An Adaptive Hybrid Soft Computing Approach for Wind Energy Prediction

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ABSTRACT

The prediction of wind farm output power is considered as an emphatic way to increase the wind energy capacity and improve the safety and economy of the power system. The wind farm output energy depends upon various factors such as wind speed, temperature, etc., which is difficult to be described by some mathematical expression. This paper introduces a method of wind energy prediction for a wind farm of Vietnam based on historical data of wind speed and environment temperature. Wind energy is free, renewable resource, and non-polluting. This paper consists of the hybridization of the ant colony optimization (ACO), particle swarm optimization (PSO) and Adaline Neural Network (ANN) to predict the hourly wind energy. By applying this hybrid technique over the historical data of wind the MAPE determined is 3.08%.

Keywords

Ant colony optimization, Particle swarm optimization, Adaline neural network, hybrid.

1. INTRODUCTION

Wind energy is the most promising energy in the present day world. The assimilation of wind energy has become a contention in the modern power system. The uncontrolled nature of the wind energy is a confrontation to the power system [1]. Wind energy prediction depends upon various factors like temperature, speed, humidity, direction of wind etc. So the methods of wind energy prediction can be divided into different classes that is basing upon the prediction time, the methods of energy prediction are classified into long-term prediction method, mid-term prediction method, short-term prediction method and super short-term prediction method [2,3,4]. Basing on parameters, the methods are classified into wind speed-based prediction method and output power-based prediction method. Basing on prediction models, the methods of energy prediction are classified into physical prediction method, statistic prediction method, and learning method. Statistical approaches use historical data to predict the wind speed on an hourly basis. On the other hand, short term prediction and learning approaches is based on meteorological data. Neural network is a popular learning approach for wind power forecasting.

This paper uses a hybrid technique that takes the advantage of both swarm intelligence and neural network to predict the wind energy. This paper incorporates the hybridization of the ant colony optimization (ACO) which is used for finding the local optimum value from the search space, Particle swarm optimization (PSO) is used for finding the global optimum value from the search space [5]. To improve the convergence rate and processing speed an Adaline Neural Network Algorithm (ANN) has been used. The propose technique is applied on historical data of wind speed and environment temperature which is collected from a wind farm of Vietnam for predicting the wind energy. This paper consists of the following: section 2 contains the literature review of wind energy prediction, section 3 contains the overview of Ant colony optimization, Particle swarm optimization, Adaline neural network, section 4 contains the proposed hybrid model and the result analysis of the model.

2. LITERATURE REVIEW

2.1 Hybrid technique of ant colony and particle swarm optimization

This hybrid technique consists of two meta-heuristic techniques of swarm intelligence known as ant colony optimization (ACO) and particle swarm optimization (PSO) [5]. The hybridization of the two algorithms is used to optimize the parameters of the model for finding a better result. In this paper, the ant colony optimization (ACO) and particle swarm optimization (PSO) techniques are used to forecast the wind power output of Binaloud Wind Farm in Iran. The hybrid technique is applied on the historical weather information which consists of wind speed and ambient temperature for 364 days [6].In this hybrid model, the pheromone trails are updated for each ant for finding solutions by using the ACO technique. PSO gives freedom to the particles for flying in the solution space. Therefore, PSO gives the wider portion of the solution space at each iteration, while ACO has the ability to find a better solution around the search space [5]. So the hybrid technique of both ACO and PSO will provide the advantages of both algorithms. As a result the best solution is obtained for both the algorithms and the MAPE of the proposed model is 3.513%. In this hybrid technique PSO finds its solution from the global search space but it slows its convergence speed towards the solution and takes more iteration for finding the minimum error.

2.2 Hybrid evolutionary adaptive approach to predict electricity prices and wind power

The HEA approach is applied over the historical data of wind from the year 2007 to 2008 in Portugal. This paper provides a new hybrid evolutionary adaptive approach (HEA) for wind power and electricity market prices prediction. The HEA approach is the hybridization of Mutual information, Wavelet transform, Evolutionary particle swarm optimization and ANFIS techniques. In this paper Mutual information is used for avoiding the randomness during the selection of input data from the data set, Wavelet transform is used for decomposing the input data for better result, ANFIS network is used for predicting the decomposed data [7]. Evolutionary particle swarm optimization is used for optimizing the parameters of

ANFIS network and determined mean absolute percentage error is 3.73%.

2.3 Current method and advances in forecasting of wind power generation, Renewable energy

This model consists of genetic algorithm (GA), particle swarm optimization (PSO) and ant colony optimization which comes under evolutionary computational algorithm for forecasting the wind speed [1]. In this model fuzzy is applied on dataset, then the fuzzified data is taken as input for neural network. To optimize the parameters of the neural network particle swarm optimization (PSO) is used and the average mean absolute percentage error is 5.41%.

3. OVERVIEW OF TECHNICAL SURVEY

3.1 Ant Colony Optimization

Ant Colony Optimization was first introduced by Dorigo and Gambardella in the year 1997. Ant Colony Optimization uses artificial stigmergy. This technique is used for solving the problems such as finding good paths through graphs like travelling salesman problem [8]. In this technique the ant tries to find the shortest path between its nest and the food source which is known as the destination.At first the ants are moving randomly by leaving some pheromone trail on the way. If food source is found, then the ant returns to its nest by laying down pheromone trail. If the pheromone is found in more amount, then the other ants follow the same path. The pheromone is a volatile substance, so it is vaporized over time. Hence, the chances are more for the presence of pheromone trail in the shortest path and so the ants try to find the shortest possible path. The ACO technique is based on updating the pheromone trail which gives a good solution.

3.2 Particle swarm optimization (PSO)

Particle swarm optimization (PSO) is one of the meta-heuristic optimization technique of swarm intelligence [5]. It was first introduced by Kennedy and Eberhart (1995). It was first intended for social behaviour of the flocking and schooling of birds and fishes. In PSO, each particle flies in the multidimensional search space and adjusts its position in every step until it reaches an optimum solution. In particle swarm optimization each particle has some fixed distance from the food source and that distance is considered as fitness value of each particle. From that fitness value the particle best (p_{best}) value is calculated. Then all the particles move in the direction of P_{best} particle by changing their velocity and calculate the P_{best} value for each particle. The velocity and the location of the particles are updated after every iteration . From that particle best (p_{best}) and the global best (g_{best}) values are determined.

Algorithm of PSO

Step: 1 Initialize the swarm particle in the search space randomly.

Step: 2 Calculate the fitness value by using objective function and consider it as Pbest.

Step: 3 Update the velocity and the location for each Particle .

Velocity of each particle is updated by using the equation

$$V_t = (w * v_{t-1}) + (c_1 * r_1 * (gb_{t-1} - p_{t-1})) + (c_2 * r_2 * (pb_{t-1^k} - p_{t-1^k})) \quad \text{.......................... (1)}$$

Location of each particle is updated by using the equation

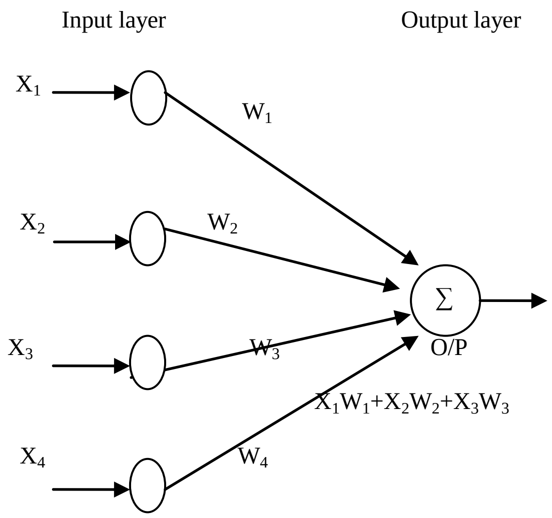
$$P_t = P_{t-1} + V_t \quad \text{........................... (2)}$$

Step:4 Update the Pbest and gbest.

Step:5 Stop if max iteration is reached otherwise repeat from step 2.

3.3 Adaline neural network (ANN)

In computational intelligence Neural networks are the weighted directed graph where the nodes are the neurons and edges are connected in between two neurons in the network [9]. Different types of neural networks are there. Adaline network is a simple two-layer neural network with only input and output layer, having a single output neuron. The number of input layer neurons equals the number of inputs.



[Figure 1 Adaline Neural Network]

The above figure 1 represents the adaline neural network in which the output neuron receives input from all input neurons. The above diagram consists of four neurons that is X_1, X_2, X_3, X_4 in the input layer and the output layer consists of only one neuron.

Output of the input layer is X_1, X_2, X_3, X_4 multiplied with four weights that is W_1,W_2,W_3,W_4 which is taken as input for the output neurons .

Output of the output neuron is $O = \sum_{i=0}^{n} (Xi * Wi)$

.... (3)

Error of the Adaline network will be calculated by using the equation

$$E = (d - o)^2 \quad \text{... (4)}$$

Mean Absolute percentage error is determined by the equation given below .... (5)

3.4. Proposed Hybrid Model

This paper proposed the hybridization approach for wind energy prediction which is based on Particle swarm optimization (PSO), Adaline neural network (ANN) and Ant colony optimization (ACO). In this algorithm Ant colony optimization is used for finding the local optimum value from the search space. Particle swarm optimization is used for finding the global optimum value from the search space. To improve the convergence rate and processing speed an Adaline Neural Network Algorithm (ANN) has been used. Particle swarm optimization algorithm is combined with the Adaline algorithm to reduce the error .

The hybrid method is applied on historical data of wind data which is collected from the wind farm of Vietnam for 365 days from November 2013 to October 2014. The wind maximum speed, minimum speed, temperature high and low is taken as input for the hybrid model for predicting the energy.

In the proposed hybrid method the wind data set is normalized by using the equation

$$Y' = {}^{Y - Y_{min}}/_{Y_{max} - Y_{min}} \quad \ldots\ldots\ldots\ldots\ldots \ (6)$$

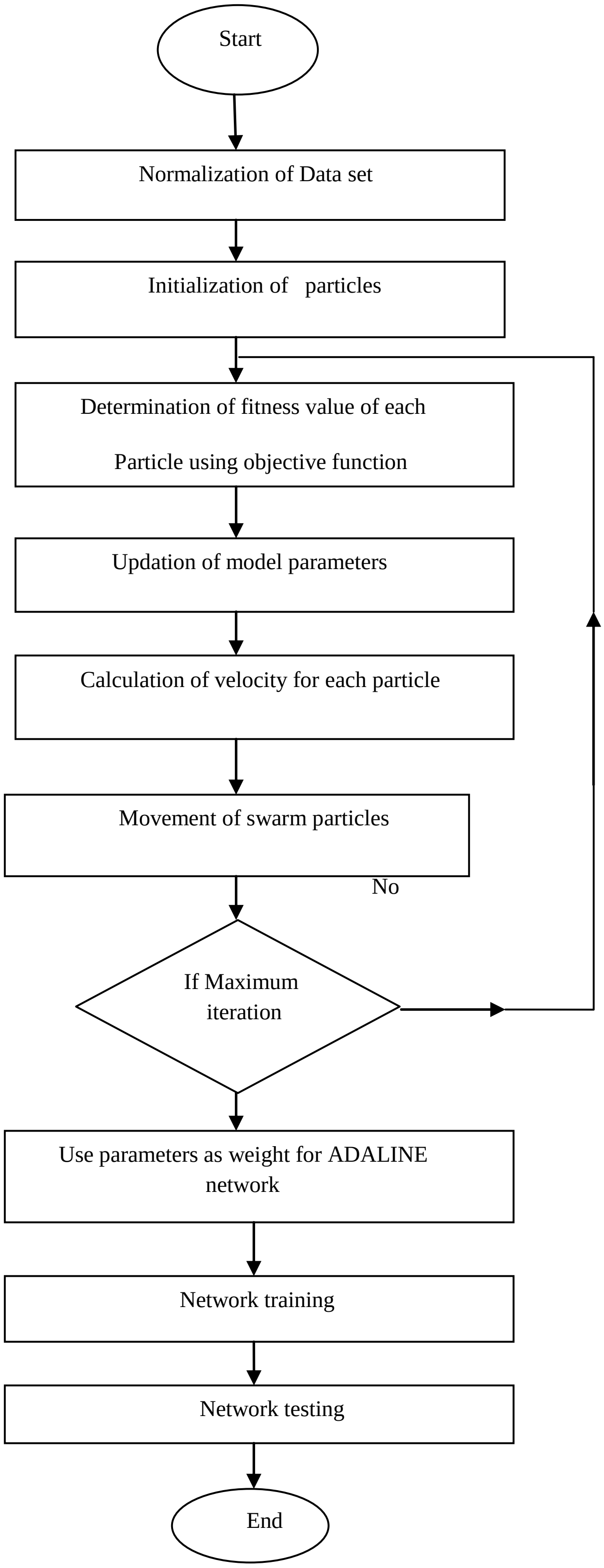
Number of swarm particles used is 10. The acceleration coefficients c_1 and c_2 has taken as a constant that is 2 and the inertia weight factor has taken as constant value to influence the particle velocity. The constant expresses how much a particle has the confident that he is nearest to food source. In PSO technique, 4 parameters are choosen such as a, b, c, d. Calculate fitness value of each swarm using the parameters. From the fitness value determine particle best (p_b) value based on the following equation.

$$\text{If } f(x) > Pb(x)$$

$$Pb(x) = f(x)$$

$$\text{Else } Pb(x) = swarm(x) \quad \ldots\ldots\ldots\ldots \ (7)$$

Where f(x) is the fitness value of each particle and swarm (x) is the current or previous fitness value. After number of iteration parameters are updated, and from that maximum fitness value is considered as global best (g_b) value of PSO technique. The inertia weight factor is considered for calculating the velocity of particles by using equ^n (1) .The parameters of the PSO are used as weights for the Adaline network.



[Flow chart of proposed hybrid model]

Proposed Algorithm

Step:1 Normalization of Data set.

Step:2 Initialize 10 number of particles.

Step:3 Determine the fitness value of each particle using objective function.

Step:4 Find the particle best value from the fitness value.

Step:5 Update the model parameters.

Step:6 Calculation of velocity for each particle.

Step:7 Movement of swarm particles.

Step:8 If max iteration then step 8 else step 3

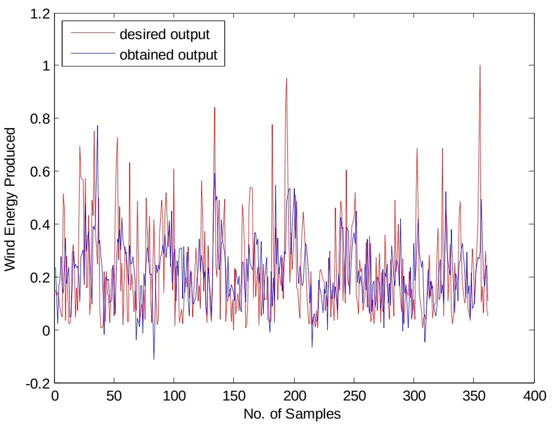
Step:9 Use parameters as weight for ADALINE network

Step:10 Determine the output of the network and calculate the mean error.

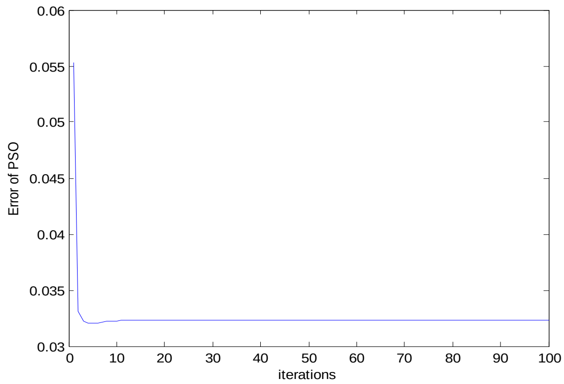
4. RESULT ANALYSIS

The wind energy is predicted by using the hybrid of PSO, ANN and ACO and the hybrid technique is applied over the historical data of wind for 365 days and the Mean square error is obtained 0.0308 and MAPE is obtained 3.08%. The Mean Absolute Percentage error is calculated by applying the hybrid model over wind data set by using the equation (5). The graph for desired vs. obtained values of the dataset are shown in Figure 2 where the blue line represents the obtained output and the red line represents the desired value. Figure 3 the blue line represents the mean error obtained by using PSO technique and the mean error is determined as 0.032. Figure 4 the blue line represents the mean square error obtained in the network. Figure 5 represents the mean error obtained for the entire year. Figure 6 represents the error from the month of November to February, Figure 7 represents the error from the month March to June, Figure 8 represents the error from the month July to October.

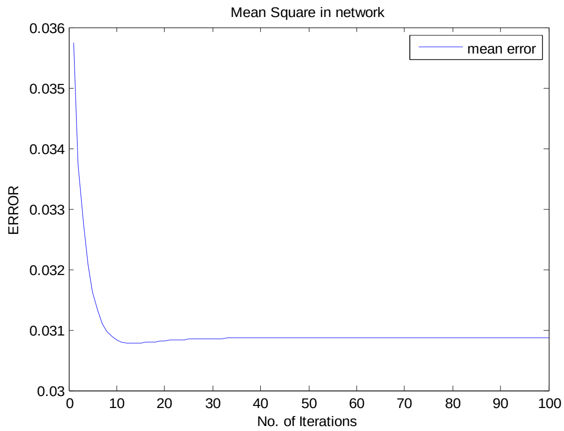
Table 1 represents the hourly error for wind energy prediction, Table 2 represents iteration comparison result, Table 3 represents the comparative MAPE result for wind energy prediction, Table 4 describes the parameters which are used in the proposed hybrid technique for predicting the wind energy.



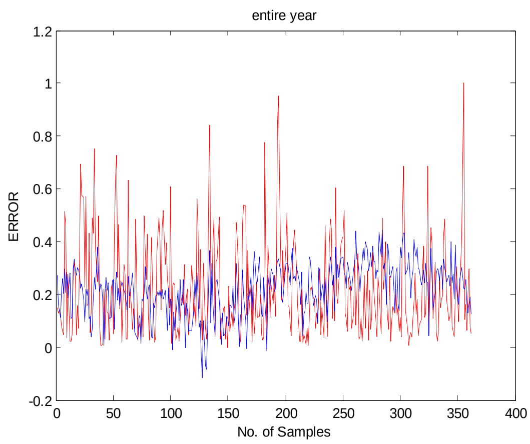
[Figure 2 The blue line is the obtained output of wind energy produced and the red line is the desired output of wind dataset.]



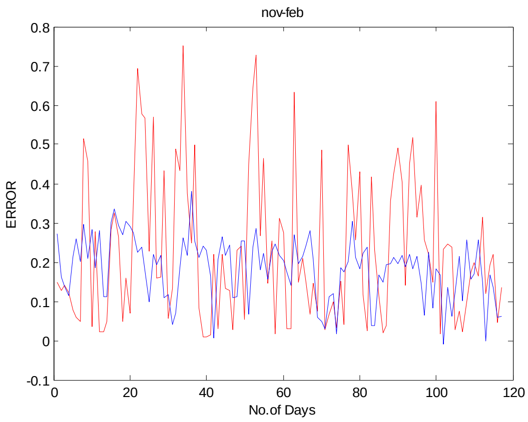
[Figure 3 represents Mean error of PSO]



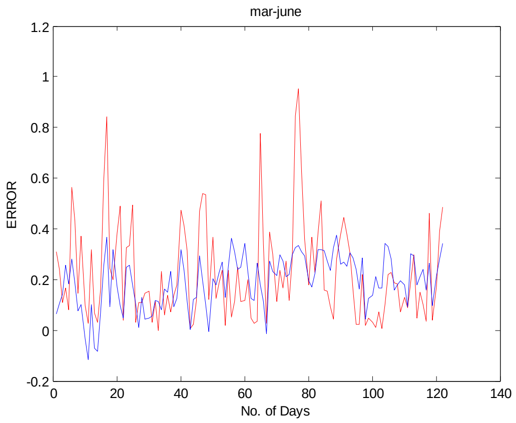
[Figure 4 Blue line is the mean square error of the network of wind dataset]



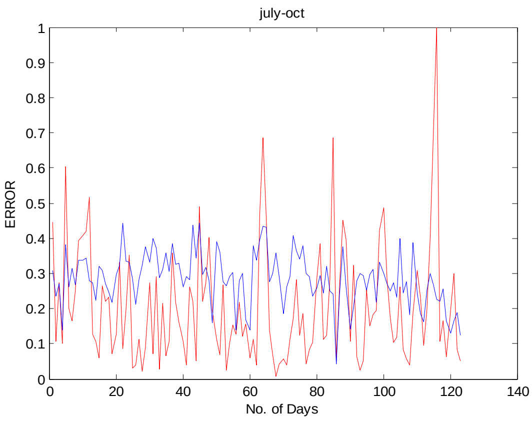
[Figure 5 represents the error of the entire year]



[Figure 6 represents the error from the month Nov-Feb]



[Figure 7 represents the error from the month March-June]



[Figure 8 represents the error from the month Jul-Oct]

TABLE 1 Hourly Error for wind energy prediction

Month	**Mean Error**
November-February	0.0012
March –June	0.0013
July- October	0.0013
Average	0.0012

TABLE 2 Iteration comparison result for wind energy prediction

No of Iterations	**50**	**75**	**100**	**200**
PSO	0.325	0.323	0.32	0.032
ACO-PSO-ANN	0.0309	0.0308	0.0308	0.0308
November-February	0.0012	0.0012	0.0012	0.0012
March –June	0.0013	0.0013	0.0013	0.0013
July- October	0.0013	0.0013	0.0013	0.0013

TABLE 3 Comparative MAPE result for wind energy prediction

Model	**Mean Error**	**MAPE**
Persistence	0.804	80.4
NN	0.804	80.4%
NNWT	0.465	46.5%
NF	0.438	43.8%
HEA	0.0373	3.73%
ACO-PSO	0.03513	3.513%
ANN-PSO	0.0541	5.41%
PSO	0.032	3.2%
ACO-PSO-Adaline	0.0308	3.08%

TABLE 4 Parameters of proposed model

No. of Swarm particle	10
No. of iteration	100
Acceleration co-efficient (C_1 , C_2)	2
r1, r2	Random
Maximum inertia weight	0.6
Min of inertia weight	0.4
Learning rate	0.3
Necessary iteration	25

5. CONCLUSION

The proposed hybrid approach of ACO-PSO-ANN is used for short-term wind energy prediction. The proposed algorithm in this study, led to a higher quality of result with a faster convergence profile. For the comparison purpose, PSO and ANN algorithms are also applied to the same model and the results obtained are tabulated based on the mean average percent error (MAPE). The empirical hourly wind energy for 365 days is used to train and test the prepared model. The empirical results indicate that the proposed technique can predict the hourly energy of wind with an MAPE of 3.08% which is completely acceptable, and better than other model. This approach is working with MATLABR10_a on a laptop with 1.90GHZ processor and 4 GB RAM.

6. REFERENCES

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