International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958 (Online), Volume-9 Issue-4, April 2020

# Wind Resource Assessment using Machine Learning Algorithm

**Stanly Abraham S, Meenal R, Abishekkevin K, Pravina M, Belsha Jackline Princess J**

***Abstract:*** ***The wind speed prediction is very important for wind resource assessment, renewable energy integration in to the electricity grid, electricity marketing and so on. Because of the arbitrary fluctuation characteristics of wind, the prediction results may change quickly. This enhances the significance of the accurate wind speed prediction The objective of this paper is to predict the wind speed for Tamil Nadu cities using machine learning algorithm. There are three broad categories of wind forecasting models namely physical model, statistical and computational models and hybrid models. Artificial Neural Network is the most commonly used method for wind speed prediction. Recently machine learning and deep learning algorithms are widely used for forecasting applications. In this work wind speed is predicted for Tamil Nadu cities using decision tree regression algorithm. The Machine Learning (ML) model is trained using measured wind speed data for six cities of India collected from India Meteorological Department (IMD), Pune. The ML model based on decision tree regression algorithm is good in prediction with better performance metrics of MSE in the range of 0.3 to 1.2 m/s and*** $R^2$ ***=0.87.***

***Keywords: Machine learning; wind speed; prediction; forecasting; ANN***

## I. INTRODUCTION

The energy is the most important factor for the growth of social and economic of any country. Wind energy is considered as the greatest renewable energy source due to its simplicity of access and surplus in most parts of the world. Wind energy technologies are widely utilized in many applications. The available wind energy mainly depends on the wind speed. The prediction results of wind power may change quickly because of the arbitrary fluctuation characteristics of wind. This enhances the importance of the precise wind speed prediction. Wind speed prediction plays an important role in efficient and proper utilization of wind power. There are many approaches available in the literature to improve the accuracy of wind speed prediction including the physical method, the statistical method like ARMA model, the spatial correlation model and the artificial intelligence and machine learning algorithm based methods and so on.[1-4] Artificial Neural Network(ANN) is inspired by biological neural network. This model is economically profitable [5-11]. Hybrid method is giving better prediction accuracy when compared to conventional statistical models [12-14]. The forecasting method using mathematical models gives good performances for short term prediction [15]. Physical methods are based on meteorological data like temperature, pressure etc. as their inputs. Statistical models are suitable for short time periods [16, 17].

Revised Manuscript Received on April 12, 2020.
* Correspondence Author
**Stanly Abraham S*,** Karunya Institute of Technology and Sciences, Coimbatore – 641114, Tamilnadu, India. Email: abisheik11@gmail.com
**Abishekkevin K,** Karunya Institute of Technology and Sciences, Coimbatore – 641114, Tamilnadu, India.
**R. Meenal,** Karunya Institute of Technology and Sciences, Coimbatore – 641114, Tamilnadu, India. Email: meenasekar5@gmail.com
**Belsha Jackline Princess J,** Karunya Institute of Technology and Sciences, Coimbatore – 641114, Tamilnadu, India. Email: beljacky67@gmail.com
**Pravina M,** Karunya Institute of Technology and Sciences, Coimbatore – 641114, Tamilnadu, India.



## II. METHODS FOR WIND SPEED FORECSTING

There are three broad categories of wind forecasting models namely physical model, statistical and computational models and hybrid models. Artificial Intelligence and Machine learning based models are widely used for wind speed prediction [18, 19].

### A. Artificial Intelligence based models

ANN is the most commonly used algorithm for wind speed prediction. It is inspired by biological neural network. There are three layers in ANN. The layers are Input layer, hidden layer and output layers. The network has a complex non linear statistical data between inputs and outputs. Figure 1 shows the simple model of an artificial neuron and the steps used for building the ANN model. $x_1$,$x_2$,$x_3$ are the inputs and $w_1$, $w_2$, $w_3$ are weights linked with the inputs respectively. An artificial neuron that collects a signal then processes it and can signal neurons associated to it.

Applications of ANN includes system identification and control, image processing, prediction and forecasting, Process control, Natural resource management, Quantum chemistry, Face identification, Signal classification, etc. It is used in the fields of medical, robotics, data processing, clustering, forecasting etc.

### B. Machine Learning Method

Machine learning is the branch of artificial intelligence in which the model can learn by itself with the given data to make decision and to predict new or future data. Every field like medical, banking, government, transportation, forecasting etc. is using machine learning models for their various purposes. In this work, decision tree regression algorithm is used for wind speed prediction.

### C. Decision tree regression model

Decision trees are extremely popular and powerful prediction method. The decision tree is a supervised machine learning model used to predict a target by learning decision rules from features.

Regression is a data science assignment of predicting the value of target output variable by constructing a model based on one or more predictors. The monthly wind speed in m/s for Tamil Nadu cities is predicted using decision tree regression algorithm which is implemented using python programming language. The following python packages are utilized to predict the wind speed.

*sklearn*:a machine learning package which consist of a lot of ML algorithms.

*NumPy*:numeric python module which provides fast maths functions for calculations.

*Pandas*:Used to read and write different files.

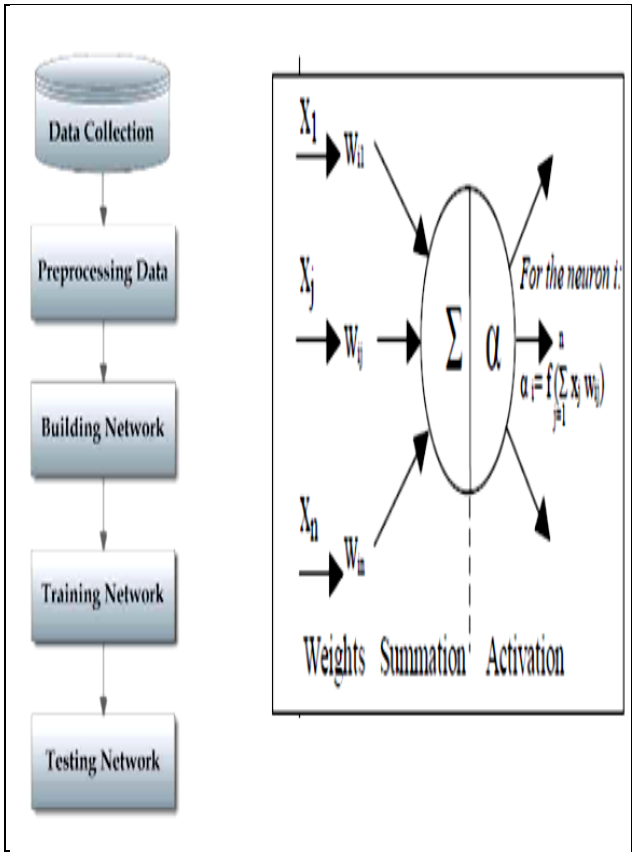



**Fig.1 Simple Model of an artificial Neuron**

*Data Set*

The machine learning model with decision tree regression algorithm is built with the following input parameters.

1. Month number

*Geographical parameters* namely

2. Latitude and longitude

*Measured parameters*

3. Minimum Temperature (°C)
4. Maximum Temperature (°C)
5. Relative Humidity (%) and
6. Surface Pressure (kPa)

The measured input parameters are collected from India Meteorological Department, Pune for 13 locations. For wind resource assessment in Tamil Nadu cities, parameters related to the locations New Delhi, Mumbai, Bangalore, Jaipur and Trivandrum is considered. The output of the model is wind speed in m/s. The ML model is trained with measured experimental data collected from IMD, Pune for the selected locations and the wind speed is predicted for 10 smart cities of Tamil Nadu namely Chennai, Coimbatore, Cuddalore, Dindigul, Erode, Madurai, Pondycherry, Salem, Thanjavur, Tirunelveli, Trichy and Tuticorin. Due to page restriction input parameter graphs are presented only for three locations namely New Delhi, Mumbai and Bangalore.

### D. Performance Metrics

The following metrics are used to determine the accuracy of the model.

*MSE-Mean Square Error*

MSE measures the average of the squares of the error. It estimates the variation between the actual and predicted value. The mean square value is always positive. The values closure to zero is better.

The MSE expression is given by

$$MSE = \sum_{i=1}^{n} \frac{(x_i - \hat{x_i})^2}{n}$$

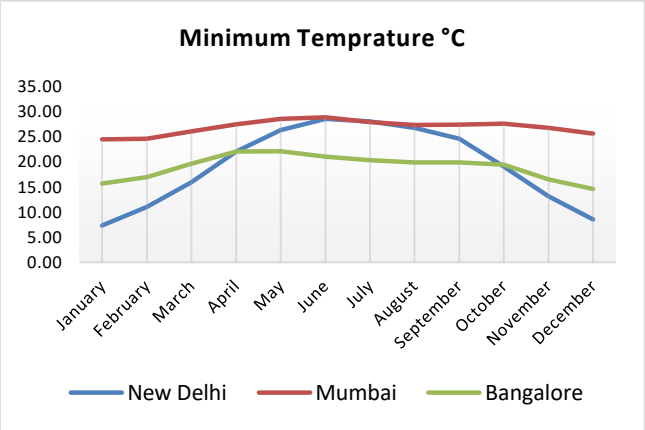
Where, $\hat{x_i}$ is the actual value$x_i$ is the predicted value and *n* is the sample size of the data.

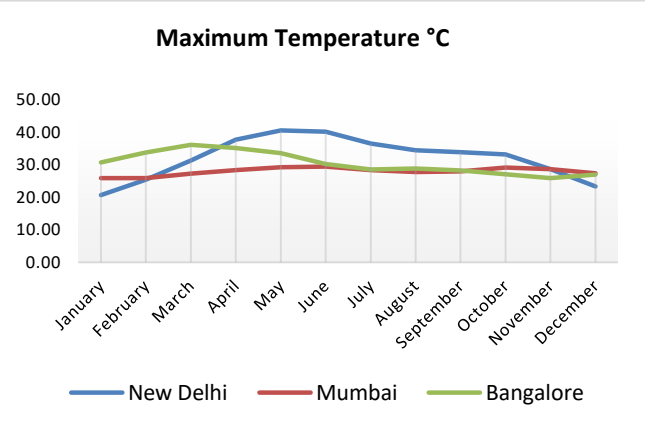
$R^2$ / Coefficient of determination

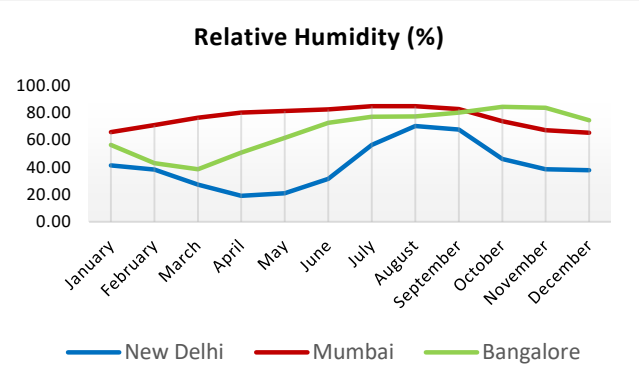
Coefficient of Determination is the square of Coefficient of Correlation. $R^2$ or coefficient of determination shows percentage variation in predicted value which is explained by all the input variables together. The range is from 0 to 1.A higher coefficient is an indicator of better prediction model.

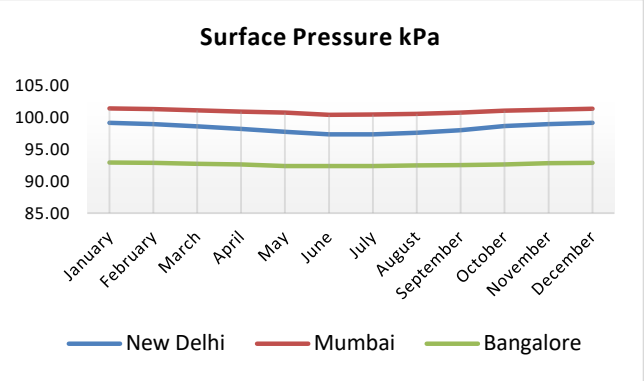
## III. RESULT AND DISCUSSION

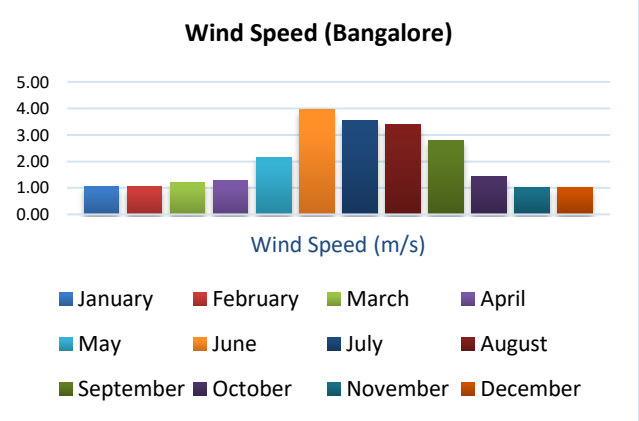
In this paper, ML model using decision tree regression algorithm is used to predict the wind speed for Tamil Nadu cities namely Chennai, coimbatore, Cuddalore, Dindigul, Erode, Madurai, Pondycherry, Salem, Thanjavur, Tirunelveli, Trichy and Tuticorin.The ML model is trained with experimental wind speed data from IMD, Pune. The predicted wind speed value is compared with NASA data.The performance of the model is evaluated with the metrics namely the MSE and $R^2$ value.For better model quality, the $R^2$ should be nearer to one and MSE value should be less.Table 1 summarizes the permarmance metrics of the ML model.From the table it is observed that the MSE value is in the range of 0.3 to 1.2 and $R^2$ nearer to one. Figure 2 shows the measured input parameters such as the maximum and minimum temperature,percentage relative humidity and surface pressure, also the output parametter namely the wind speed data in m/s for the selected three locations. Figure3 shows the monthly predicted wind sped in m/s and NASA data for the 10 cities of tamil Nadu.Table 2 shows the predicted wind speed values.From the table it is observed that the average maximum wind speed is available at Tuticorin.

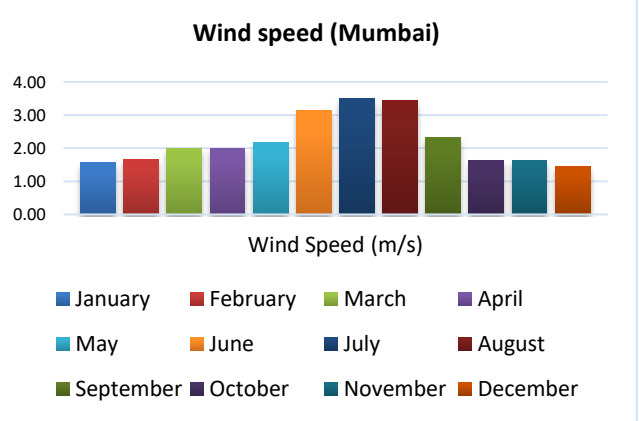


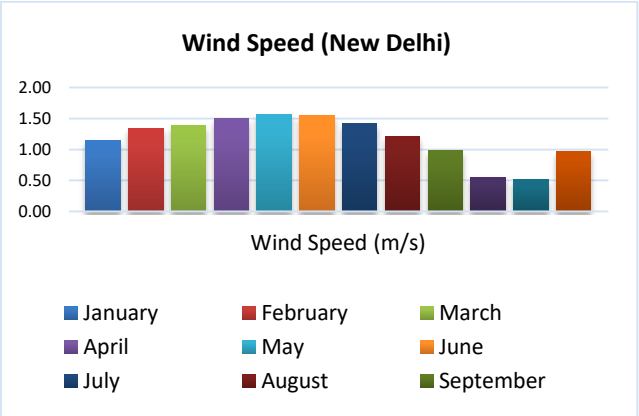




**Input Parameters**

- Maximum temperature **°C**
- Minimum temperature **°C**
- % Relative humidity
- Surface pressure kP

**Output parameter**

- Wind Speed in m/s

**Fig- 2: Measured input and output parameters for training the ML model**

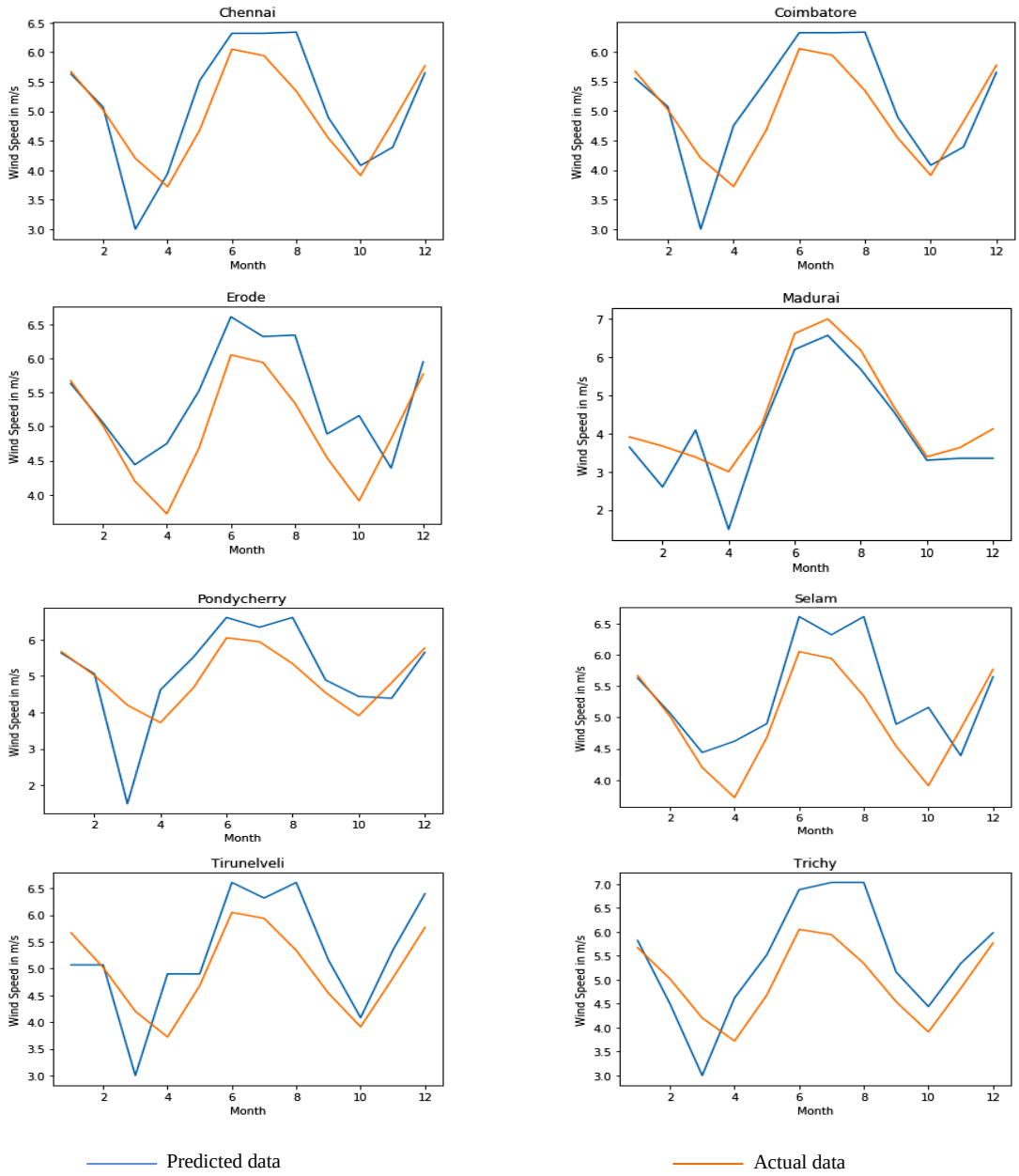



**Fig- 3: Predicted wind speed of the ML model in m/s and NASA data for selected cities in Tamil Nadu**

**Table- 1: Performance metrics of the ML model for selected cities in Tamil Nadu**

| Location | Geometric information | | Performance Metrics | |
|---|---|---|---|---|
| | Latitude N | Longitude E | $R^2$ | MSE |
| Tirunelveli | 8.71 | 77.76 | 0.8056 | 1.0453 |
| Coimbatore | 11.01 | 76.95 | 0.6302 | 0.9438 |
| Chennai | 13.08 | 80.27 | 0.7754 | 1.0279 |
| Cuddalore | 11.74 | 79.77 | 0.6020 | 0.9135 |
| Dindugul | 10.36 | 77.98 | 0.7508 | 0.8916 |
| Madurai | 9.93 | 78.11 | 0.7731 | 0.3848 |
| Pondycherry | 11.94 | 79.80 | 0.6096 | 0.9318 |
| Tutucorin | 8.76 | 78.13 | 0.8742 | 1.2009 |

**Table- 2: Predicted monthly wind speed in m/s for Tamil Nadu cities**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chennai | 5.77 | 5.07 | 5.32 | 4.62 | 4.9 | 6.61 | 5.78 | 5.78 | 4.89 | 4.47 | 4.47 | 5.95 | 5.30 |
| Coimbatore | 4.23 | 4.23 | 4.21 | 4.72 | 3.67 | 6.08 | 5.78 | 1.61 | 1.61 | 1.61 | 1.62 | 1.62 | 3.42 |
| Cuddalore | 5.77 | 4.94 | 4.5 | 4.75 | 5.8 | 6.61 | 6.32 | 5.78 | 4.89 | 4.47 | 5.98 | 6.62 | 5.54 |
| Dindigul | 5.65 | 2.6 | 3.67 | 1.49 | 4.21 | 6.36 | 6.57 | 5.68 | 4.25 | 3.58 | 3.58 | 3.58 | 4.27 |
| Erode | 4.73 | 4.44 | 4.44 | 4.44 | 4.21 | 6.44 | 6.44 | 6.18 | 4.25 | 3.58 | 4.53 | 5.08 | 4.90 |
| Madurai | 5.82 | 5.07 | 1.49 | 4.62 | 4.9 | 6.61 | 6.32 | 6.61 | 4.89 | 5.16 | 4.39 | 5.65 | 5.13 |
| Pondycherry | 5.77 | 4.94 | 4.5 | 4.75 | 5.8 | 6.61 | 6.32 | 5.78 | 4.89 | 4.47 | 5.98 | 6.62 | 5.54 |
| Salem | 3.67 | 3.38 | 3.38 | 3.37 | 1.21 | 1.21 | 7.15 | 1.21 | 1.21 | 3.39 | 3.63 | 3.93 | 3.06 |
| Thanjavur | 5.77 | 4.5 | 5.06 | 5.06 | 6.61 | 4.9 | 7.14 | 6.34 | 4.89 | 4.47 | 5.34 | 5.65 | 5.48 |
| Tirunelveli | 5.82 | 5.06 | 3.94 | 3.58 | 6.15 | 7.82 | 7.89 | 7.29 | 6.35 | 4.61 | 4.39 | 5.65 | 5.71 |
| Trichy | 4.73 | 4.44 | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 | 1.61 | 1.61 | 2.11 |
| Tuticorin | 6.94 | 5.96 | 4.55 | 4.21 | 7.07 | 8.53 | 8.33 | 7.73 | 7.03 | 5.26 | 5.34 | 6.78 | 6.48 |

## IV. CONCLUSION

Wind energy is one of the cleanest sources of renewable energy. Wind speed prediction plays an important role in efficient and proper utilization of wind power. The wind speed was predicted for 10 Tamil Nadu cities using decision tree regression machine learning model. The machine learning model is trained using measured wind speed data for six cities of India collected from IMD, Pune. The machine learning model based on decision tree regression algorithm is good in prediction with better performance metrics of MSE = 03 to 1.2 m/s and $R^2$ =0.87.

## REFERENCES


1. Wen-YeauChang , "A literature review of wind forecastingMethods" Journal of Power and Energy Engineering , volume 2 , pages 161-168 , 2014.
2. Saurabh S. Soman,HamidrezaZareipour , Om Malik, Life Fellow, Paras Mandal , "A review of wind power and wind speed forecasting methods with different time horizons" North American power symposium (NAPS) , 2010.
3. Rahul Sharma, Diksha Singh ,"A review of wind power and wind speed forecasting"Journal of Engineering Research and Application , volume 8 , pp 01-09 , 2018.
4. ZhenhaiGuo , Yao Dong , Jianzhou Wang , Haiyan Lu , "The forecasting procedure for long-term wind speed in the zhangye area" Research Article , volume 2010 , pages 17 , 2010.
5. Ivan Marović , Ivana Susanj , NevenkaOžanić , "Development of ANN Model for Wind Speed Prediction as a Support for Early Warning System" volume 2017 , 10 pages , 2017.
6. Ramesh Babu ,Arulmozhivarman , "Forecasting of Wind Speed using Artificial Neural Networks" 2014 .
7. IreneSchicker , PetrinaPapazek , alexander Kann , Yong Wang "Short-range wind speed predictions for complex terrain using an interval-artificial neural network" volume 125 , Pages 199-206 , 2017.
8. UmmuhanBasarnFilik ,TansuFilik ,"Wind speed prediction using artificial neural networks based on multiple local measurements in Eskisehir"volume 107 , Pages 264-269 , 2017.
9. B. Deepa Lakshmi ,K. Sujatha ,"Artificial Neural Networks for Wind Speed Prediction" , pp. 179-185, 2016.
10. Cabral Lima, Valk Luiz de Oliveira Castellani, Jos Francisco Moreira Pessanha , Adriana Soares, "A Model to Forecast Wind Speed through SingularSpectrum Analysis and Artificial Neural Networks"2017.
11. Salisu Muhammad Lawan, Wan Azlan Wan Zainal Abidin , U. Abubakar,"Wind Speed Prediction in Non-Monitored Areas Based on Topographic Radial Basis Neural Network (T-RBNN)" IOP Conf , 2018 .
12. Jian Jiao,"A hybrid forecasting method for wind speed"MATEweb of conference
13. WenyuZhang ,ZhongyueSu , Hongli Zhang , Yanru Zhao , Zhiyuan Zhao , "Hybrid wind speed forecasting model study based on SSA and intelligent
14. *Osamah Basheer Shukur, Muhammad HisyamLee ,* "Daily Wind Speed Forecasting Through Hybrid AR-ANN and AR-KF Models", volume 72 , 2014.
15. Moniki Ferreira , Alexandre Santos , Paulo Lucio , "Short-term forecast of wind speed through mathematical models" Volume5 , pp. 1172-1184, 2019.
16. Pablo Rozas-Larraondo, CSIRO Black Mountain, Bldg. 5, Clunies Ross St., Acton ,"A Method for Wind Speed Forecasting in Airports Based on Nonparametric Regression", 2014.
17. MakarandA.Kulkarni , Sunil Patil , G.V.Rama , P.N.Sen , "Wind speed prediction using statistical regression and neural network" Journal of Earth System Science , volume 117 , pp 457 – 463 , 2008.
18. Bhuiyan MdAbul Ehsan ,Fatema Begum , Sheikh Jawad Ilham , Raihan Sayeed Khan , "Advanced wind speed prediction using convective weather variables through machine learning ," Volume1, 2019
19. G. Santamaría-Bon_l, A. Reyes-Ballesteros, C. Gershensona, "Wind Speed Forecasting For Wind Farms: A Method Based on Support Vector Regression", Volume 85, Pages 790-809, 2015