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Artificial Neural Networks for Wind Speed Prediction

B. Deepa Lakshmi[1] **and K. Sujatha**[2]

ABSTRACT

Wind energy has become a main challenge of conventional relic fuel energy, chiefly with the flourishing operation of multi-megawatt sized wind turbines. Though, wind with sensible speed is not sufficiently sustainable all over to construct an inexpensive wind farm. The probable site has to be systematically investigated at least with respect to wind speed profile and air density. Modelling and forecast of wind speed are indispensable rudiments in the setting and sizing of wind power applications. In this study, the sketch of wind speed in Mediterrean Sea of Turkey is modelled using artificial neural network (ANN). The aim of this project work is to show that a feed forward neural network can symbolize a practical tool to cautiously monitor the wind speed output. Simulation results can be reported, showing that the estimated wind speed values can be in good concurrence with the investigational values.

Keywords: Wind speed estimation, Artificial neural network, Generalized Regression neural networks and Back Propagation Algorithm

1. INTRODUCTION

Renewable energy has been considered as one of the strong contenders to improve plight of 2 billion people who are not having access to modern forms of energy. At the same time, at least another half a billion people living in the regions where the population is growing most rapidly, have limited or unreliable access to energy. Wind, as an energy resource has gained significant focus around the world. The power of wind is generally regarded as one of the very important sources of renewable, inexhaustible and clean energy. Wind power is economically competitive and provides a plethora of benefits to the environment. These advantages have made wind power the fastest growing power generation sector in the world with a global cumulative installed capacity increase from 93 GW in 2007 to 194 GW in 2010.

With the fast growth of wind power generation and the increasing integration of wind power into energy systems, effective techniques and methods of wind speed prediction are becoming more and more important and immediately needed for the characterization and prediction of wind resource as well as for the integration of wind power into energy systems. However, this absolutely free energy source is not adequately available everywhere to build an economical wind farm. The potential site has to be thoroughly investigated at least with respect to wind speed profile and air density. Prediction of wind speed at the surface or near the surface is essential in many areas of science and technology, e.g. Wind energy generation, aviation, space vehicle launching, weather forecasting and agro-meteorology. The prediction of wind speed to a desired level of accuracy using least number of input parameters is always appreciated [1]. In order to achieve the highest possible prediction accuracy, the methods should consider appropriate parameters and data that may indicate future trends.

Different research works have been proposed to develop predicting models. Some good reviews on wind speed prediction and power generation could be found in the literature. The approaches found in the literature

[1] Research Scholar, Dr. M.G.R. Educational and Research Institute, Chennai, India.

[2] Professor, Dept. of EEE, Center for Electronics, Automation and Industrial Research (CEAIR), Dr. M. G.R. Educational and Research Institute, Chennai, India.

include many physical methods, statistical methods, hybrid physicalstatistical models, artificial intelligence and some other new methods. Physical methods, such as Numerical Weather Forecast (NWF) and mesoscale models usually provide the satisfactory forecast precision by combining multiple physical considerations. Statistical methods, such as autoregressive integrated moving average models, make forecasts by finding the relationship of the observed wind speed time series. Several studies have emerged which estimate and predict the power produced by wind turbines. In the literature, artificial intelligence techniques such as neural networks, fuzzy logic, etc. are found to be more accurate as compared to traditional statistical models. Often, both physical and statistical models are utilized together, where NWF results are usually regarded as input variables, together with historical data, to train the system on the local conditions according to statistical theories.

Recently, some new methods based on artificial intelligence techniques have been developed, including the ANN of multi-layer perceptrons, radial basis function, recurrent neural networks and fuzzy logic. Artificial Intelligence approaches usually use artificial neural networks (ANN) where the processing of information in the network is carried out through calculations which have been internally determined from a training period of available data [2]. Researches may need to prepare an inventory on the availability of wind energy of the area where wind speed data are not available. For this type of situation, it seems useful to predict the wind energy potential using the ANN method. It is very important to know the statistical characteristics, persistence, availability, diurnal variation and prediction of wind speed. The values of wind power distributions are needed for site selection, performance prediction and planning of wind turbines. Moreover, prediction of wind speed is needed for any regional inventory wind energy studies in advance. In the present work, the ANN method is applied to predict the wind speed for Mersin and Silifke stations in Mediterranean Sea of Turkey using atmospheric pressure, temperature and relative humidity.

2. METHODS FOR FORECASTING THE WIND SPEED

The main conventional techniques that are currently available and considered as industry practices are the Numerical Weather Prediction (NWP), Persistence and the Statistical and Artificial Neural Networks (ANN) methods [3].

2.1. Numerical Weather Prediction Method

This meteorological-based technique uses as inputs with the current weather conditions into a 4 dimensional (longitude, latitude, elevation and time) grid model of the location of study and applies conservation equations (mass, momentum, etc.) at different places to predict changes in the wind. NWP models are originally designed to perform forecasting for large area weather patterns over many countries and for long time scales ranging from several hours to months ahead. Since the NWP models mimic the place of interest, any changes in the real system would require the remodeling of the NWP models in order to produce accurate results. The NWP method may be costly and time consuming but it provides more accurate results for forecasting.

2.2. Persistence Method

This model works on the basis that there is a high correlation between the wind speed in the immediate future and the current wind speed. That indicates the wind speed at time; t is the same at the time, $t + x$ in the future. As expected, the accuracy of this model degrades rapidly with increasing prediction lead time. However, it tends to be more robust than the NWP method in this regard.

2.3. Statistical and Neural Network methods

The statistical and neural network methods are projected for forecasting time steps ranging from minutes to one hour. The reason for these methods' success at these time steps is that they both use the current wind speed at the location of interest as one of the inputs into the system. The main difference between the statistical and neural networks method lies in the time span of the data used in the models' development. While the statistical method uses auto recursive mathematical algorithms to find the difference between the predicted and actual values in the immediate past to tune model parameters. The neural networks method looks for patterns between input data and the output wind speed over a long period of time. One of the disadvantages of these techniques is that their accuracy tends to degrade with increasing lead time; they begin to produce poor results for forecasts over 5 hours in advance [6].

3. INTELLIGENT ALGORITHM FOR WIND SPEED ESTIMATION

Artificial neural networks are a network system which is built by simulating the learning behavior of human being. The fundamental processing elements are the neurons, which are placed in successive layers with three components: the input layer, the hidden layer and the output layer [7]. The data enters the network from the input layer to the output layer through the hidden layer. Neural networks are useful when it is necessary to simulate the behavior of systems characterized by noisy and incomplete data. Neural networks learn by example and they cannot be programmed to perform a specific task [5]. In the present work, artificial neural network methodology has been applied for regional wind speed estimation. A feed forward neural network with Back Propagation algorithm is implemented using MATLAB toolbox.

The input variables for the developed neural network have been selected as monthly average relative humidity, monthly average atmospheric pressure and monthly average atmospheric temperature. The output variable is the monthly average wind speed of the considered stations. Monthly meteorological variables collected by the Turkish State Meteorological Service at two measuring stations, located in Mersin and Silifke districts are used. All the data have been collected for a period from January 1975 to December 2006. Locations of the measuring stations located between 34.36" and 36.48" north latitude in the eastern Mediterranean region of Turkey. Altitudes of meteorological stations of Mersin and Silifke are 3 m above the sea level.

The block diagram given in Figure 2 shows the procedure for estimating the wind speed. Data can be collected from the Meteorological department for training and testing. The data, including all the Meteorological parameters is now sent for normalization. The training data is used to train the ANN. Once the network is trained, the architecture of ANN is finalized. Now the proposed ANN is said to estimate the wind speed. Tables 1, 2, 3 and 4 represent mean monthly variation of Meteorological parameters. Table 1. Represents the Atmospheric temperature of Mersin and Silifke station of Turkey. Table 2. Represents the wind speed of Mersin and Silifke station of Turkey. Table 3. Indicates the atmospheric pressure of Mersin and Silifke station of Turkey. Table 4. Humidity of the two Mersin and Silifke station of Turkey.

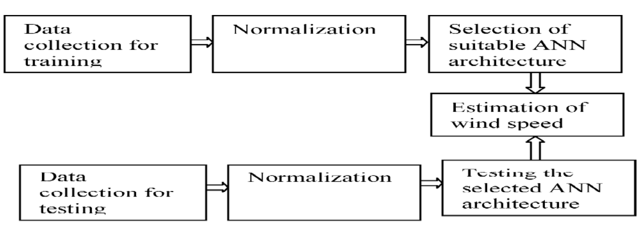


Figure 1: Block diagram for estimating wind speed.

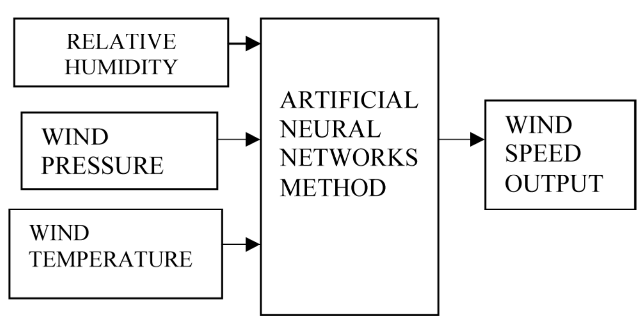


Figure 2: Methodology for Wind Speed Estimation

Table 1
Mean monthly variation of temperature

Month of the year (1975-2006)	*Atmospheric Temperature(°c)*	
	Mersin station	Silifke Station
Jan	10	10
Feb	11	11
Mar	13	13
Apr	17	17
May	21	21
Jun	25	25
Jul	28	28
Aug	28	28
Sep	25	25
Oct	21	21
Nov	15	15
Dec	11	11

Table 2
Mean monthly variation of wind speed.

Month of the year (1975-2006)	*Wind Speed(m/s)*	
	Mersin station	Silifke Station
Jan	2.0	3.1
Feb	2.0	3.1
Mar	2.1	2.6
Apr	2.3	2.1
May	2.4	1.7
Jun	2.7	1.7
Jul	2.7	1.8
Aug	2.7	1.9
Sep	2.4	2.2
Oct	2.0	2.5
Nov	1.7	2.7
Dec	1.9	2.8

Table 3
Mean monthly variation of pressure

Month of the year (1975-2006)	*Atmospheric Pressure (hPa)*	
	Mersin station	Silifke Station
Jan	1018	1017
Feb	1016	1015
Mar	1014	1013
Apr	1012	1011
May	1011	1010
Jun	1008	1007
Jul	1005	1004
Aug	1006	1005
Sep	1010	1009
Oct	1014	1013
Nov	1017	1016
Dec	1018	1017

Table 4
Mean monthly variation of humidity

Month of the year (1975-2006)	*Relative humidity (%)* Mersin station	Silifke Station
Jan	68	59
Feb	68	59
Mar	70	60
Apr	71	64
May	73	66
Jun	75	66
Jul	76	66
Aug	74	66
Sep	68	60
Oct	63	58
Nov	64	59
Dec	68	60

4. RESULTS AND DISCUSSION

4.1. Simulation Results for Wind Speed Estimation Using Feed Forward Neural Network

In this research, wind speed will be predicted using the feed forward neural network. First, Input data is selected based on air pressure, temperature, humidity and time. It extended and considered from these categories. As the result, In addition to the selected inputs, minimum, maximum and average values of temperature, humidity, and air pressure are also added to the data for better performance of the wind speed prediction.

Second, the form of training (learning) and test (prediction) data is decided because it has the characteristics, which the accuracy depends on. So, the Validation data is prepared in training data. Validation data sets up in order to improve a prediction result more. In training, total error function is changed by whole training data. But the result network is decided by the best validation data. This has improved the result of prediction. Next, the structure of ANN is decided. As wind speed is changing continuously, we are using another form of ANN, known as Recurrent Back Propagation (RBP) [4].

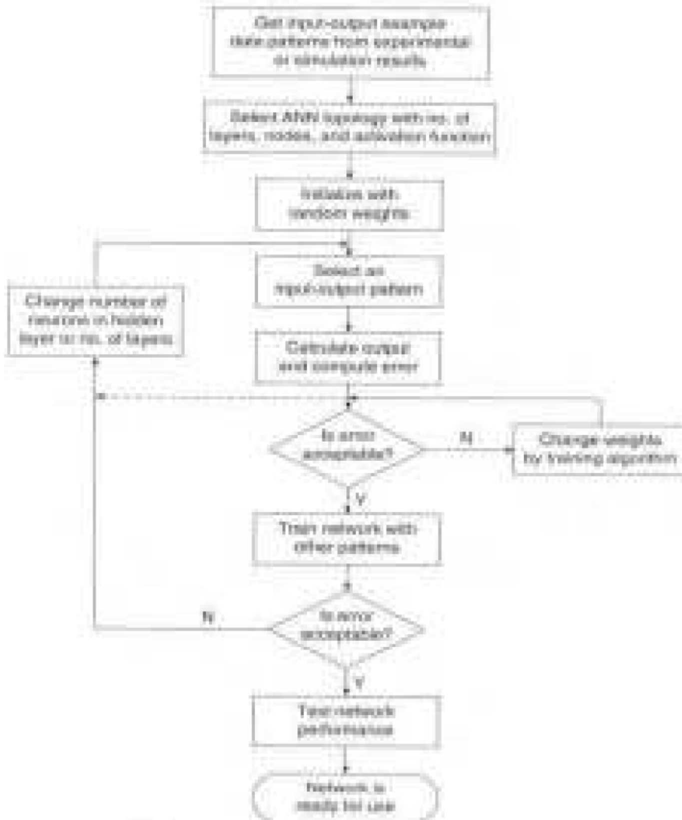
4.2. Selection of the ANN model for the prediction of wind speed

This section illustrates how the two-hidden layers neural network can be used for predicting the wind speed of two stations located in Mediterranean Sea. The schematic diagram of the developed neural network trained with BPA is shown in Figure 3. For this application, the hidden layers are the logarithmic sigmoid function and the output layer is the linear activation function in the neural network architecture.

The network possesses three input neurons, representing, the monthly average relative humidity, the monthly average atmospheric temperature and the monthly average atmospheric pressure. Finally, the network has one output layer with one neuron, representing the total wind speed output of the considered stations. The learning algorithm considered here in is the back propagation. The accuracy of the trained network is now evaluated. The predicted wind speed output values are compared with the measured values for Mersin and Silifke.

5. PROPOSED FEED FORWARD ANN ARCHITECTURE FOR WIND SPEED ESTIMATION

Instead of using the feed forward neural network with two hidden layers, we are proposed to use the feed forward neural network with only one hidden layer for this project. This will reduce the computational



$$SSE = \sum_{p=1}^{P} \sum_{q=1}^{Q} [D(q) - a(q)]^2 \ldots (1),\ P = \text{Patterns},\ Q = \text{output neurons}$$

$$MSE = 1/Q\ [SSE]$$

Figure 3: Flowchart for BPA to train the neural network architecture.

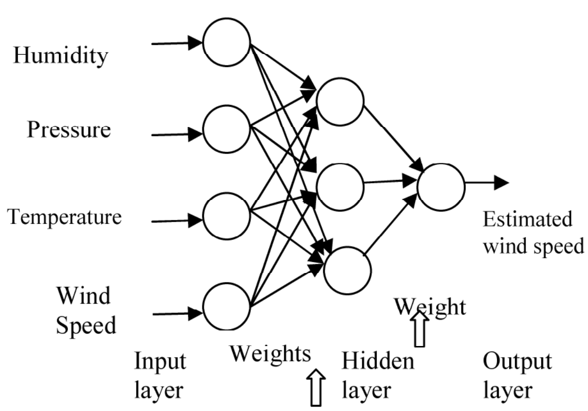


Figure 4: The block diagram of the proposed ANN architecture

complexity of the neural network. The proposed architecture developed for this project is shown below in Figure 4.

6. RESULTS AND DISCUSSION

Modelling and Prediction of Wind speed are the essential requisites of Wind Power Applications. In order to achieve effective wind power generation, several techniques are available by considering appropriate wind parameters.

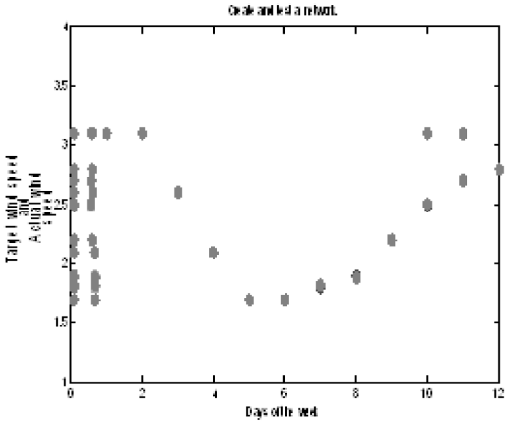


Figure 5: Training with GRNN

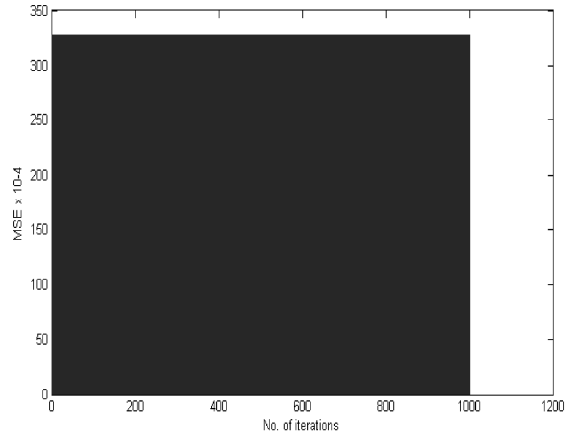


Figure 6: Training with BPA

7. CONCLUSION

The prediction of wind energy production can be very useful for energy planners and wind farm owners. Moreover, prediction of wind speed is needed for any regional inventory wind energy studies in advance. In this sense, the establishment of a model for wind speed correlation in a region is of great importance in the management of wind energy resources for power generation, as well as in other research fields related to energy conservation. In this study, assessments of the wind characteristics in Mediterranean Sea of Turkey for the years 1975-2006 were investigated. The conclusion of the conducted analysis is that the estimated wind speed values. In particular, by using proper experimental data a suitable neural network architecture has been found. The results show that ANN is an efficient tool for estimating wind speed values.

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