUCTION

Growing environmental concern is a challenging issue in Indonesia; as a result, the government intends to increase the usage of renewable energy to increase energy usage efficiency [1]. Indonesia, as an archipelago country, has huge potential for wind power generation, due to high wind intensity in most regions. Wind energy as a new source, is rapidly developing in the world due to its natural abundance, renewability, low cost, and inability to pollute the environment. There are several important factors in obtaining wind speed power. One of which is determine the characteristics of wind speed statistically [2]. It is well-known that wind energy potential can be estimated by using the distribution of the wind speed. Over the past years, research activity in the area of wind-speed distribution modelling has increased considerably. For the prediction of wind-speed distributions statistical models, several statistical distributions have been used for the description of the wind speed distribution. Determining the distribution of wind speed is quite effective in calculating the wind force [3]. In the literature, Weibull distribution has been used commonly in modelling the wind speed data [4,5,6,7,8]. There are also studies in which different distributions are preferred in modelling these data [9,10,11,12]. Morgan et al. [13] have used Generalized Rayleigh, Bimodal Weibull Mixture, Kappa and Wakaby distributions for modelling the wind speed data. In this study, preliminary study on wind energy potential was evaluated statistically using the daily wind speed data between 2008 and 2017 in Pekanbaru. Research on the use of several of the best models for daily wind speed data in the city of Pekanbaru has also been carried out by several researchers [19,20,21]. The objective of this study is to propose six distributions such as Two Parameters Gamma (GM), Three Parameters Slashed Quasi-Gamma (SQG) [14], Three Parameters Quasi Gamma (QG)[15], Three Parameters Generalized Gamma (GG)[16], Four Parameters Poly Weighted Exponentiated Gamma (PWEG)[17] and Four Parameters Exponentiated Gamma Exponential (EGE)[18] distributions were used for modelling the wind speed data of Pekanbaru. Comparison of the proposed distributions with existing distribution functions is done to demonstrate their suitability in describing wind speed characteristics. Unknown parameter estimations were obtained with the Maximum Likelihood Method. Graphical methods and Numerical criteria such as AIC were used to obtain the distribution which provides the best fit the wind speed data. In the following section, the distributions to be used in modelling the wind speed data are included.

Table 2. Probability Density Function (pdf) of some distributions

The Dist-ribution s	Probability density function (pdf)
GM	$f(y)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}y^{\alpha-1}exp\left(-\frac{y}{\beta}\right),\quad y>0,\ \alpha,\beta>0$
SQG	$f(y)=\frac{q\beta^{q}y^{-(q+1)}}{\Gamma\left(\frac{1}{10}\right)}\Gamma\left(\frac{q}{\theta}+\frac{1}{10}\right)F\left(\left(\frac{y}{\beta}\right)^{\theta},\frac{q}{\theta}+\frac{1}{10},1\right), y>0,q,\beta,\theta>0$
QG	$f(y)=\frac{2k\theta^{\alpha}y^{2k\alpha-1}exp(-\theta y^{2k})}{\Gamma(\alpha)}, y>0,\ k,\theta,\alpha>0$
GG	$f(y)=\frac{\beta\theta^{\alpha}}{\Gamma(\alpha)}y^{\beta\alpha-1}exp(-\theta y^{\beta});\quad y>0,\alpha>0,\beta>0,\theta>0$
PWEG	$f(y)=\frac{2^{a+c}}{\Gamma(a+c)b^{a+c}}(y-\theta)^{a+c-1}\,exp\left(\frac{-2(y-\theta)}{b}\right);\quad y>\theta\ \ and\ a,b,c>0$
EGE	$f(y)=\frac{c}{\Gamma(\alpha)\beta^{\alpha}}\theta\ exp(-\theta y)\left(1-exp(-\theta y)\right)^{c-1}\times\left(-log\left(1-\left(1-exp(-\theta y)\right)^{c}\right)\right)^{\alpha-1}\times\left(1-\left(1-exp(-\theta y)\right)^{c}\right)^{\frac{1}{\beta}-1};\quad \theta,\alpha,\beta,c>0$

II. DESCRIPTION OF DATA

Data used in this work were downloaded from the website of the Federal Office of Meteorology and Climatology of Indonesia (BMKG, Indonesia).

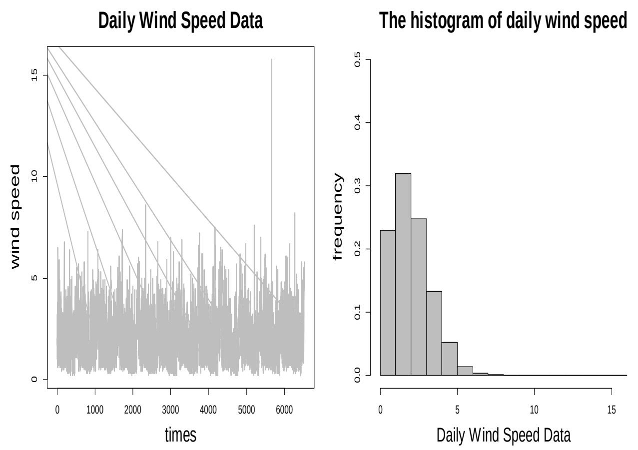

Figure 1. Plot and histogram daily wind speed data on Pekanbaru respectively

The original data consisted of wind speed records from 2008 to 2017, which were provided BMKG of Pekanbaru city, Indonesia. The data and the histogram or characteristic wind speed are presented in Figure 1. Pekanbaru City located in Riau Province, with a tropical climate that has wind speeds that vary from 0.2 m/s to 15.8 m/s. Initial information on wind speed in the city of Pekanbaru can be seen in the descriptive statistics for daily wind speed are presented in Table 1.

Table 1. The descriptive statistics for daily wind speed

Statistics	Mean	Variation	Min	Max
Value	2.088	1.51451	0.200	15.800

III. METHOD

A. Probility Density Function (PDF)

In this study, six probability density function (pdf) associated with modeling daily wind speed, GM, SQG, QG, GG, PWEG and, EGE are considered in this paper. The equations defining the probability density functions (pdf) for various candidate distributions of interest are given below, for each distribution that we consider are as given in Table 2, where y (daily wind speed) denote the observed values of the random variable representing the event of interest. In order to fit a particular theoretical distribution to the observed distribution of daily wind speed, parameters are estimated. The parameter estimation of the distribution function are calculated using maximum likelihood method. The parameter estimation of the distribution function are calculated using maximum likelihood method (MLE). The function of maximum likelihood for this model is in implicit and complicated and we will not discuss detail in this paper. The non-linear equation generated by the maximum log likelihood function ($l(\Omega)$, Ω are parameters) requires a numerical method, namely the newton rhapshon to get the solution of the equation.

However, this method has been employed in the iteration system to find the solution. Some initial value, have been tested for this procedure. If the initial value coverge to the same value, it is considered to be the chosen estimated parameter. The procedure of goodness of fit tests for model selection, both numerically and graphically, is discusse

B. *Maximum Likelihood Estimate (MLE) and Goodness of Fit Test (GOF)*

Let $(y_1, y_2, \cdots, y_n)$ be random sample from GM, SQG, QG, GG, PWEG and EGE Distributions. The log likelihood **$(l(\Omega))$** are presented in Table 3. The MLE $\Omega\hat{}$ of Ω is the solution of the equation $\frac{\partial l(\Omega)}{\partial \Omega} = 0$ and thus it is the solution of the following nonlinear equation. The most appropriate distribution is identified using results found based on several GOF.

Table 3. The Log Likelihood of some distributions

The Distributions	Log Likelihood
GM	$l(\alpha,\beta) = \alpha - 1\sum_{i=1}^{n} log(y_i) - \frac{1}{\beta}\sum_{i=1}^{n} y_i - n\alpha\, log(\beta) - n\, log(\Gamma(\alpha))$
SQG	$l(q,\beta,\theta) = c(q,\beta,\theta) - (q+1)\sum_{i=1}^{n} log(y_i) + \sum_{i=1}^{n} F\left(\left(\frac{y}{\beta}\right)^{\theta}, \frac{q}{\theta} + \frac{1}{10}, 1\right)$ Where, $c(q,\beta,\theta) = n\, log(q) + nq\, log(\beta) - n\, log\left(\Gamma\left(\frac{1}{10}\right)\right) + n\, log\left(\Gamma\left(\frac{q}{\theta} + \frac{1}{10}\right)\right)$ and $F(y,\alpha,\beta) = \int_0^y \frac{\beta^\alpha}{\Gamma(\alpha)} y^{\alpha-1} e^{-y\beta}\, dy$
QG	$l(k,\theta,\alpha) = n\, log(2) + n\, log(k) + n\alpha\, log(\theta) + (2k\alpha - 1)\sum_{i=1}^{n} log(y_i) - \theta\sum_{i=1}^{n} y_i^{2k} - n\, log(\Gamma(\alpha))$
GG	$l(\alpha,\beta,\theta) = n\left(log(\beta) + \alpha log(\theta) - log(\Gamma(\alpha))\right) + (\beta\alpha - 1)\sum_{i=1}^{n} log(x_i) - \theta\sum_{i=1}^{n} x_i^{\beta}$
PWEG	$l(\theta,a,b,c) = n(a+c)log(2) - n(a+c)log(b) - nlog(\Gamma(a+c)) + (a+c-1)\sum_{i=1}^{n} log(x_i - \theta) - \frac{2}{b}\sum_{i=1}^{n}(x_i - \theta)$
EGE	$l(c,\alpha,\beta,\theta) = nlog(c) - nlog(\Gamma(\alpha)) - n\alpha log(\beta) + nlog(\alpha) - \theta\sum_{i=1}^{n} x_i + (c-1)\sum_{i=1}^{n} log(1 - exp(-\theta x)) + (\alpha-1)\sum_{i=1}^{n} log\left(-log\left((1 - (1 - exp(-\theta x))^{c})\right)\right) + \left(\frac{1}{\beta} - 1\right)\sum_{i=1}^{n} log\left((1 - (1 - exp(-\theta x))^{c})\right)$

The GOF tests considered are based on graphical inspection (pdf plot) and numerical criteria Akaike's information criterion (AIC) were applied to determine the GOF criteria of the distributions. In most the cases, graphical inspection gave the same result but their AIC result differed. The best fit result was chosen as the distribution with the lowest values of AIC. The formula of numerical methods such as AIC is exhibited in the following Table 4.

Table 4. The formulas of numerical criteria for model evaluation

Numerical Criteria	Formula
AIC	$-2l + 2p$

l = log likelihood, p = Number of parameters

IV. RESULT AND DISCUSSION

In this section, we analyze a daily wind speed data set to demonstrate the performance of the GM, SQG, QG, GG, PWEG and EGE distributions in practice. The fitting of that distributions was considered using data from the period between 2008 and 2017. Computed parameter values of different probability density function used for the BMKG Pekanbaru stations are presented in Table 5.

Table 5. Computed parameter values of different probability density functions

Var	GM	SQG	QG	GG	PWEG	EGE
α	2.679	-	-	-	-	-
β	1.283	-	-	-	-	-
q	-	3.925	-	-	-	-
β	-	2.902	-	-	-	-
θ	-	13.238	-	-	-	-
k	-	-	0.678	-	-	-
θ	-	-	0.541	-	-	-
α	-	-	1.589	-	-	-
β	-	-	-	1.356	-	-
θ	-	-	-	0.541	-	-
α	-	-	-	1.588	-	-
a	-	-	-	-	1.138	-
b	-	-	-	-	1.661	-
c	-	-	-	-	1.293	-
θ	-	-	-	-	0.069	-
α	-	-	-	-	-	2.744
β	-	-	-	-	-	0.249
c	-	-	-	-	-	0.979
θ	-	-	-	-	-	0.322

Figure 2, 3 and 4 shows the fitted GM and SQG distributions, QG and GG distributions, PWEG and EGE distributions, based on pdf respectively. From this figure, all distribution model are able to provide a good result for wind speed data. However, instead of graphical evaluation, Table 6 provides a more meaningful comparison using AIC values.

Table 6. AIC values

	GM	SQG	QG	GG	PWEG	EGE
AIC	19922.2 7	20333.7 2	**19893.7 1**	**19893.7 1**	19919.1 7	19926.2 1

Tables 6 shows the GOF of pdf namely AIC currently analyzed for the six distribution at Pekanbaru station. From Table 6, by comparing each model, it is clear that the SDQ Distribution has the highest AIC values, implying that pdf is not a good model for wind speed in Pekanbaru. However, as the number of components increase for QG and GG distributions, the AIC values decrease, which implies that the use of more components in the six distributions models provides a model that more adequately fits the data.

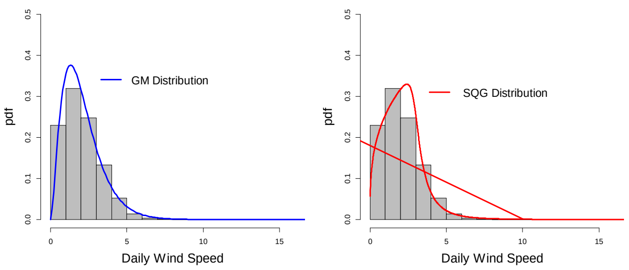

Figure 2. Fitted pdf plots of GM and SQG distributions

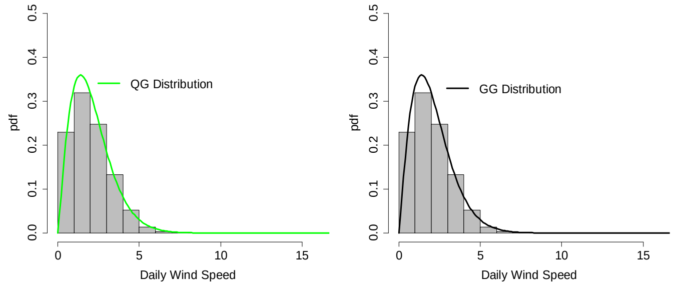

Figure 3. Fitted pdf plots of QG and GG distributions

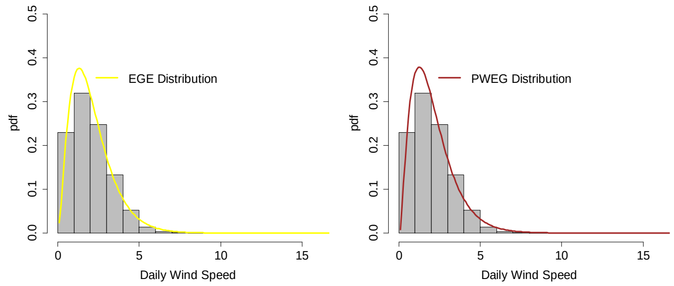

Figure 4. Fitted pdf plots of EGE and PWEG distributions

V. CONCLUSION

In this research focused on determining the best statistical model wind speed in Pekanbaru. The Six distribution such as Two Parameters Gamma (GM), Three Parameters Slashed Quasi-Gamma (SQG), Three Parameters Quasi Gamma (QG), Three Parameters Generalized Gamma (GG), Four Parameters Poly Weighted Exponentiated Gamma (PWEG) and Four Parameters Exponentiated Gamma Exponential (EGE). Thise of were fit to the data. The results obtained based on graphical and AIC values indicated that QG and GG distributions adequately modelled the wind speed distribution in Pekanbaru. Additionally, from Figure 3, can be seen that the most probable wind speed occurs at a speed of 0.5-1 m/s with the probability of 32%.

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