COMPARATIVE STUDY OF WIND SPEED FORECASTING TECHNIQUES

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ABSTRACT

Wind is one of the renewable energy resource, as it is clean energy and less in maintenance, it is alluring many researchers to work on it, but the wind is time varying in nature. It is essential to predict the wind speed for effective and efficient planning of the load demand.

Forecasting is an important aid in wind speed prediction. The wind speed forecasting can effectively reduce or avoid the adverse effect of wind farm on power grid and it will also ensure the safe and economic operations of the power system.

This major project is aimed to design an appropriate model for wind forecasting with less mean square error (MSE). A model is proposed to achieve above mentioned objective and it is observed that the proposed model gives the better performance than the existing models with respect to MSE

Keywords-Forecasting;Artificial Neural Network.

INTRODUCTION

Wind is a renewable energy source which is driven by sun. Wind is set in motion by the difference in temperature and air pressure due to solar radiation on earth surface. Wind moves from high atmospheric pressure to low atmospheric pressure.

Wind speed is generally based on forecasting horizon. There are two methods to do forecast based on horizon of forecast;namely

1. Physical Method. (Numerical based approach)
2. Statistical Method.

Physical method considers meterological information like temperature,pressure,humidity,surface terrain and so on. These are calculated using numerical formulas to predict wind speed.

Stastical method find the relation between them to predict wind speed. It collects historical data to predict wind speed. These models are self attune in nature.

Wind speed forecasting is critical for wind energy conversion systems since it greatly influences the issues such as the scheduling of a power system, and the dynamic control of the wind turbine. The paper present a comprehensive comparison study on the application of different artificial neural networks in one hour ahead wind speed forecasting [1]. The analysis of prediction of wind speed and also describes about different neural networks which shown that the root mean square error can be reduced and the uncertainty of prediction and calculation time is also decreased in such a way that the efficiency of prediction is improved[2]. In the paper[3], the author describes the model based on the neural network, demonstrated a good agreement and produced the wind forecast with high accuracy.

In the paper[4], the author describes about back-propagation using taboo search algorithm to predict wind speed. In paper [5], it gives detailed survey of the wind speed forecasting techniques have been provided since past 15 years. An attempt is also made to identify different wind forecasting providers available in the market. In the paper[6], the author proposes a wind power forecasting methodology based on two methods: direct wind power forecasting and wind speed forecasting in the first phase followed by wind power forecasting using turbines characteristics and the aforementioned wind speed forecast. Short-term wind speed forecasting is for power system stability and improves its operational efficiency is important [7]. The neural network forecasting is also found to be more accurate than traditional statistical time-series analysis.

The networks are trained based on past data in an auto-regressive manner using back-propagation and cascade correlation algorithm [8].In the paper [9], it focuses on a particular type of neural network model, known as a "feed-forward back-propagation network". This model is easy to understand, and can be easily implemented as a software simulation.[10] A short-term wind speed forecasting method based on auto-regressive integrated moving average (ARIMA) and least square support vector machine (LS-SVM) is proposed. The weights are calculated by two methods, equal weight average method and covariance optimization combination forecast. In the paper[11], the author aims to perform analysis of the different activation functions and provide a benchmark of it. The purpose is to figure out the optimal activation function for a problem. The paper [12] explains how the wind speed signal is decomposed with wavelet transform, and reconstructed to get each scale's sub-series. Then the subseries are predicted by compact wavelet and neural network respectively. The paper [14] discuss about the regression models. In this paper, the concept of prediction of wind speed is discussed, the prediction of wind is done by using back propagation neural network, time series method and regression method.

A. *Back Propagation Neural Network(BPNN)*

BPNN consists of input layer,hidden layer and output layer.The hidden layer is composed of one or more layers. The hidden layer with one layer is continous or integrable functions according to the theory. The predictions are mostly done by one hidden layer as it is easy to implement. The input layer,hidden layer and output layer is connected by nerve cells.The nerve cells connections are connected in one way for different layers,but the nerve cells are connected independent of same layer. The transfer function of the neural network is sigmoidal function. The training algorithm of back propagation involves four stages, they are

1. Initialisation of weights
2. Feed forward
3. Back propagation of errors
4. Updation of the weights and bias

The training function used for the neural network is done by Levenberg-Marquardt optimization(LMO). LMO increases the learning capability.

B. Design of BPNN

The input used for the network is historical wind data. The input is previous wind velocities i.e from the year 2006 to 2012 of feb month. The transfer function is sigmoidal.The training function is LMO to update weights and bias.

The target used for the network is the wind speed and the network is trained based on the target. The weight and bias are updated. The no of neurons is selected as "4" based on the repeated training to get optimised results. The network is trained as shownin the figure 1.

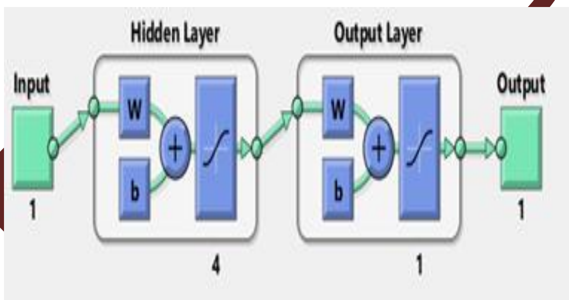


Fig 1:Neural Network

The network is simulated to predict the wind speed of year 2013 of feb month.
By using BPNN the febraurary month of 2013 is predicted from the historical data.

Table1:prediction using back propagation

Febraury	Actual	mean	Predicted
1	12.88	6.49	7.71
2	6.31	6.28	6.60
3	2.07	5.91	2.97
4	4.37	6.62	3.60
5	8.21	7.80	6.60
6	8.57	6.58	6.12
7	4.91	6.21	3.37
8	6.35	6.24	4.19
9	4.19	8.41	5.48

10	13.39	7.20	12.85
11	9.51	7.17	8.02
12	5.79	6.86	5.84
13	4.61	6.94	5.61
14	3.32	7.46	4.81
Febraury	Actual	mean	predicted
15	2.52	8.70	3.85
16	3.6	8.05	4.92
17	5.77	9.12	6.49
18	5.77	6.85	5.81
19	3.11	6.91	3.93
20	4.75	6.98	3.59
21	5.56	7.59	3.26
22	5.72	7.79	5.06
23	5.64	8.01	5.53
24	4.75	7.74	7.82
25	5.28	7.00	3.31
26	5.06	4.70	4.19
27	9.77	6.03	6.45
28	7.19	5.56	4.44

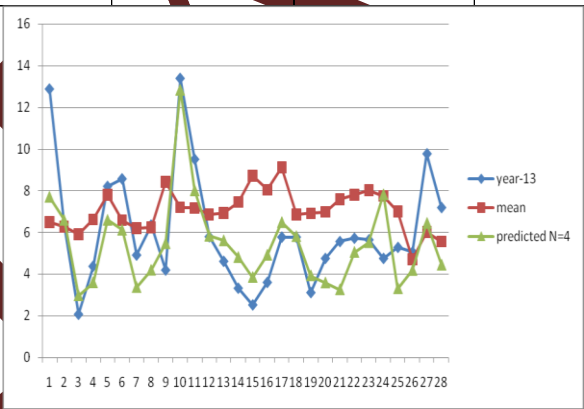


Fig 2:The plot between actual and predicted wind speed

The actual wind speed is indicated by using blue colour line in the fig 2. The mean with red colour. The predicted wind speed is indicated using green colour.

Table 2:parameter values

ME	0.59
MAE	1.47
MAPE	26.33
MSE	3.42

$$W_{mse} = \frac{1}{n}\sum_{i=1}^{n}(W_a - W_p)^2 \qquad (1)$$

Where
Mean error(ME)=(actual-predicted)/n
Mean absolute error(MAE)=mod(actual-predicted)/n
Mean absolute percentage error(MAPE)=% of MAE
Mean square error(MSE)=equation 1

The symbol W_{mse} indicates the mse between the actual and predicted wind speed.The symbol n indicates the number of prediction values. The symbol W_a indicates actual wind speed data and the symbol W_p indicates the predicted wind speed.

C. *Linear regression*

The simple linear regression is the least squares estimator of a linear regression model with a single explanatory variable. In other words, simple linear regression fits a straight line through the set of n points in such a way that makes the sum of squared residuals of the model (that is, vertical distances between the points of the data set and the fitted line) as small as possible. The slope of the fitted line is equal to the correlation between *y* and *x* corrected by the ratio of standard deviations of these variables. The intercept of the fitted line is such that it passes through the center of mass (*x*, *y*) of the data points.

For linear regression we calculate intercept and slope

Slope(b) = (NΣXY - (ΣX)(ΣY)) / (NΣX^2 - $(ΣX)^2$) (2)

Intercept(a) = (ΣY - b(ΣX)) / N (3)

Where, x and y are the variables.
b = The slope of the regression line
a = The intercept point of the regression line and the y axis.
N = Number of values or elements
X = period, Y = wind
ΣXY = Sum of the product of period and wind
ΣX = Sum of period
ΣY = Sum of wind
ΣX^2 = Sum of square period

Forecast=intercept+(slope*period) (4)

Table 3:prediction uing linear regression

Febraury	Actual	Predicted
1	12.88	7
2	6.31	7
3	2.07	7
4	4.37	7
5	8.21	7
6	8.57	7

7	4.91	6
8	6.35	6
9	4.19	6
10	13.39	6
11	9.51	6
12	5.79	6
13	4.61	6
14	3.32	6
15	2.52	6
16	3.6	6
17	5.77	6
18	5.77	6
19	3.11	6
20	4.75	6
21	5.56	6
22	5.72	6
23	5.64	6
24	4.75	5
25	5.28	5
26	5.06	5
27	9.77	5
28	7.19	5

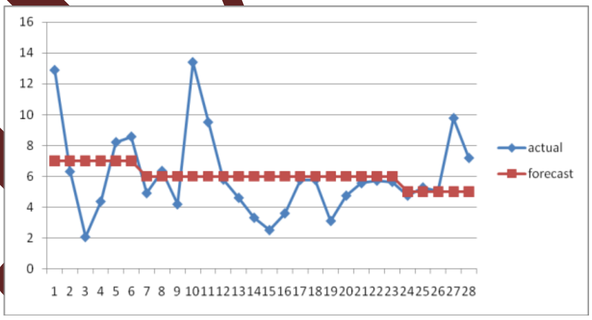


Fig 3:The plot between actual and predicted wind speed using linear regression

The actual wind speed is indicated by using blue colour line in the fig 3. The predicted wind speed is indicated using red colour.

Table 4:parameters

ME	-0.21889
MAE	1.798889
MAPE	39.33526
MSE	6.381122

The mean square error is calculated is based on the equation (1).

The linear regression doesn't followed the pattern the mean quare error is more i.e. 6.38. The neural network prediction has predicted well than the linear regression model.

So to follow the pattern new algorithm is proposed.

D. *Proposed Model*

The proposed model is implemented based on the regession to predict the wind speed and to reduce the mean square.The constant matrix is implemented based on the prediction error.

The wind is collected from the satavento galacia to predict the wind speed. The correlation is done for the input data to know whether the historical data will provide relation.The correlation has given relation so we took the historical wind speed data i.e. from to 2006 to 2012and the predicted the wind speed of 2013.

The wind speed is predicted by using historical data. The predicted wind speed is W_{tp}. The wind speed of previous wind speed are W_1,W_2,W_3,.....W_n.(n=no of historical data).

$$[W_{tp}]_{1*1}=[Ap]_{1*n}[Wp]_{n*1} \qquad (5)$$

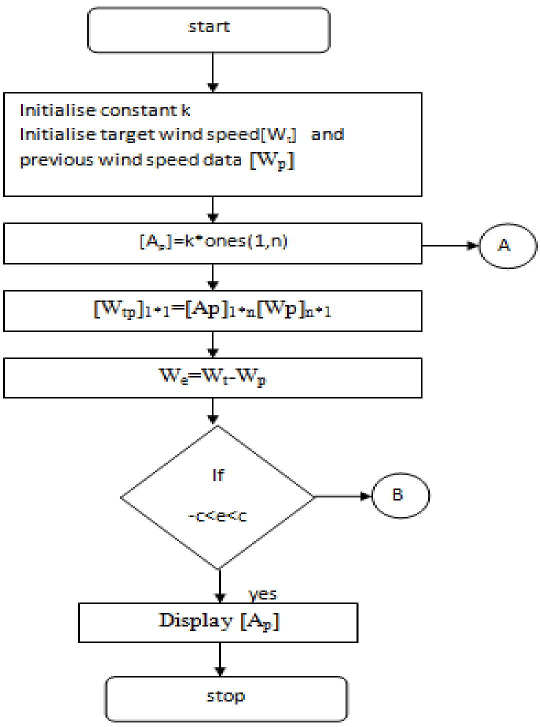
Where n-previous years

A_p-constant matrix

A_p-$[A_1\ A_2\ .\ .\ .\ .A_n]$

W_p-$[W_1\ W_2 .... W_n]^T$

Flow chart of proposed model



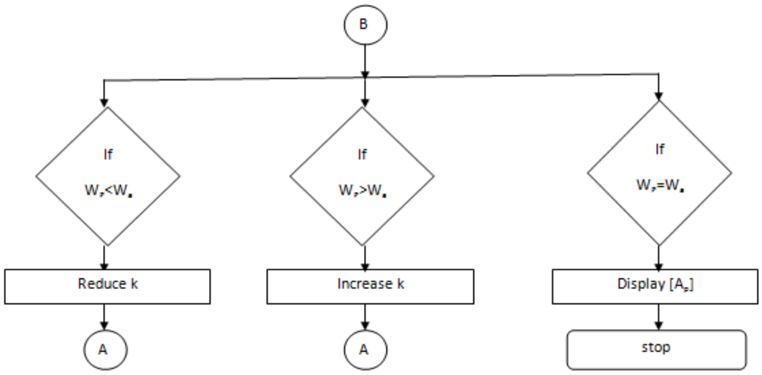


Table5:prediction using proposed model

Febraury	Actual	Predict
1	12.88	13.63
2	6.31	4.40
3	2.07	2.07
4	4.37	4.17
5	8.21	10.92
6	8.57	4.61
7	4.91	4.35
8	6.35	4.37
9	4.19	4.12
10	13.39	15.11
11	9.51	5.02
12	5.79	4.80
13	4.61	4.37
14	3.32	3.13
15	2.52	2.44
16	3.6	3.38
17	5.77	5.74
18	5.77	4.80
19	3.11	2.90
20	4.75	4.40

21	5.56	5.31
22	5.72	5.45
23	5.64	5.61
Febraury	Actual	Predict
24	4.75	4.34
25	5.28	4.90
26	5.06	3.29
27	9.77	8.44
28	7.19	3.89

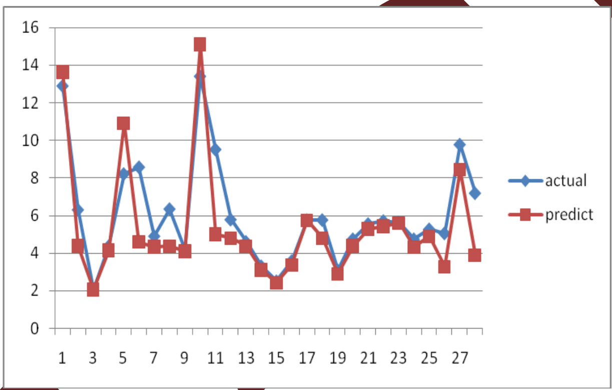


Fig 4:plot between actual and predicted wind based on proposed model

The actual wind speed is indicated by using blue colour line in the fig 4. The predicted wind speed is indicated using red colour.

COMPARATIVE ANALYSIS

The models mentioned above are compared to show that the proposed model is better than the other model. The comparision is done based on the mean square error.

Table 6:Comparative Analysis

	BPNN	Linear Regression	Proposed Model
ME	.59	-0.21	0.68
MAE	1.47	1.80	1.05
MAPE	26.33	39.33	14.75
MSE	3.42	6.38	2.61

CONCLUSION & FUTURE SCOPE

This paper work aimed to design a new forecasting model for wind speed prediction. The wind speed is predicted using historical data. Both time series model and back propagation model is used to predict the wind. Training the network and the prediction of wind speed using back propagation was simulated by Matlab.

An algorithm for wind speed forecasting is designed and the comparative analysis on all above mentioned models was performed and it is observed that the proposed algorithm has better results with respect to MSE. The mean square error (MSE) is less for the proposed algorithm (i.e. 2.61%).

This work can be further extended.

- Predicting the missing data of the wind farm by using proposed algorithm.
- Comparative analysis between the proposed algorithm and the genetic algorithm can be performed.

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