AN INTELLIGENT HYBRID NEURAL NETWORK MODEL IN RENEWABLE ENERGY SYSTEMS

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Abstract
This paper presents a hybrid neural network approach to predict wind speed automatically in renewable energy systems. Wind energy is one of the renewable energy systems with lowest cost of production of electricity with largest resources available. By the reason of the fluctuation and volatility in wind, the wind speed prediction provides the challenges in the stability of renewable energy system. The aim is to compute predicted wind speed based on hybrid model which integrates a Self Organizing Map (SOM) and Back propagation (BP) neural network. The simulation result shows that the proposed approach provides significant result of wind speed prediction with less error rates. Due to seasonality, single computing models have some disadvantages such as fluctuality, randomness and unstable. These disadvantages are rectified by using hybrid computing neural network models. Wind speed prediction is an important in the field of wind power plants.

Keywords:
Back Propagation, Hybrid Model, Wind Speed Prediction, SOM, Neural Network

1. INTRODUCTION

The wind energy is an important potential renewable energy source with lowest cost of electricity production. With the accurate wind speed data, the wind farm operator can predict the power output. This is useful for power system planning, scheduling, and storage capacity optimization. Due to the random fluctuation of wind, the prediction results of wind power may change rapidly. Two critical issues in renewable energy are how to make wind energy cost effective and how to integrate wind energy into electricity grids. This increases the importance of the accurate wind speed prediction to assessment of wind energy and site selection of wind farm. To obtain proper and efficient wind power utilization, the wind speed prediction plays an important role in forecasting. To increase the accuracy of wind speed prediction, there are many approaches proposed, including physical method like numerical weather prediction, statistical method like ARMA model [1], the spatial correlation model and the artificial intelligence method, and so on.

Much work has been developing models in predicting of wind speed from historical data (Fonte P M et al 2005, Goncalo Xufre et al 2006, Bei chen et al 2009, LI Xingpei et al 2009, Umit Kemalttin Terzi et al 2011) [2]-[6].According to the literature review wind speed prediction is needed to be improving accuracy [7].So hybrid neural network model is proposed for predicting wind speed in renewable energy systems. The single neural network model may lead to problems, Firstly mismatch between input and output due to noise variation within the input. Secondly, it is difficult to get inner relation between input and output variable.

The back propagation network (BPN) is one of the most popular methods for training multi layer perceptron networks. The training process of BPN for prediction problem consists of two tasks, the first one is the selection of the appropriate architecture for the problem, and the second is the adjustment of connection weights of the network. The input layer is set of numerical inputs. The inputs are then multiplied by weights and processed by individual processing units in second layer. The BP algorithm has two phases. In the first phase the inputs are given and propagated through to compute output. The output is compared with desired value, to obtain the error. The second phase involves backward pass through network during which error signal is passed to each unit in network and appropriate weight changes calculated. The gradient descent rule is adopted for updating the weights of neural network.

The Self Organizing Map (SOM) is known as an effective technique for the clustering of multi dimensional data. The SOM is a powerful tool for knowledge and visualization of high dimensional data. It is an unsupervised training method [8]. The objective of SOM is to maximize the degree of similarity of patterns within a cluster, minimize the similarity of patterns belonging to different clusters, and then to present the results in a lower dimensional space. The SOM algorithm is applied to unsupervised learning, where the target values are not specified. SOM is a topological structure made up of cluster units. The training algorithm builds in competition among neurons. Learning is restricted to neurons that are winners of the competition relating to the closeness of weights to the inputs.

Wind speed prediction is necessary as wind is an intermittent, randomness and nonlinear source of energy. Wind speed prediction from past observations has many applications in fields such as Target tracking, Rocket launch, Ship Navigation ,Missile guidance, Satellite launch and Electrical power demand forecasting etc[9]. There are different types of neural network models available for wind speed prediction. Mainly wind speed forecasting models are multi- layer perceptron, Back Propagation Network (BPN), Radial Basis Function Network, Recurrent Neural Network and Hybrid Neural Network. The wind speed prediction is needs to be improving accuracy. The single NN model may lead some problems, Firstly mismatch between input and output due to noise variation within the input. Secondly, it is difficult to get inner relation between input and output variable.

In this paper, proposed hybrid neural network model which is the combination of SOM and BPN to understand a much better prediction system. SOM are unsupervised neural networks that build up an adequate representation of a high dimensional input space by means of a learning process into a lower dimensionality. SOM is used for clustering the input data and back propagation neural network is used for prediction. This

paper predicts wind speed using hybrid neural network model which integrates SOM and BPN for renewable energy systems.

2. BACK PROPAGATION NEURAL NETWORK

In 1986, Rumel hart, R O Williams and Hinton introduced Back Propagation Network. Back propagation algorithm (BPA) is a systematic method [10] for training used by feed forward neural network with the gradient descent rule. BPN provides an efficient method for updating the weights with differentiable activation functions. The aim is to train the network to achieve a balance between ability to respond correctly to the input pattern.

Back propagation network consist of 3 layers an input layer, hidden and output layer. In output and hidden unit have bias is always 1.The input layer is connected to hidden and hidden layer is to output layer by weights [11] - [12].A feed forward neural network has layers of processing elements which make independent computations on data that it receives and passes the results to another layer and finally, determine the output from the network. Each processing element makes its computation based upon a weighted sum of its inputs. The weights are modified in each training set using BPN so as to reduce the mean squared error [MSE] between the network's prediction and the actual target value. These modifications are made in the reverse direction, from the output layer, through each hidden layer down to the first hidden layer, till the terminating condition is reached. In the ANN models using back propagation models, the predicted wind speed is dependent on Error tolerance, learning parameter, momentum factor, Number of epochs, Number of input layers, and Number of neurons in each layer. The selections of above parameters are important to improve the performance of system.

3. SELF ORGANIZING MAPS

Self-organizing map is a data visualization technique invented by Prof. Teuvo Kohonen in 1972. The SOM is a popular tool that maps high dimensional space into a small number of dimensions by placing similar elements close together, forming clusters [13]. When the learning is based only upon the input data and is independent of desired output data, no error is calculated during the training of the network. This network is learning in unsupervised method.

The objective of SOM is to maximize the degree of similarity of patterns within a cluster, minimize the similarity of patterns belonging to different clusters, and then present the results in a lower dimensional space. Such self organizing networks can be used for compressing, clustering, quantizing, classifying, or mapping input data. Here we are using SOM as clustering of input data. The back propagation neural networks have more than two layers (at least one hidden layer), and the Kohonen SOM networks have only two layers (no hidden layers).It has two layers i.e. input and output layer. The output layer act as clustering unit. When the network has adapted, the output layer processing elements represent clusters of the input pattern vectors.

4. HYBRID NEURAL NETWORK MODEL

The proposed hybrid neural network model is a combination of self organizing map and back propagation neural network. This is to realize for much better prediction system. SOM can be used for classification of data before the starting of the prediction. Back propagation neural network is used for predictor. The objective of hybrid model is to benefit from the advantages of each model and to obtain globally optimal forecasting performance. The hybrid neural network model has better properties than single model, it is able to interpolate and extrapolate much more accurately is easier to analyze and interpret the data. Hybrid neural network model is also used to reduce the errors. This model reject noise input and provides better prediction system for power generation applications.
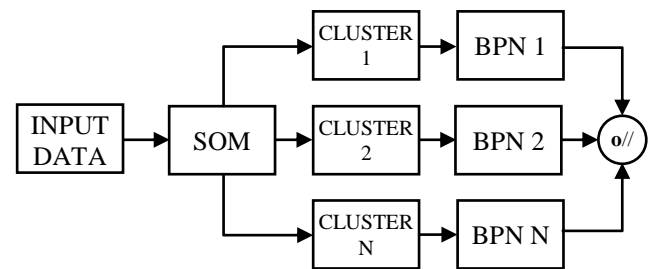
4.1 ARCHITECTURE

Fig.1. Hybrid NN (SOM_ BPN) Architecture

The hybrid model architecture includes a combination of self organizing map and back propagation neural network. The non stationary character also indicates that the dynamic behaviors during different periods are dissimilar, which will results in the variations of dependency between input and output vectors. Therefore, many single forecasting models always lead to the following problems: initially, there is a mismatch between input and output spaces because of noise variations within input space, and secondly, it is difficult to get the inner relation between input and output variables. To improve the accuracy of forecasting, this hybrid model has been proposed.

The architecture of hybrid neural network model is shown in Fig.1. Initially the partition of all the input data into similar subgroups and then use back propagation neural network model to produce forecasting results on all partitioned groups separately.

4.2 DATA USED FOR STUDY

The wind data and related parameters are collected at wind farm at periodic time intervals; every 10s.Our work involves the utilization of four parameters acquired from wind farm. The following parameters are used for develop the proposed hybrid neural network model.

Table.1. Input Parameters

Temperature	Degree. C
Humidity	% RH
Wind gust	m/s
Wind speed	m/s

The various parameters are that are considered as input to the model are shown in Table.1. The data set used for development of wind speed prediction was divided into two independent subsets: training data set and test data set. The training data set was used to develop models of wind speed prediction, while test data set was used to validate performance of models from training data set. Here one month data is used for developing the hybrid neural network model.70 % data is used training data set and 30 % data is used for testing data. This paper predicts wind speed one month in advance.

4.3 METHODOLOGY

Step 1

Data Collection: The wind data and related parameter values are collected from the wind farms. Here temperature, humidity, wind gust and past wind speed have been used as an input and predicted wind speed as an output to train an neural network in prediction applications.

Step 2

Data Normalization: The input data are normalized, in the range of [0, 1] .The normalization is to eliminate the situation where some variables are given values with great impact on clustering than others.

Data Normalized = Data(actual) – Data (min)/Data(max) – Data(min)

Step 3

Clustering SOM: Set up parameter which includes learning rate, epoch and dimensions and so forth. The training can be learned from the past data after normalization. Once the training is stopped, SOM partitioned the input data into clusters. The cluster outputs are generated. The wide pattern data is converted to lower pattern by placing similar pattern closed together to form clusters. Let number of clusters is 'K'. Then each clusters have each BPN stages i.e. 'K' BPN stages

Step 4

Training/Testing BPA: Let the number of clusters be 'K'. So there are 'K' BPN stage, each receives inputs. Each BPN can be trained from past input data. Apply testing data to evaluate the performance of the trained network.

Step 5

Merge SOM and BPA: The product of self organizing map output and back propagation neural network output are computed.

Step 6

Data denormalization: The output is carried out after de-normalization. Finally, the wind speed is predicted which is the output of the proposed hybrid neural network model. De normalization is the reverse of the normalization procedure. The network typically produces output values in a limited range defined by the logistic or other activation function. These values bear little resemblance to the real world values of the application environment, and steps should be taken to de normalize the data back to the original data domain. After de-normalization of data it will get the predicted wind speed.

5. EXPERIMENTAL RESULTS

The experiments were carried out to test performance of hybrid NN model in comparison with that of back propagation neural network. SOM divides the input data into clusters, in order to improve the accuracy of forecasting. Each cluster has BPA stages. The product of each BPN with SOM output is found to produce the predicted output. The RMSE value of hybrid computing model is less than conventional BP neural network. ANN learns these data, and simulates wind speed in an advance. All the simulation results were generated using the MATLAB (version7.11).

Table.2. Parameter Selection

Selection of parameters
Learning rate=0.25
Momentum factor=0.9
No. of neuron in hidden layer=7
Inputs=3
Epochs=2000
Trainfn=traingdm

Table.2 shows the parameter selection for the implementation of wind speed prediction in wind farms. The performance can be improved depends on the selection of parameters.
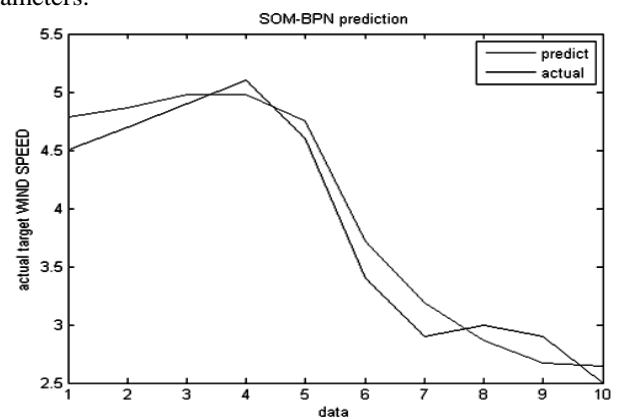

Fig.2. Actual/Predicted output (wind speed) waveform

The Fig.2 shows the comparison between actual and predicted wind speed. The prediction error is noted. The RMSE value of back propagation neural network is 0.233. The RMSE value of hybrid neural network is 0.15.The performance of hybrid neural network model is better than back propagation neural network. The hybrid model was an effective, accurate than the other models.

Table.3. Comparison of models

Models	MSE (m/s)	Correlation coefficient, R	Performance of error
BPN	0.233	0.996	0.0298
Hybrid NN model	0.15	0.99865	0.00149

The Table.3 shows the comparison between conventional and hybrid model. The prediction error is noted. The performance of hybrid model is better than back propagation neural network. The correlation coefficient, R values denoting discrepancy between actual and predicted wind speed. Ideal case the value of R is about 1.If the value of R is near to one i.e. best matching is obtained. More higher is R value, more adequate is the network. But the best compromise between lower MSE, lower performance of error and higher R is achieved.

6. CONCLUSION

The suggested hybrid model of neural network can be used in prediction of wind speed in renewable energy systems. The hybrid approach presents best performance as compared to other neural network models. Each network is trained and tested using wind data. An experimental result shows that hybrid model outperforms the best agreement with lower error rates. Future studies are expected to present improve hybrid neural network model with superior performance.

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