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A novel hybrid technique for prediction of electric power generation in wind farms based on WIPSO, neural network and wavelet transform

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ABSTRACT

This paper proposes a novel hybrid technique for prediction of power generation in wind farm. Using this technique, the effective number of input parameters is determined by data correlation analysis. Then, the type of the effective number of parameters are selected from current parameters via neural network. The WT (wavelet transform) is used for filtering input data related to wind power; while, neural network 'RBF (Radial basis function)' is utilized as a preliminary predictor. Main predictor motor is combined three neural networks of MLP (Multilayer perceptron) with learning algorithms: BR (Bayesian regularization), RP(Resilient back propagation), and LM(Levenberg Marquardt). The heuristic technique 'WIPSO (Weight improved particle swarm optimization)' is used to improve the accuracy of predictions and escape from local minimum to optimize weights of neural networks. Input data is realistic data of wind farms in Southern Alberta, Canada for recent years. The data is a complete set of wind power and five meteorological characteristics including wind speed, wind direction, temperature, air pressure and humidity. Simulation results verify appropriate selection of the number and type of input parameters and heuristic algorithm application. Additionally, the absolute superiority of this technique is validated compared with the other methods. Prediction error is also reduced perceptibly.

1. Introduction

Fossil fuel depletion, environmental pollution, greenhouse gas rise, and consequently, Earth temperature increase are among influencing factors for development and use of renewable energies [1]. Among renewable energy types, wind energy is of great importance due to high power density and its wide availability [2]. The use of this type of energy has being increased remarkably worldwide [3]. It is estimated that wind power generation will supply approximately 12% of total electric demand of the world by 2020 [4]. One of the main challenges of wind power generation is its uncertainty because of its oscillating nature [5,6]. Due to deregulation in power system along with electricity market, wind power generators in such conditions requisites appropriate strategy as its generation is uncertain [7,8]. The most proper strategy for making decision in the future is the use of prediction techniques [9]. Various methods have been reported in the literature and their main aim was reduction of prediction error. Due to background of wind power generation methods, they can be categorized into two main classes [10,11]: (1) Physical methods and the methods that use hard computation; (2) Methods that use soft computation. Hard computation requires higher time and complicated mathematical relationships in order to describe prediction model [12]. And, the accuracy of predictions is varying due to model parameters [8,13]. With regard to soft commutation, several methods have been suggested [14]. However, all these methods suffer from drawbacks because of variation of influencing parameters resulting from non-linear nature of wind power signal [15,16]. Thus, the novel approach in recent works was the use of hybrid technique of intelligent and heuristic algorithms such as neural networks, wavelet transform, diverse heuristic algorithms and fuzzy logic, etc. [10,17,18]. A hybrid model using fuzzy logic and ANN was proposed to forecast wind speed [19]. In Ref. [20] a hybrid model combining with input selected by deep quantitative analysis, Wavelet Transform, Genetic Algorithm and SVM (Support Vector Machines) was proposed. A neural network-based prediction intervals & PSO was proposed to load and wind power forecasting [21]. Importance of wind farms in islanding mode considering energy management is paramount. Thus, accurate prediction of the output and error reduction of planning problem in predicted power is possible.

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Because in islanding mode, required power procurement is the main principle of operating system. The most important factor disturbing this energy management is uncertainty of wind farm. By accurate energy prediction methods, reliability of islanding mode is increasing by the time [22–24]. Gird-connected wind farms are very important from electricity market viewpoint since it is required for exact prediction, particularly, for network planning operators (voltage control) and energy sale. Influencing factors on the accuracy of wind power are: 1) the number and type of input and influencing parameters on the amount of wind power generation, 2) an algorithm used for modeling the relationship between input and output parameters. In this research, In order to further improve the prediction, first, the type and number of influencing input parameters are selected using neural networks. Then, historic data non-linear signal of wind power is converted into relatively less distorted signals using wavelet transform. In the next step, the best combination of various neural networks with the highest prediction accuracy is selected for different conditions. Heuristic algorithms are utilized in order to improve the accuracy of predictions and the obtained results of comparing operations are proposed to select the best heuristic algorithm. Appropriate prediction of wind farm is of paramount importance from electricity market viewpoint and for the utilities. Thus, it is tried to highly reduce prediction error in these power plants. And, providing prediction methods with low error is still continuing. The advantage of the current method is that using preliminary prediction function leads to preventing trapping in local minima. In addition, the use of sequential neural networks in each stage results in approaching to global optimum solution. Also, metaheuristic algorithms in these stages are effective by preventing trapping in local optima, approaching global optimum solution and more accurate prediction.

1.1. Contributions

- Evaluation of the effect of various parameters on accuracy of predictions and selection of influencing parameters by neural networks.
- Determination of the number of each parameters influencing the accuracy of predictions by data correlation analysis [25].
- Proposing of effective and optimized combination of neural networks with various learning algorithms as a main motor of predictions.
- Proposing of a novel method for prediction of wind power in wind farms.

The rest of the paper is organized as follows. In Section 2, WIPSO, MPSO (Modified Particle swarm optimization), PSO, wavelet transform, and error measurement criteria are described. Section 3 details combined method for prediction and how it runs. Section 4 discusses evaluation and analysis of prediction results. Finally, the paper is concluded in Section 5.

2. Methodology

In this research, heuristic algorithm 'PSO' and its optimized derivatives are utilized in order to optimize modeling of non-linear signals. Additionally, mathematical method 'wavelet transform' is employed for signal noise filter and straightforward analysis of decomposed signals. Error analysis criteria are often used for examination and validity of simulation results. Here, appropriate criteria reported in the literature are used. These criteria are discussed briefly in the following context.

2.1. Particle swarm optimization (PSO) algorithm

Particle swarm optimization (PSO) algorithm is inspired by birds flying pattern. Two aspects have been considered in modeling available arrangement in swarm movement: one aspect is social interaction among swarm members, and the other aspect is individual privilege. In the first aspect, all members of the swarm are required to modify their direction following the best individual in the group. In the second aspect, each of the individuals are required to store their best individual position and simultaneously move toward their best experienced position. In objective optimization, finding the optimum solution is based on problem variables. An array of problem variables to be optimized is developed and named particle. In optimization of N_{var}-dimension problem, a particle is a row array with N_{var} arrays given by:

$$particle = [P_1, P_2, ..., P_{Nvar}] \tag{1}$$

For algorithm initialization, a number of particles should be created. Thus, total particles matrix is constructed by random.

$$particle = \begin{bmatrix} particle_1 \\ particle_2 \\ \vdots \\ particle_N \end{bmatrix} = \begin{bmatrix} p_{1,1}, p_{2,1}, \dots, p_{N_{var},1} \\ p_{1,2}, p_{2,2}, \dots, p_{N_{var},2} \\ \vdots \\ p_{1,N}, p_{2,N}, \dots, p_{N_{var},N} \end{bmatrix} \tag{2}$$

Cost of each particle is obtained by evaluation of function 'f' in terms of $P_1, P_2, ..., P_{Nvar}$. Thus,

$$\cos t_i = f(p_1, p_2, ..., p_{NVAR}) i = 1, 2, 3, ...N \tag{3}$$

A particle with the lowest cost is considered as the best global solution. It should be mentioned that initial velocity for each particle is constructed randomly.

$$V = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_N \end{bmatrix} = \begin{bmatrix} v_{1,1}, v_{2,1}, \dots, v_{N_{var},1} \\ v_{1,2}, v_{2,2}, \dots, v_{N_{var},2} \\ \vdots \\ v_{1,N}, v_{2,N}, \dots, v_{N_{var},N} \end{bmatrix} \tag{4}$$

Once initial population is created and an initial velocity is considered for each particle, each particle should be calculated based on its position. Each particle modifies its velocity based on the best solution obtained in the swarm and the best past position. In time unit variations, this velocity is added to the particle position and thus new position of the particle is achieved. As seen in Fig. 1, particles velocity in each step is calculated by Eq. (5) and particle position is updated.

$$v_{k+1}^i = wv_k^i + c_1.r_1.\left(p_k^i - x_k^i\right) + c_2.r_2.\left(p_k^g - x_k^i\right) \tag{5}$$

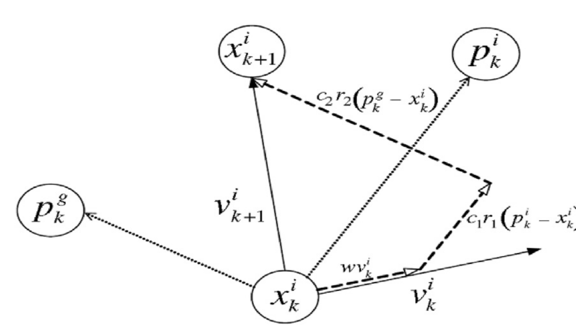

Fig. 1. Particle's position and velocity updating process.