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AUTOREGRESSIVE INTEGRATED MOVING AVERAGE MODEL (ARIMA) FOR FORECASTING WIND SPEED

Shamshad A. [1], Wan Hussin W. M. A., Bawadi M. A., Mohd. Sanusi S. A.
School of Civil Engineering, University of Science Malaysia

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ABSTRACT

For proper planning and efficient utilization of wind energy, wind speed predictions are important. In the present study the hourly wind speed data from 1995 to 2001 at three meteorological stations at a height of 14 m above the ground level have been analysed for fitting autoregressive integrated moving average (ARIMA) models. First, the analysis has been carried out to detect any trend that can be present in the data series using Kendall's tau test. The wind speed data were subjected to standard time series analysis. For fitting the *ARIMA model* to the time series of the wind speed data, the three stage procedure of model identification, estimation of model parameters and diagnostic checking of the estimated parameters have been adopted. To determine the possible persistence structure in the data, the autocorrelation function (ACF) and the partial autocorrelation function (PACF) have been used. The examination of the ACF and PACF correlograms revealed that the data have non-stationarity. Therefore, ACF and PACF correlograms with various seasonal and non-seasonal differencing schemes have been used. All the possible models have been identified for the data series. For checking the adequacy of the model fitted to the data series, statistical tests have been carried. The Akaike Information Criteria (AIC) has been used to select the most appropriate fitted model out of the various competing models.

INTRODUCTION

Wind is pollution free, inexhaustible and free source of energy that has served man kind for many centuries by propelling ships and driving wind turbines to grind the grains and pumping the water. The cost of wind energy in the recent past has reduced. In spite of the high cost of wind energy as compared to those of coal and nuclear, wind may become the major source of energy in the time to come. Many countries have started to harness the energy from the wind and many more are trying their best. The modelling and forecasting of wind speed data is important for designing a proper wind energy system.

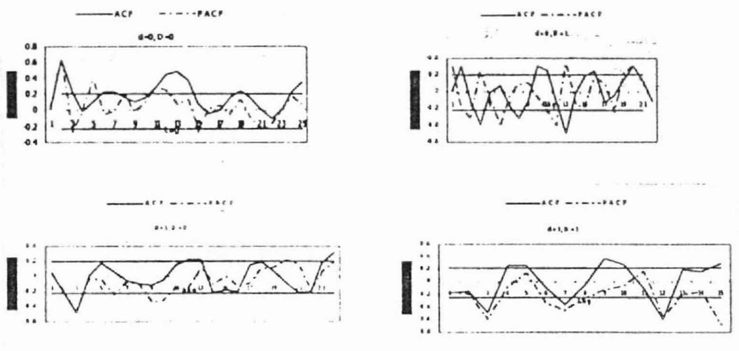

FIGURE 1 ACF and PACF Correlograms with 95% Confidence Limits for Various Combinations of Non-seasonal Differencing (d) and Seasonal Differencing (D) of Wind Speed Time Series at Kuantan

TABLE 1 Statistical Parameters of the Selected ARIMA Models for Wind Speed

Possible Model	ϕ_1	θ_1	Φ_1	Θ_1	AIC	Remarks
Mersing						
ARIMA $(1,1,1)x(0,0,0)_{12}$	0.70	1.00			-77.4	
ARIMA $(1,0,1)x(0,0,0)_{12}$	0.95	- 0.15			-62.9	
ARIMA $(1,0,0)x(0,1,1)_{12}$	0.33			0.86	-97.1	most appropriate model
ARIMA $(0,1,1)x(0,1,1)_{12}$		0.46		0.72	- 73.59	
ARIMA $(0,0,1)x(1,1,0)_{12}$		- 0.29	- 0.60		- 65.85	
ARIMA $(0,0,1)x(0,1,1)_{12}$		- 0.30		0.85	- 94.74	
Kuantan						
ARIMA $(1,1,1)x(0,0,0)_{12}$	0.53	0.86			- 171.8	most appropriate model
ARIMA $(1,0,0)x(0,1,1)_{12}$	0.66			0.71	- 153.3	
ARIMA $(0,1,1)x(0,1,1)_{12}$		0.95		0.77	- 146.3	
ARIMA $(0,0,1)x(1,1,0)_{12}$		- 0.45	- 0.48		- 118.0	
ARIMA $(0,0,1)x(0,1,1)_{12}$		- 0.42		0.49	- 144.1	
Kuala Terengganu						
ARIMA $(1,1,1)x(0,0,0)_{12}$	0.71	1.00			- 136.9	
ARIMA $(1,0,0)x(0,1,1)_{12}$	0.71			0.62	- 155.8	most appropriate model
ARIMA $(0,1,1)x(0,1,1)_{12}$		0.34		0.65	- 151.1	
ARIMA $(0,0,1)x(1,1,0)_{12}$		- 0.58	- 0.45		- 115.4	
ARIMA $(0,0,1)x(0,1,1)_{12}$		- 0.42		0.39	- 132.7	

In the next step the parameters of all the tentative selected models have been estimated using the least square techniques. The AR and MA coefficients have been optimized by varying the values within a specified range from -1 to 1 till the sum of squares of residuals were minimum. The maximum likelihood estimates of all the model parameters, corresponding to the minimum sum of squares of the residuals, have been obtained as shown in Table 1. To check the adequacy of the model the residual autocorrelations have been computed. Two or three models on each station have shown that the residuals of the model can be considered as white noise. To further test these models the Akaike information criteria (AIC) (Akaike, 1974) values have been computed. The model having the minimum value of AIC has been selected as the most appropriate model. The best models for Mersing, Kuantan and Terengganu are ARIMA $(1,0,0)x(0,1,1)_{12}$, ARIMA $(1,1,1)x(0,0,0)_{12}$ and ARIMA $(1,0,0)x(0,1,1)_{12}$ respectively. It is observed that in general the models having both a regular and seasonal components were the most appropriate models. The observed and fitted values of the most appropriate models have been shown in Figure 2. The fitted values are quite close to the observed values. The models performance for forecasting has been evaluated in terms of root mean square error (RMSE). RMSE in each case has been found nearly 0.30 m/s which is quite satisfactory.

CONCLUSION

The results obtained in the study reveal that the ARIMA models provide a useful quantitative description of the mean monthly wind speed. The technique is accurate but requires a lot of computational skill. The data should be available in sufficient large numbers if possible at least 50 and preferably 100 successive observations should be used to achieve the appropriate model. The technique is site specific and need to be used carefully and it can not respond to 'what if' type of questions. The forecasting accuracy of ARIMA model decreases with time;