MODELLING DISTRIBUTIONS AND FORECASTING OF WIND SPEED IN SELECTED WEATHER STATIONS OF SRI LANKA

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Introduction

Energy need of the world increases 4-5% every year whereas fossil fuel reserves covering that need decrease much faster than the need. So developing and analyzing of wind helps in energy forecasting, planning, research and policy making (Zaharim et. al. 2009). The most important factors which influences wind energy production are wind speed and wind direction. Not only in case of energy production but wind plays an important role in the process of building making (Veysel and Eray, 2008).

The objective of this study is to find best fitted probability distributions, study the behavior of wind speed and forecasting of wind speed for wind speed data collected by the Department of Meteorology Sri Lanka during the year 2007 and 2008 from 10 stations. Sri Lanka is situated in the belt of monsoon climates in South Asia. The climate of the island is control by its location as well by the monsoonal regime, has a strong seasonal and spatial dependence. In general the winds during the monsoons are somewhat stronger. During the inter-monsoon periods the winds are weaker.

Methodology

Due to difficulty of obtaining daily average wind speed data in all stations only ten stations Colombo, Anuradhapura, Ratnapura, Kurunegala, Hambantota, Batticaloa, Maha-Illuppallama, Trincomalee, Puttalam and Bandarawela were selected based on past literature (Fernando, and Sonnadara, 2007) covering different geographical regions in Sri Lanka.

To determine the best fitted distribution to wind speed data two parameter weibull distribution, lognormal distribution, exponential distribution and loglogistic distributions has been investigated as done by the previous studies. Goodness of fit of the distributions were checked by using plots of histograms with density line, probability plots of the data, Anderson darling test and Kolmogrove-Simirnov test. The hypotheses considered for this purpose are H_0: Estimated probability distribution fits to the data. Vs. H_1: Estimated probability distribution does not fit to the data

Then the parameters of the distribution were estimated using Maximum Likelihood method. To forecast the wind speed the simplest form of exponential smoothing ($S_t = \alpha X_t + (1-\alpha)S_{t-1}$) is used as the average level of the time series slowly changing over time. In order to find the best value of α that minimizes the differences between the real data and the forecasting values, the single exponential smoothing method was used changing the α value 0.1 to 0.9. Five statistical error measurements were calculated namely as Mean Error (ME), Mean Square Error (MSE), Mean Absolute Error (MAE), Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE). Then α value that provided minimum error measurement was taken as best α value.

Results and Discussion

The results of statistical tests used to determine the effective distribution are given in Table 1. According to these results it is clear that wind speed data follows the two parameter weibull distribution. Histograms with density lines and probability plots of the wind speed data also demonstrated that Weibull distribution gives the best fit.

Then the frequency distributions were generated for model fitting analysis to obtain the shape parameter k and the scale parameter c of the Weibull distribution. These parameters are estimated for all stations separately for 2007 and 2008. The shape parameter k has a much smaller variation than the scale parameter c. The parameter k varies from 0.607324 to 2.71047, with an average value of 1.05157 where as the parameter c varies from $2.88ms^{-1}$ to $27.2723ms^{-1}$, with an average value of $12.19ms^{-1}$. Hambantota showed the highest value for scale parameter c. Next to Hambantota, Jaffna and Puttalama showed higher values for parameter c.

In order to study the seasonal variability of model, parameters of weibull distribution was evaluated separately for seasons, and these results show that the seasonal shape parameter k ranges between 1.749627 and 20174833 where as the seasonal scale parameter c ranges between 18.93413 and 28.32826. In general, compared to the parameter c the variation of the parameter k is much less between the seasons. NE and SW monsoons show higher parameter values compared to the inter-monsoon seasons. Fig. 1 shows the seasonal weibull distributions for Hambantota. According to this figure SW monsoon has the highest probability and lowest probability occur during the two inter monsoons and it is very similar.

The time series plot for the wind speed data was drawn, and according to the plot it can be seen that the average level of the time series is slowly changing over time and there is no any trend. Hence the single exponential smoothing was used changing the α value of 0.1, 0.5 and 0.9. Then it can be observed that for the α value of 0.1 just a rough tendency was obtained, however for α value of 0.5 and 0.9 the forecasting shows good results. In order to find the best value of α that minimizes the differences between the real data and the forecasting values, the single exponential smoothing method was used by changing the α value from 0.1 to 0.9, and five statistical error measures ME, MSE, MAE, MPE and AMPE were obtained. According to these values it can be observed that the α value of 0.9 minimizes the error measurements.

Fig. 2 compares the single smoothing against the last real 20 data of the wind speed forecasting. It can be seen that the single exponential smoothing method adjusts better to the real data, and only a small delay can be observed between the two series.

Conclusion

Based on 5% significance level it was concluded that two parameter weibull distribution fits the wind speed data well. The highest values of parameters were recorded at Hambantota. The highest seasonal values of shape parameter and scale parameter were recorded during the North-East and South-West monsoon periods. Single Exponential Smoothing method with α=0.9 provided best forecast to the wind speed. Since the most important parameter of the wind energy is the wind speed, an accurate determination of probability distribution of wind speed values is very important in evaluating wind speed energy potential of a region. Hence these results can be used to predict the wind speed data for each season.

References

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Appendix

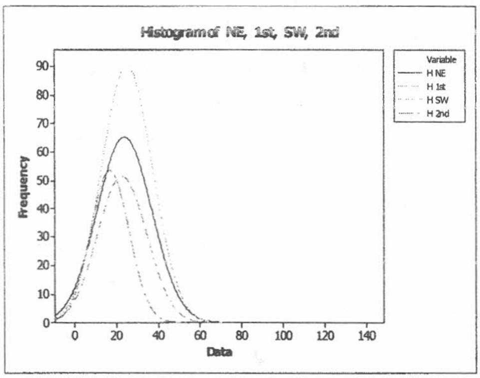

Fig. 1. Seasonal weibull distributions

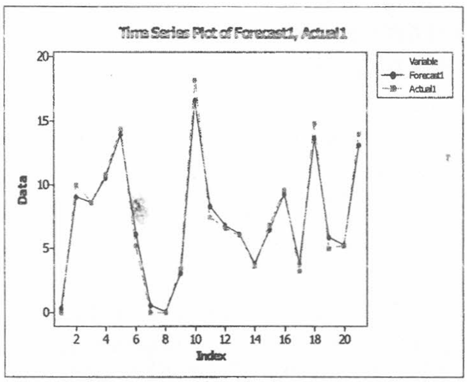

Fig. 2. Time series plot to compare predicted vs. actual values of wind speed

Table 1. Results of the goodness of fit tests

Test	Kolmogorov Smirnov			Anderson Darling		
Distribution	Test Statistic	Critical Value	Decision	Test Statistic	Critical Value	Decision
Weibull	0.048	0.0496	**Accept at 5%**	1.036	2.490	**Accept at 5%**
Lognormal	0.148	0.0496	Reject at 5%	2.968	2.490	Reject at 5%
Exponential	0.247	0.0496	Reject at 5%	161.918	2.490	Reject at 5%
Loglogistic	0.0555	0.0496	Reject at 5%	4.795	2.490	Reject at 5%