Wind Speed Forecasting Using New Adaptive Regressive Smoothing Models

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Problem Statement

The energy need of countries is increasing day by day. Majority of energy is generated by fossil fuels. But fossil fuels are causing environmental pollution this lead to use renewable energy sources more and more. Wind energy is cheapest and commercially viable option for energy generation form renewable energy sources. But wind power is highly random in nature so when it penetrate power of wind speed exceeds a certain value, it will affect the quality of electric power as well as power system operation. If we able to forecast the wind speed and the wind generated output power, more accurately, the power system scheduling can be done to adjust the scheduling plans promptly, which reduces the impact of wind power on the electric power grid. It also lower downs the power system operating costs and increase wind power penetration power limit. To install wind power station, it is important to investigate and analyze the geographical positions of wind speed in the locations.

Approach Used to Solve Problem

In this work monthly average wind speed data between the years 2012 to 2016 are used for three cities Pune, Ahmednagar and Nashik (Maharashtra, India). Geographical positions of three locations are given in table 1.

Table 1 Geographical position of selected locations

Location	Latitude	Longitude
Pune	73.8569	18.5204
Nashik	73.7898	19.9475
Ahmednagar	74.7496	19.0952

The wind speed forecasting can effectively reduce the adverse effect of wind farm on power grid and it will also ensure the safe and economic operations of the power system. In this study we have determined the wind speed forecasting of three geographical locations in India using adaptive regressive models.

Moving average model, weighted moving average model, regressive smoothing model, regressive smoothing with trend model and regressive adaptive smoothing models were used for forecasting. To evaluate model's performance, mean error (ME), mean absolute error (MAE), mean square error (MSE), mean absolute percentage error (MAPE) and root means square error (RMSE) statistics were calculated.

Tool Used

Matlab Software for code building and graph analysis

Result Achieved

As compare to old classical models like 3 month moving average, 3 month weighted moving average and regression smoothing models, the newer adaptive 1 and 2 models provide better accuracy in WSF. The proposed models can improve the WSF by effectively identifying and adjusting the errors from wind speed using difference of wind speeds.

Abstract

This work proposes two new adaptive regressive smoothing models for wind speed forecasting (WSF). Generally WSF largely depends on the numerical models used which contribute the most error in WSF. This paper first uses most commonly used moving average and regressive smoothing models for WSF. Second, two new adaptive models are proposed for WSF. These adaptive models reduce the error in WSF by using difference of wind speeds with respect to the back period and current period wind speed values. In this paper model's quality measures are calculated by using mean error (ME), mean absolute error (MAE), mean square error (MSE), mean absolute percentage error (MAPE) and root means square error (RMSE) statistics. Simulations are performed to compare different models. It proves that the proposed models can improve the wind speed forecasting by effectively identifying and adjusting the errors from wind speed.

Keywords

Wind speed forecast, Regressive smoothing models, Adaptive regressive smoothing models, Quality measures

Methods Used

- Moving Average Method (MA)
- Weighted Moving Average Method (WMA)
- Regressive Smoothing Method
- Adaptive 1- Regressive Smoothing Method
- Adaptive 2 - Regressive Smoothing method

Moving Average Method

- Most Basic Method
- Calculated by finding the current average wind speed over a set number of periods.
- Moving average method (MA) calculated as;

$$F_n = \frac{1}{n} \sum_{t=1}^{n} A_t$$

- Where, n=number of observation, A_t=actual value at observation t.

Weighted Moving Average Method

- Estimated by multiplying each of the previous month's data by weight. It puts more weight on recent data and less weight on past data. It gives better volatility estimates than the simple moving average.
- Calculated as:-

$$F_{t+1} = \frac{\sum_{i=1}^{n} w_i d_{t-i+1}}{\sum_{i=1}^{n} w_i}$$

Regressive Smoothing Method

- Decreases the lag by applying more weight to recent wind speed. The weighting applied to the most recent wind speeds depends on the number of periods in the moving average.
- Unlike the Moving Average Method, this regression method calculates the average of all historical values, starting at the point you specify.

$$F_{t+1} = \alpha \sum_{n=0}^{t-1} (1-\alpha)^n y_{t-n} + (1-\alpha)^t y_1$$

- We are using regressive smoothing method of order one (method 3a), regressive smoothing method of order one with linear trend (method 3b).

$$F_{t+1} = \alpha \sum_{n=0}^{t-1} (1-\alpha)^n y_{t-n} + (1-\alpha)^t y_1$$

- Where α=smoothing constant, F_t=forecast value for observation t.For calculating linear trend following expression is used.

$$T_t = \beta(F_t - F_{t-1}) + (1-\beta)T_{t-1}$$

- Where β=smoothing constant for trend, T_t =smoothed trend for observation t.

Adaptive 1- Regressive Smoothing Method

- The adaptive regressive smoothing method is defined as per the first order equation.

$$F_{t+1} = \alpha \sum_{n=0}^{t-1} (1-\alpha)^n y_{t-1} + (1-\alpha)^t (y_{t-1} + (y_{t-1} - y_t)$$

Adaptive 2 - Regressive Smoothing method

- Similar to the Adaptive-1 method an alternate adaptive regressive smoothing method is defined as per another first order equation defined as

$$F_t = \alpha \sum_{n=0}^{t} (1-\alpha)^n y_t + (1-\alpha)^t (y_t + (y_t - y_{t-1})$$

Quality Measures

In order to compare quality of the above proposed models against the old classical models several quality measures are used.

They are as follows

a) Mean Error:-

$$ME = \frac{1}{n}\sum_{t=1}^{n} e_t$$

b) Mean Absolute Error:-

$$MSE = \frac{1}{n}\sum_{t=1}^{n} e_t^{\,2}$$

c) Mean Square Error:-

$$MAE = \frac{1}{n}\sum_{t=1}^{n} \left|e_t\right|$$

d) Moving Average Percentage Error(MAPE):-

$$MAPE = \frac{100}{n} \sum_{t=1}^{n} \left| \left(\frac{e_t}{A_t} \right) \right|$$

e) Root Mean Square Error(RMSE):-

$$RMSE = \sqrt{\frac{1}{n} \sum_{t-1}^{n} e_t^2}$$

Results

The descriptive statistics for three locations are shown in table 3.The comparative variation in wind speed by forecast models with actual wind speed are given in figure1, figure 2 and figure 3 for Pune, Nashik and Ahmednagar locations respectively

Table 3 Statistics for three locations

Location	Pune	Nashik	Ahmednagar
Mean	5.565	5.4583	4.6542
Maximum	13.8	12.8	9
Minimum	0.7	0.5	1.4
Std. Deviation	2.9009	2.5825	2.0099
Kurtosis	0.3570	0.2648	0.6539
Median	5.7	5.4	4.5

Location - Pune						
Quality Measures	Method 1	Method 2	Method 3a	Method 3b	Method 4	Method 5
ME	2.6587	2.6561	-0.0585	-0.0002	-0.0009	-0.0058
MAE	3.0324	2.9671	0.2375	1.9692	0.1951	0.1731
MSE	14.2163	13.4546	0.2989	6.3015	0.0597	0.0500
MAPE	26.7566	30.4409	-5.0178	-17.3046	-0.5798	1.2286
RMSE	3.7704	3.6680	0.5468	2.5102	0.2444	0.2236
Location - Ahmednagar						
Quality Measure	Method 1	Method 2	Method 3a	Method 3b	Method 4	Method 5
ME	1.8825	1.8851	-0.0380	-0.0058	0.0003	-0.0032
MAE	2.0316	2.0001	0.1501	1.2394	0.1212	0.1089
MSE	7.5153	7.2342	0.0784	1.2394	0.1212	0.1089
MAPE	32.4223	33.7298	-1.8685	-8.7767	-0.5627	0.6908
RMSE	2.7414	2.6896	0.2801	1.1132	0.3481	0.3304
Location - Nashik						
Quality Measure	Method 1	Method 2	Method 3a	Method 3b	Method 4	Method 5
ME	2.5919	2.5932	-0.0396	-0.0263	-0.0026	-0.0013
MAE	2.9046	2.8617	0.3153	3.0586	0.2793	0.2743
MSE	13.5568	12.9457	0.2126	13.6390	0.1188	0.1118
MAPE	24.5240	24.5240	-5.6177	-48.1377	-4.1847	4.2520
RMSE	3.6819	3.5980	0.4610	3.6931	0.3447	0.3344

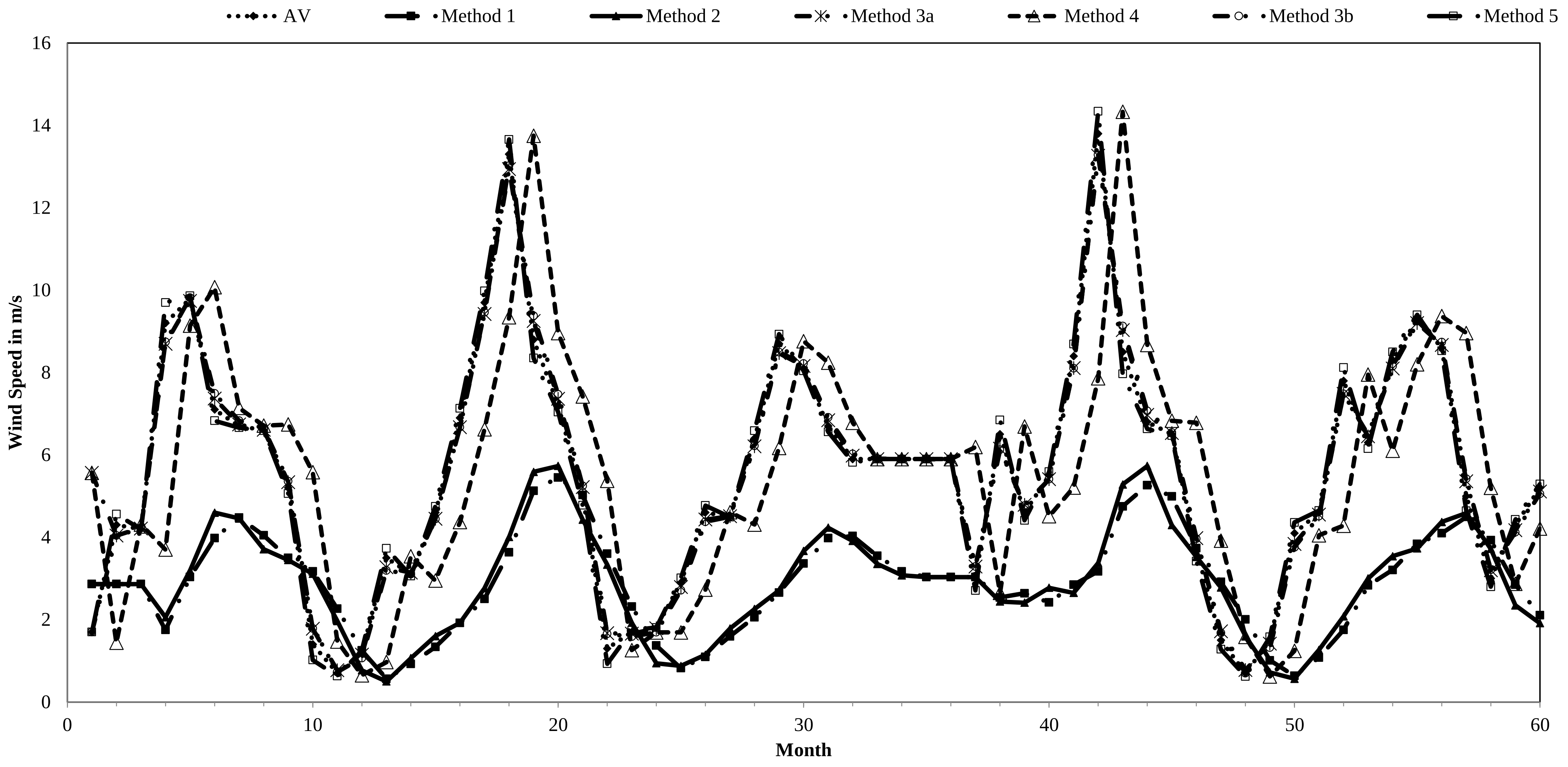

Fig. 1 Wind Speed Forecast for Pune Location

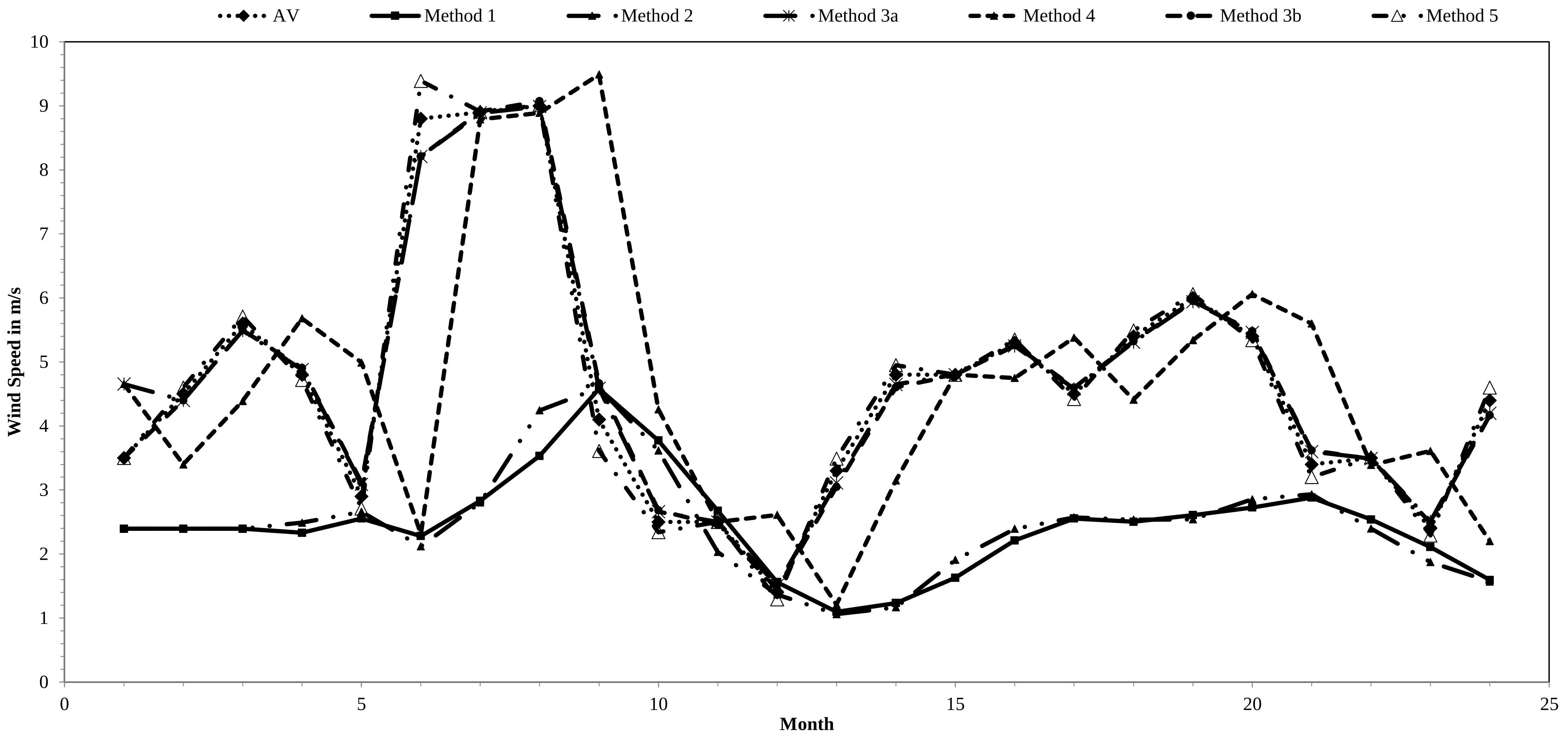

Fig. 2 Wind Speed Forecast for Ahmednagar Location

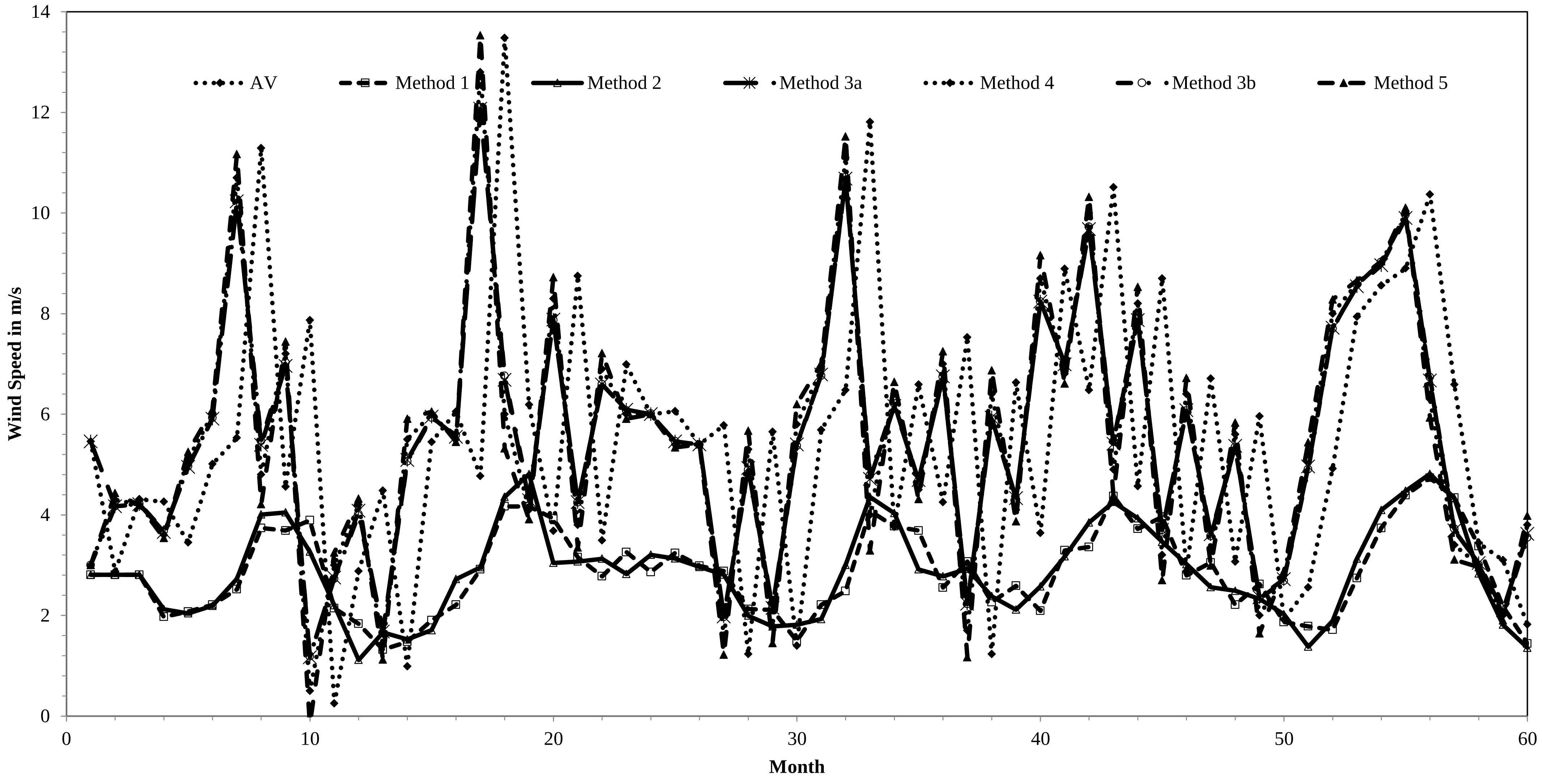

Fig. 3 Wind Speed Forecast for Nashik Location

- These figures show the cognizance of the proposed adaptive models in tracking the time series of the actual data. In this paper monthly averaged wind speed data are used in developing the prediction models for the next time interval. These adaptive models keep adapting themselves to the changes in wind speed values.
- For a good forecasting model, quality measure values should be low. In table 2, the Mean Error (ME), the Mean Absolute Error (MAE), Mean Square Error (MSE), Moving Average Percentage Error (MAPE), Root Mean Square Error (RMSE) is used for comparative analysis. Based upon the data in table 2, it can be said that adaptive-1 and adaptive-2 models are the best fit for all locations as they shown lesser values of errors and other quality measures (ME, MAE, MSE, MAPE and RMSE).
- It was found that the smallest error (MAPE) was 0.58%, 0.56% and 4.18% for Pune, Ahmednagar and Nashik locations respectively using adaptive 1 model while maximum error was 30.44%, 33.44% and 24.52% using WMA Model. It can be seen that the rising and falling trend in wind speed was properly picked by observing time series of wind speed. For location Pune, reduction in ME, MAE, MSE, MAPE and RMSE values are 0.75%, 5.17%, 0.351%, 1.905% and 5.93% respectively for adaptive models as compared to conventional WSF methods. For location Nashik, reduction in ME, MAE, MSE, MAPE and RMSE values are 0.05%, 9.44%, 0.82%, 17.06% and 9.08% respectively for adaptive models. For location Ahmednagar, reduction in ME, MAE, MSE, MAPE and RMSE values are 0.015%, 5.36%, 1.45%, 1.668% and 12.05% respectively for adaptive models.

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