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An Intelligent Computing Model for Wind Speed Prediction in Renewable Energy Systems

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Abstract

This paper presents an intelligent computing model for wind speed prediction, which uses back propagation algorithm. Wind energy is inexhaustible unlimited clean energy. Wind power in the world has been rapidly growing. The prediction of wind speed has an important role in wind energy. The back-propagation algorithm (BPA) is used in the majority of neural networks application. The objective of this paper is to compute predicted output (wind speed) based on BP algorithm. The results are obtained using back propagation algorithm by training and testing methodologies. Simulation results show the performance of ANN for predicting wind speed in renewable energy systems

Keywords: learning rate; momentum factor; back propagation; wind speed prediction; neural networks.

1. Introduction

The wind energy is the important potential renewable energy resource currently available. With the accurate wind speed data, the power producer can predict the power output .This is useful for power system planning and scheduling, and storage capacity optimization. Due to the random fluctuation characteristics of wind, the prediction results of wind power may change rapidly. This increases the importance of the accurate wind speed prediction. 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 the physical method, the conventional statistical method like ARMA model, the spatial correlation model and the artificial intelligence method, and so on. Artificial neural networks (ANN) simulate the human brain in processing information through

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a series of interconnected neurons, and have excellent ability of mapping complex and highly nonlinear input output patterns without the knowledge of the actual model structure .

Wind energy is one of the renewable energy systems with lower cost of electricity production with largest resources available. During recent years, according to global environmental pollutions, a trend towards the sustainable energy and green power sources such as wind energy was largely increased. Wind energy is one of the economic renewable sources and a valuable supplement to conventional energy sources [12].One of the important problems in wide uses of wind power is difficulties of accurate wind speed forecast and it is not able to be stored because of wind is intermittent, randomness, nonlinear nature. An accurate forecast allows grid operators to schedule economically the efficient generation to meet the demand of electrical customers [13].Artificial Neural Network (ANNs) exhibit the properties ,such as: adaptability, capability of learning by examples, and ability to generalize. One of the most used ANN model is the well-known Multi-Layer Perceptron (MLP) .Most of the available training methods for ANNs only focus on the adjustment of connection weights with in a fixed topology.

Multi-layer Perceptrons (MLPs) are used successfully in many applications which includes pattern classification, image processing, prediction etc. The back-propagation (BP) algorithm [1] is one of the most popular methods for training MLP networks. The training process of MLPs 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. More research works has been conducted to overcome these problems.

ANN is a computing methodology which resembles a human biological neuron. There are different types of neural network are available, mainly feed forward networks and feedback neural networks. The feed forward network has no feedback. But the feedback neural network has a feedback. BP network and Radial Basis Function (RBF) network plays a major role in feed forward networks. Recurrent Neural Networks (RNN) and pulsed neural networks are examples of the feedback networks. This paper mainly focused on the feed forward neural network (BPA).

The main advantage of the BPN is that, it can fairly approximate a large class of functions, relatively simple implementation and uses standard method. To be most effective, the momentum parameter and the learning rate coefficients are adjusted. Many optimization methods have been developed to improve the convergence speed of the conventional BP algorithm.

This paper is organized as follows. Section 2 presents needs for the wind speed prediction. Section3 explains back propagation algorithm. Section 4 describes intelligent computing model. Section 5 describes methodology used and Section 6 describes the simulation results. Finally, Section 7 concludes the work that is presented in this paper and suggested some improvements to this paper.

2. Need for wind speed prediction

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. The most important factor influencing wind power generation is the local wind speed. The wind farm operator schedule the wind power availability in advance of the power grid. It improves power transmission schedule and resource allocation and hence improves the reliability of power grid. The forecasting enables an adaptation between demand generations.

A lot of studies have been performed to accurately predict the wind power and local wind speed. Wind speed and power prediction is an essential issue for wind farms maintenance, optimal power flow between power network and wind farms, electricity marketing, power system scheduling, and energy reserves and storages planning and scheduling. Artificial neural network (ANN) [8] is one of the most widely used models in the last decade**.**

3 Back Propagation Algorithm

Back propagation Neural Network is a feed-forward network formed by the non-linear transformation .The BP algorithm has two phases: The first phase (forward propagation) gives input information. From input layer, it calculates the actual output value of each unit layer by layer through hidden layer .If we are not getting the expected output in output layer we go for the second phase. In second phase, we calculate the difference of actual output and expected output recursively layer by layer .And we can adjust the weights based on this difference. The goal of training algorithm is to minimize global error. This algorithm calculates the error and distributes it backward from output to hidden and input nodes. This is done using steepest gradient descent rule.

BP algorithm generally has two major limitations,

3.1 *Low Convergence*

As back propagation network requires adequate study sample, the output error may be small during the network training, but the output error may be very big when the other samples of the network training, at this time, the connection weights must be largely adjusted, and the training samples are set and repeated and circulate to input to learn more times, the process is enough to consume time.

3.2 *Local minimum*

BP algorithm inherited the thinking of the error back-propagation learning algorithm LMS (Least-Mean-Square) that error gradient to the minimum. In the multilayer-network model, error are minimum, this problem not only make the expression of error space to become difficult but also that it cannot gain the global optimal solution because the solution usually remain in the local minimum.

For improving the performance of BP algorithm and to eliminate the limitations, we use add momentum factor and vary the learning rate. The selection of learning rate is of critical importance in finding global minima of error distance .BPA with too small learning rate will make slow progress. Too large learning rate will proceed much faster and produce oscillation between relatively poor solutions. Slow convergence and the continuous instability will be happened, if the parameters are selected improperly. Mean squared error (MSE) is converged after many epochs which were varied with respect to momentum and learning rate. The BPA is modified by adding various parameters to the existing algorithm to increase overall efficiency of algorithm and to increase the speed of convergence.

4. Intelligent Computing Model

An intelligent computing model is made by combining some artificial neurons. First, the input data are selected. Input data depends on air pressure, temperature, humidity, and time. As the result, in addition to the selected inputs, the information is also added for better performance of the wind speed prediction.

Second, the training and test data are decided. In wind speed prediction, it has the characteristic that the accuracy falls. So, validation data is prepared from the training data. Validation data are formed in order to improve the prediction results. In training, total error function is changed with training data. But the result of network is decided from the best validation data. This improves the result of prediction.

(1) *Selection of Input and Output*

The selection of input and output depends on nature of problem. In wind speed prediction temperature, humidity, wind gust and past wind speed have been selected as input and predicted wind speed as an output.

(2) *Selection of Hidden Neuron*

To construct Neural Network architecture, selection of the hidden neuron is very important. Here, a single hidden layer is used. 7 neuron are used this network and uses trial and error method. The hidden layer(s) are providing the network with its ability to generalize. In theory, a neural network with one hidden layer with a sufficient number of hidden neurons is capable of approximating any continuous function.

(3) *Selection of Neural Network Architecture*

For predicting the wind speed, a single hidden layer with 4 inputs, 7 hidden neuron and one output neuron is constructed.

(4) *Learning/Training network*

Initially, we initialize the weights and number of epochs. In this model, weights are calculated using gradient descent rule .The difference between target and actual data is called an error. The error is propagated backwards and weights are adjusted to minimize the prediction errors.

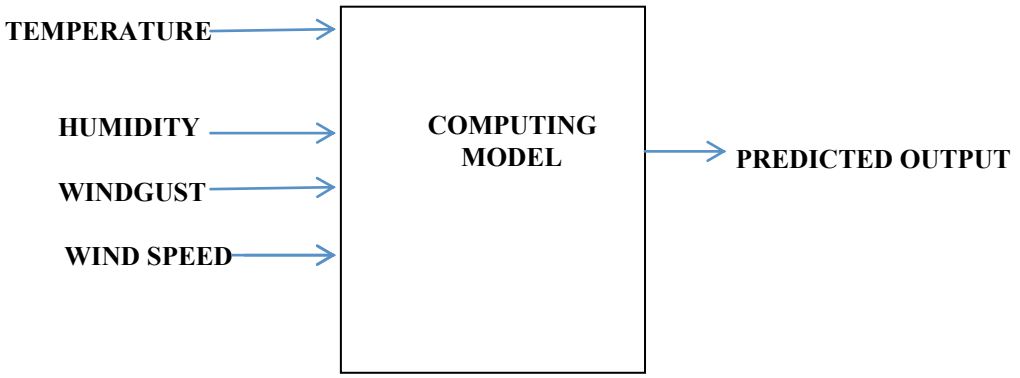

Fig.1.Architecture

5. Methodology

Step 1

Data Collection:- The wind data and related parameter values are collected at wind farm. The detailed information about the previous data is the inputs. Input data depends on air pressure, temperature, humidity, and time. Our work involves the utilization of four different parameters values which are acquired from the wind farm.

Step 2
Data Coding: - we have converted (normalized) data into required form (0 to 1).Normalized data were used
(Data) normalized = [(Data) actual – (Data) min)] / [(Data) max–(Data) min]

Step 3
Training/Learning BPA: - we set up the BPA parameters including input, hidden and output layer , neuron number, learning cycles and so forth. The training can be learned from the past data and recognize a hidden pattern in historical data and they are used forecast future wind speed.

Step 4
Test BPA: - we apply testing data to evaluate the performance of the trained BPA.

Step 5
Predict output (wind speed). Finally, the wind speed is predicted which is the output of the Neural Network.

6. Simulation Results

The wind speed can be predicted using available data. The wind data depends on temperature, humidity, wind gust and wind speed, atmospheric pressure and temperature. Here temperature, humidity, wind gust and past wind speed have been used as input and predicted wind speed as output variables to train an neural network model in power prediction applications. The RMSE value of intelligent back propagation computing model is less than back propagation without momentum. ANN learns these data, and simulates wind speed in an advance.

All the simulation results were generated using the MATLAB (version7.11) neural network toolbox. After simulation of ANN in these situations, it is predicted wind speed in an advance. The RMSE value obtained using intelligent back propagation computing algorithm is 0.231

Figure2 shows the results of actual and predicted output.

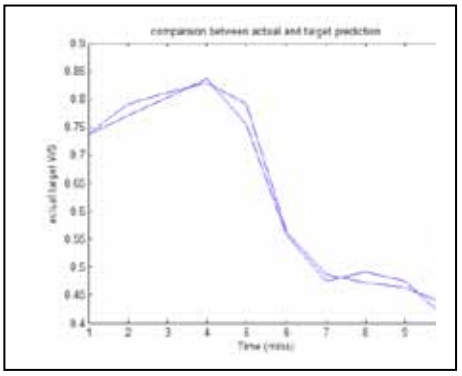

Fig.2. Actual and Predicted wind speed

7 Conclusion

The proposed intelligent back propagation algorithm is more accurate than conventional back propagation algorithm. The graph shows the comparison between actual and predicted wind speed. The prediction error is noted. It shows that, by varying momentum and learning rate, the convergence and training time the process of minimization of error prediction is improved. Further the MSE are minimized by increasing epochs. The selection of parameter is critical importance in finding the global minima of error distance. In future research, we can improve the performance of the network if we are implementing this using DSPIC and Advanced embedded micro controllers.

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