ANALYSIS OF WIND SPEED DISTRIBUTIONS FOR WEEKLY DATA

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ABSTRACT

Accurate wind modeling depends on transmitting the power harnessed effectively. Grid connected wind-turbine-driven unit features the electricity generation system. The objective of this study is to describe the better among probability density function of various distributions that provide better fit and low error prediction. Results show that Weibull is able to closely related with wind assessment data than any other distribution.

Keywords: wind energy, weibull, PDF, wind speed.

INTRODUCTION

The growing demand for the power potential and the lack of non renewable resources enable us to shift our focus to renewable resources which are abundant. The solar and wind energy plays a vital role among other renewable resources. There are many onsite and offshore wind farms used to harvest wind energy. The betterment in the wind power projects lies on the grid connectivity and the transportation [1]. The site selection is also crucial factor which withholds the infrastructure and feasibility of the projects.

India's wind potential is pegged at 302GW and in addition to 175GW of renewable energy by 2022. The wind resource assessment should consider the climatic factors that affects at the particular site. The size of the turbine formulated on considering the wind resource on a particular site.

Wind distribution models

The month wind data are slatted into weekly and processed with different distribution models. The distribution such as Weibull, Gamma, Lognormal, Extreme Value, Generalized Extreme Value and Rayleigh distribution are used. The statistical errors are calculated and the best fit among the distribution are studied. It gives a better model for wind resource assessment and for future installation.

Weibull distribution

The weibull function[2] is commonly used for fitting measured wind data.

Two-Parameter weibull distribution is given by[3]:

$$f(x,k,c) = \frac{k}{c}\left(\frac{x}{c}\right)^{k-1} \exp\left\{-\left(\frac{x}{c}\right)^{k}\right\} \tag{1}$$

Weibull cumulative distribution function (CDF):

$$F(x,k,c) = 1 - \exp\left\{-\left(\frac{x}{c}\right)^{\kappa}\right\} \tag{2}$$

Weibull shape and scale parameters are calculated [4]

$$k = \frac{\sum_{i=1}^{n} x_i^k \ln(x_i)}{\sum_{i=1}^{n} x_i^k} - \frac{\sum_{i=1}^{n} \ln(x_i)}{n} \tag{3}$$

where x_i is the wind speed at time 'i' and 'n' is the number of data points.

$$c = \left[\frac{1}{n}\sum_{i=1}^{n} x_i^k\right]^{\frac{1}{k}} \tag{4}$$

Gamma distribution

The probability density function of gamma distribution is expressed as:

$$g(x,\alpha,\beta) = \frac{x^{\alpha-1}}{\beta\Gamma(\alpha)} exp\left[-\frac{x}{\beta}\right] \tag{5}$$

The cdf of gamma distribution is given as:

$$G(x,\alpha,\beta) = \int \frac{x^{\alpha-1}}{\beta\Gamma(\alpha)} exp\left[-\frac{x}{\beta}\right] dx \tag{6}$$

Lognormal distribution

Lognormal distribution is probability distribution of a random variable whose logarithm is distributed normally.

The Pdf is given by

$$\ln(x,\emptyset,\lambda) = \frac{1}{x\emptyset\sqrt{2\pi}} exp\left(\frac{-\ln(x)-\lambda^2}{2\emptyset^2}\right) \tag{7}$$

The cdf is given by

$$LN(x,\emptyset,\lambda) = \frac{1}{2} + \frac{1}{2} erf\left(\frac{\ln(x)-\lambda}{\emptyset\sqrt{2}}\right) \tag{8}$$

Extreme value distribution

The Extreme value distribution usually refers to the distribution of the minimum of a large number of unbounded random observations.

The probability density function [5] can be given as:

$$f(x,\mu,\beta) = \frac{1}{\beta} e^{\frac{x-\mu}{\beta}} exp\left(-e^{\frac{x-\mu}{\beta}}\right) \tag{9}$$

The cdf can be given as

$$F(x,\mu,\beta) = 1 - exp\left(-e^{\frac{x-\mu}{\beta}}\right) \tag{10}$$

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Generalized extreme value distribution

GEV distribution is a flexible model that combines the Gumbel, Frechet and Weibull distribution. The PDF is given by[5]:

$$e(x,\zeta,\delta,l) = \left(\frac{1}{\delta}\right)\left(1+\frac{\zeta(x-1)}{\delta}\right)^{-\frac{1}{\zeta-1}} exp\left[-\left(1+\frac{\zeta(x-l)}{\delta}\right)\right]^{\frac{1}{\zeta}} if\zeta \neq 0 \quad (11)$$

The cdf is given by:

$$(x,\zeta,\delta,l) = exp\left[-\left(1+\frac{\zeta(x-1)}{\delta}\right)\right]^{\frac{1}{\zeta}} if\zeta \neq 0 \quad (12)$$

Rayleigh distribution

The Rayleigh distribution is a special case of Weibull distribution. Rayleigh distributions are used to model scattered signals that reach the anemometer by multiple paths.

The probability density function can be given as:

$$\mathrm{f}(\mathrm{x},\mu,\beta) = \frac{1}{\beta} e^{\frac{x-\mu}{\beta}} \exp\left(-e^{\frac{x-\mu}{\beta}}\right) \quad (13)$$

The CDF can be given as:

$$\mathrm{F}(\mathrm{x},\mu,\beta) = 1-\exp\left(-e^{\frac{x-\mu}{\beta}}\right) \quad (14)$$

Goodness of fit tests:

The goodness of fit test is used to find the best fit distribution for the given data set.

Sum of squares due to error (SSE):

Sum of squares due to error is the statistic measure of the deviation of the response value to the original data. A value closer to 0 indicates that the model has small error component.

$$SSE = \sum_{i=1}^{n} w_i (x_i - x_i')^2 \quad (15)$$

R-Square (RSQ):

R-Square is the square of the correlation between the original and the predicted value. R^2 test is also known as total sum of squares. R-Square takes value between 0 and 1. The value closer to 1 indicate greater proportion of variance[6].

$$R^2 = \frac{\sum_{i=1}^{n}(F_i'-F_i)^2}{\sum_{i=1}^{n}(F_i'-F_i)^2+\sum_{i=1}^{n}(F_i-F'_i)^2} \quad (16)$$

Adjusted R-square (ADRS):

Adjusted R-Square is generally best indicator of fit quality during comparison of the model.

Root mean square error (RMSE)

RMSE is an estimate of the standard deviation of the data and is defined as

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(F_i - F'_i)^2\right]^{\frac{1}{2}} \quad (17)$$

RESULTS AND DISCUSSION

The wind speed data for the month which is used is saved into excel for ease processing and evaluation. The data is then splited into weekly data by the use of MATLAB software.

The data is used for further analysis and the plot is made for the different distribution and the best among them is founded by analyzing the statistical errors.

The parameters for various distributions are also estimated in this process with specific bin ranges of the wind speed data.

The bin ranges are classified as in the range of 0,3,5,7,11,13,15,19,20,30 and the bin counts are noted.

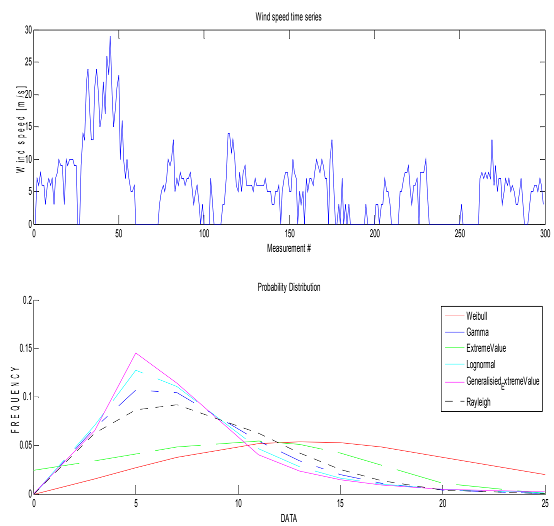

Figure-1. Predicted wind frequencies for week 1.

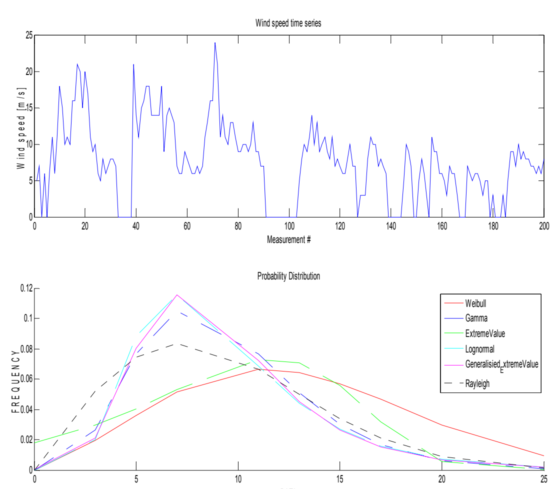

Figure-2. Predicted wind frequencies for week 2.

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Table1. Computed parameter values for different distribuion on a weekly basics.

TITLE	*BINCOUNT*	*WEIBULL*		*GAMMA*		*EXTREME VALUE*		*LOGNORMAL*		*GENERALIZED EXTRME VALUE*			*RAYLEIGH*
		k	c	α	β	μ	β	Φ	λ	ζ	δ	ξ	α
WEEK 1	*89 : 30 : 65 : 85 : 1 : 10 : 3 : 4 : 10 : 0*	*17.07*	*2.22*	*3.7*	*2.15*	*10.70*	*6.72*	*1.93*	*0.52*	*0.24*	*2.60*	*5.67*	*6.56*
WEEK 2	*39 : 9 : 34 : 69 : 4 : 15 : 9 : 5 : 6 : 0*	*14.43*	*2.33*	*5.29*	*1.77*	*11.67*	*5.02*	*2.14*	*0.45*	*0.04*	*3.17*	*7.43*	*7.43*
WEEK 3	*29 : 16 : 29 : 54 : 9 : 26 : 16 : 11 : 19 : 1*	*16.21*	*2.33*	*3.69*	*2.98*	*13.87*	*5.71*	*2.26*	*0.56*	*-0.06*	*4.63*	*8.55*	*8.70*
WEEK 4	*20 : 13 : 21 : 48 : 17 : 36 : 22 : 12 : 19 : 1*	*16.22*	*2.33*	*4.53*	*2.61*	*14.47*	*5.23*	*2.36*	*0.51*	*-0.20*	*4.81*	*9.83*	*9.13*
WEEK 5	*12 : 6 : 8 : 23 : 3 : 11 : 7 : 4 : 1 : 0*	*13.03*	*2.45*	*4.54*	*2.23*	*12.39*	*4.42*	*2.20*	*0.51*	*-0.20*	*4.15*	*8.39*	*7.82*

Table-2. Statistical errors for different distribution on a weekly basics.

Title		Week-1	Week-2	Week-3	Week-4	Week-5
WEIBULL	SSE	0.033	0.008	0.048	0.048	0.149
	RSQ	0.968	0.931	0.957	0.957	0.897
	ADRS	0.964	0.922	0.952	0.952	0.883
	RMSE	0.064	0.105	0.078	0.078	0.136
GAMMA	SSE	0.322	0.302	0.161	0.147	0.232
	RSQ	0.775	0.811	0.882	0.895	0.846
	ADRS	0.747	0.788	0.867	0.882	0.829
	RMSE	0.2	0.194	0.141	0.135	0.17
LOGNORMAL	SSE	0.345	0.306	0.174	0.153	0.227
	RSQ	0.761	0.807	0.869	0.888	0.843
	ADRS	0.7331	0.782	0.853	0.873	0.823
	RMSE	0.201	0.195	0.147	0.138	0.168
EV	SSE	0.103	0.158	0.089	0.097	0.174
	RSQ	0.882	0.862	0.92	0.919	0.871
	ADRS	0.867	0.851	0.91	0.909	0.854
	RMSE	0.113	0.14	0.105	0.11	0.147
GEV	SSE	0.359	0.315	0.162	0.141	0.234
	RSQ	0.749	0.804	0.882	0.901	0.847
	ADRS	0.718	0.78	0.868	0.889	0.829
	RMSE	0.211	0.198	0.142	0.132	0.171
RAYLEIGH	SSE	0.283	0.228	0.161	0.113	0.189
	RSQ	0.789	0.836	0.882	0.911	0.861
	ADRS	0.773	0.815	0.867	0.9	0.844
	RMSE	0.188	0.169	0.141	0.118	0.154

- The Weibull distribution shows better fit during the first week compared with extreme value than any other distribution.
- In the second week the Weibull followed by Extreme Value followed by Rayleigh shows the better fit among various distributions.
- Thus the third, fourth and fifth week follow the same type of order of distributions.

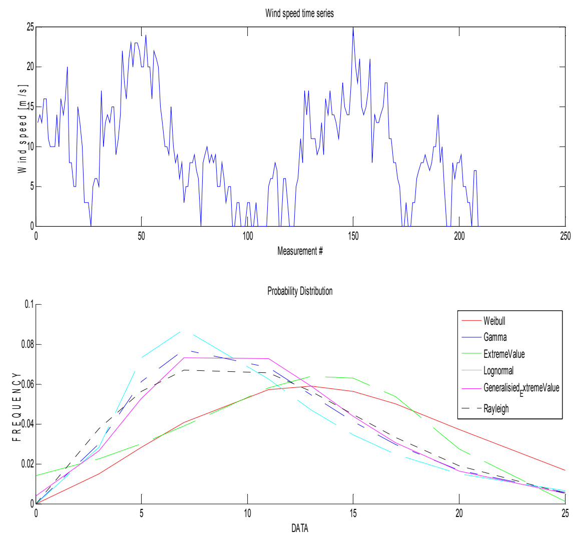

Figure-3. Predicted wind frequencies for week 3.

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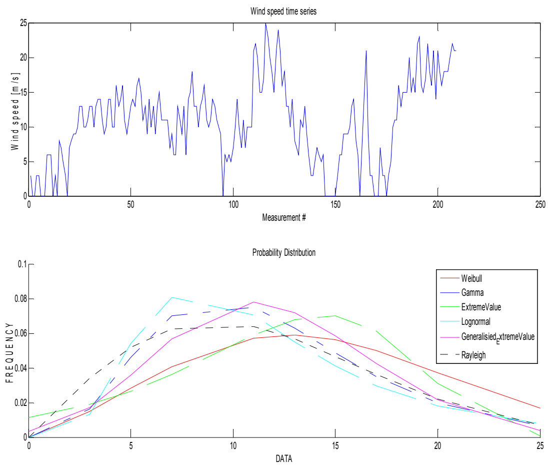

Figure-4. Predicted wind frequencies for week 4.

Weibull probability density function fits the observed distribution well. The goodness of fit test are evaluated and presented in Table-2. PDF's except Lognormal, GEV and Gamma are able to describe the wind speed characteristics.

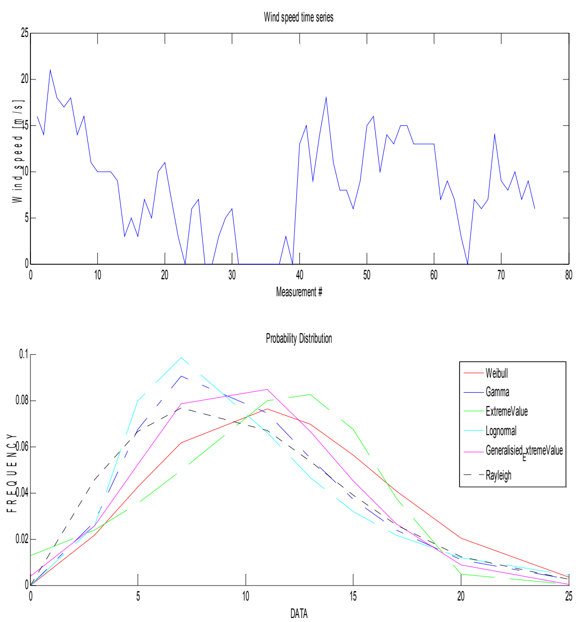

Figure-5. Predicted wind frequencies for week 5.

In modeling the wind speed for the data collected the order are as follows Weibull, Extreme Value, Rayleigh distribution.

CONCLUSIONS

In the present article, a comparison of distribution models has been undertaken. The performance differences between Weibull and Extreme Value distributions are closely equivalent and have the errors minimal. Thus compared to other distribution these are considered to be better fit. It is shown that Lognormal, GEV and Gamma distribution are inadequate. The better improvement lies in analyzing more data such as a year and lower statistical error.

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