Summary of Wind Speed Time Series Prediction Algorithms

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Abstract. Accurate prediction of wind speed is an important prerequisite for wind power integration. To hackle the large number of wind prediction outcomes in recent years, based on simple discussion of the wind power generation principle, wind speed predicted classification was summarized, the characteristics of a single algorithm wind speed forecast model was generalized, and the advantages and disadvantages of typical combination algorithm of wind speed forecast model was trying to scientific evaluated, the prediction effects of wind speed based on numerical weather prediction(NWP) was given clearly. At last, in order to provide a research reference for future the main direction that should pay more attention to predict wind speed is given.

Introduction

Energy saving and emission reduction have become the main problems facing the power industry. The use of new renewable energy structure to replace coal-fired and oil-fired thermal power units is one of the effective ways to achieve energy saving and emission reduction. Wind energy has attracted more and more attention due to its advantages of recyclability and green. The fluctuation and uncertainty of wind speed will inevitably lead to the randomness and uncontrollability of wind power generation, which brings many new problems to the stable operation and optimal dispatch of power system, such as accurate wind field modeling, reliable prediction of wind power, and Research on the optimization and reliability of power grid dispatch involving wind power.

Accurate prediction of wind speed is the necessary prerequisite to solve the above problems. Relevant researchers have made extensive and in-depth research on wind speed prediction, and have achieved a lot of meaningful results. In order to summarize and summarize the relevant results of wind speed prediction, and give objective evaluation as far as possible, this paper summarizes the basis of the principle of wind power generation. On this basis, the advantages and disadvantages of the single algorithm wind speed prediction model are summarized. Then, the combination model based on BP neural network algorithm and the typical results of the combination model based on support vector machine are evaluated in detail, and the atmosphere-based combination model is also evaluated. The effect of wind speed forecasting method based on physical model is deeply analyzed, and the advantages and disadvantages of wind speed forecasting research results are pointed out in the early stage of large-scale wind power integration, so as to provide reference ideas for future related research.

Two Different Classification Forms of Wind Speed Prediction

Generally, wind speed prediction can be divided into ultra-short-term (0-0.5h), short-term (0.5-6h), medium-term (6-24h) and long-term (24-24×7h) wind speed prediction according to the prediction time range. The classification of wind speed prediction by time is given. According to the classification of table 1, wind speed is predicted according to different time ranges. The conclusion is that the accuracy of the predicted results is proportional to the predicted time range, that is, the shorter the predicted time, the higher the accuracy of the predicted results, and vice versa.
[4] uses different algorithms to predict the same wind speed. The results show that the accuracy of wind speed prediction is related to the algorithm used. Therefore, according to the different prediction algorithms, wind speed prediction can be divided into two categories: single algorithm model and combination algorithm model.

At the same time, considering that the wind is generated by the air flow caused by atmospheric pressure difference, the dynamic equations in the atmospheric physical model can be used to describe the generation and development of the wind and other characteristics. Therefore, based on the above considerations, wind speed prediction can be divided into time series wind speed prediction model which only regards the wind speed as the numerical value changing with time. And two kinds of wind speed prediction models of atmospheric physics, which comprehensively consider the relevant parameters of hydrodynamics and thermodynamics.

It needs to be pointed out that the wind speed is roughly divided by the three methods mentioned above, but the emphasis is different. In practice, the three methods have no obvious boundaries and have great overlap and overlap. In order to illustrate the problem in detail, this paper reviews and evaluates the relevant literature with single algorithm, combination algorithm and physical model algorithm based on numerical weather prediction.

### Research Status and Development of Wind Speed Prediction

#### Wind Speed Prediction Model Based on Single Algorithms

Single prediction method refers to the use of only one model or algorithm for wind speed prediction research, a single algorithm mainly includes the following several kinds, for example, a simple prediction method that directly takes the actual wind speed of the previous moment as the prediction result of the next moment[5], and a time series to analyze the trend of future changes based on the characteristics of wind speed changes in the past. Column method[6], Kalman filter algorithm[7-8], which solves the system state equation directly based on observation data; neural network algorithm[9], which has good global approximation ability and is suitable for non-stationary data; prediction methods such as support vector machine algorithm[10-12], which processes wind speed data based on statistical learning theory. In addition, the wavelet analysis method[13] which has good noise reduction characteristics and the spatial correlation method[14] which considers the spatial and temporal similarity of wind speed have also been applied to wind speed prediction.

In view of the strong randomness and fluctuation of wind speed, it is difficult for a single algorithm to meet the engineering demand for prediction accuracy. Therefore, many literatures start from the perspective of combination of algorithms to further reduce the prediction error of wind speed and improve the prediction effect.

#### Wind Speed Prediction Model Based on Combination Algorithms

Support Vector Machine (SVM) theory and Neural Network (ANN) model have some advantages, and they are widely used in wind speed prediction and optimization algorithms.

1. **Combination Model Based on BP Neural Network Algorithms**

Multilayer forward BP neural network has good ability of non-linear mapping and fault tolerance, and is widely used in wind speed prediction combined algorithm.

However, the neural network also has the drawbacks of weak self-learning ability and long training time. Some literatures strengthen the self-learning ability of neural networks to improve the drawbacks of the long training time of BP neural network samples. For example, using wavelet theory to determine the primitives and structure of the wavelet neural network can effectively improve the self-learning ability of the neural network, and further clarify the purpose of network structure design[15]. Therefore, [16] uses wavelet neural network to predict wind speed, and compares the results with those of BP neural network with the same model structure. It shows that the wavelet neural network model with Mexican cap function as activation function can improve the accuracy of
wind speed prediction to a certain extent. [3] Predicts wind speed by combining feedforward neural network with time series of wind speed based on nonlinear regression theory with stronger self-learning ability. Compared with BP neural network, the results show that feedforward neural network can not only effectively reduce the training time of samples, but also has better accuracy than BP neural network. When the wind speed changes sharply, the prediction accuracy of the model is low, and further improvement is needed.

Because the input parameters and training samples of the neural network model have great influence on the accuracy of the prediction results, some studies use the theory of fuzzy rough sets to deal with them accordingly, so as to obtain more reasonable input parameters and training samples. For example, [17] uses the theory of fuzzy rough sets to process the input parameters so as to achieve the goal. In order to simplify the input of the neural network and combine with the improved Euclidean distance method, the training samples with high similarity are obtained to train and predict the wind speed neural network, and the better accuracy of wind speed prediction is obtained. In [18], the parameters of monthly mean temperature, monthly mean pressure and monthly mean relative humidity are taken as the influencing factors of wind speed by using rough theory set, and are input into chaotic neural network to predict wind speed, and good accuracy of wind speed prediction is also obtained. In [19], firstly, BP neural network, radial basis function neural network and particle swarm optimization BP neural network are used to get the prediction results of wind speed, and then the average values of the three prediction results are obtained. At the same time, the three prediction results and their average values are used as inputs of BP neural network optimized by genetic algorithm for weights and thresholds. To improve the accuracy of wind speed prediction, the feasibility of the combined algorithm in improving the accuracy of wind speed prediction is demonstrated. [20] uses Adaboost algorithm to train several BP neural networks with weak learner characteristics, and synthesizes them into strong learners, so as to enhance the adaptability of the neural network to samples and effectively reduce the wind speed prediction error. It provides a new idea for wind speed prediction. However, the algorithms of the above combined models are cumbersome, which is not conducive to the popularization and use of the given models in engineering.

In view of the shortcomings of the algorithm combined with the neural network, the corresponding improvement methods are given in order to achieve an effective prediction of wind speed. For example, in order to reduce the dependence of spatial correlation method on meteorological observation points, [21] uses radial basis function (RBF) neural network combined with spatial correlation method to achieve wind speed prediction. The data of the approximate spatial correlation points are obtained by the vertical line parallel to the wind direction of the existing observation points, and the RBF neural network is trained and predicted by the wind speed data. The wind speed is effectively predicted with fewer meteorological observation points. However, when choosing spatial correlation points, the model does not consider the influence of topographic factors on wind speed in detail, and has certain prediction errors.

In addition, grey algorithm[22] and Kalman filter[23] also have some combination with neural network algorithm, which further demonstrates the superiority of neural network algorithm and provides a more meaningful reference for the reliable prediction of wind speed.

In summary, there are many algorithms combined with neural network and good results have been achieved, but there are still some problems such as complicated calculation, large amount of sample data and the characteristics of sample data have a great impact on the accuracy of prediction results.

(2) Model Combining with Support Vector Machine Theory

Support Vector Machine (SVM) can achieve a good compromise between the complexity of the system and the learning ability of the model through the reasonable selection of the kernel function. It is also widely used in the combined model of wind speed prediction.

However, when solving support vector machine, it involves a large number of high-order matrix calculation (the order and sample number are equal). When the matrix order reaches a certain level, it
will affect the storage of its algorithm, which will occupy a large amount of machine memory and time.

For example, in [24], ant colony optimization algorithm is used to optimize the parameters of the kernel function, and the training sample data processed by difference is used to predict the wind speed, which verifies the feasibility of the support vector machine in wind speed prediction. However, the given model needs more training data and lacks sparsity.

Similar to the neural network, there are some literatures about how to improve the accuracy of wind speed prediction by effectively preprocessing the original wind speed series. For example, in reference [25], the wavelet algorithm is used to transform the wind speed sequence into basic components, periodic components and random components of different frequencies. The least squares support vector machine is used to predict the above three components of wind speed respectively, and the prediction results of each component are superimposed to restore the predicted values. This model effectively improves the accuracy of wind speed prediction. However, it does not elaborate on the determination criteria of each frequency component. From the angle of eliminating redundant information of original wind speed sequence, the paper obtains a simplified sequence of wind speed sequence by using triangular fuzzy function to fuzzify and granulate the wind speed sequence, and takes it as the input of support vector machine to train and forecast, which achieves better prediction effect, but it does not give a correct prediction result. The selection method of window scale, which has great influence on prediction accuracy, limits the adaptability of the given model to a certain extent.

Considering the important influence of the characteristics of training samples on the results of wind speed prediction, some literatures pre-process the data of training samples in order to improve the effect of wind speed prediction. For example, in [27], a large number of sample data are extracted directly to improve the training samples. Based on the wavelet algorithm, some high-frequency signals are removed, trend signals and random signals are retained, and the wind speed prediction results are given by using support vector machine theory. In [28], the similarity between training samples and prediction data was determined by grey correlation degree in advance, and the samples with higher similarity degree were selected to input into the support vector machine model for wind speed prediction. In view of the fact that the similarity between the training samples and the current wind speed needs to be determined in advance for both models, the implementation of the algorithm is rather tedious. In [29], the input dimension and Super-parameters of support vector machine are determined by particle swarm optimization (PSO). Then the subsequences of cluster empirical mode decomposition (EMD) wind speed are predicted separately, and the predicted results of each subsequence are combined to restore the wind speed value, which achieves better accuracy, but ignores the effect of climate factors on wind speed. As a result, all samples are treated equally, which leads to learning problems in the given models. Considering the different influence of samples in different time periods on the prediction results, the similarity weights and time weights of training samples are determined by Euclidean distance and linear incremental method respectively, and the weights of similarity weights and time weights are adjusted by the constant R between 0 and 1. Heavy. But the method of selecting the value of constant R is discussed in detail.

It can be seen from the above that the algorithm combined with support vector machine theory has achieved good research results, which provides a theoretical basis for accurate prediction of wind speed. However, the above algorithm has not completely avoided the disadvantage that support vector machine needs a certain number of sample data. At the same time, there are more or less deficiencies, which can not fully satisfy the reality. Interpersonal needs.

In addition, considering that wind generation is closely related to atmospheric physical models, numerical weather forecasting models for solving atmospheric dynamic equations for physical models have attracted more and more attention in wind speed prediction in recent years.
Wind Speed Prediction Model Based on NWP

NWP is based on meteorological observation data obtained by satellite, ship and radar. Under the initial condition that the surface is uniform roughness and the underlying surface is flat, the physical process of atmospheric evolution is described by atmospheric dynamics equations, and then the means of solving mathematical equations is used to analyze Meteorological Problems[31].

[32] attempts to predict wind speed based on the small and medium scale weather research and prediction (WRF) model. Firstly, the relevant parameters of WRF model are given by a large number of simulation experiments. Wind speed prediction is realized by mesh refinement and horizontal scale refinement. The results show that the accuracy and horizontal resolution of wind speed prediction results are not clear. Apparently connected. Because the horizontal resolution of WRF model is generally about kilometers, it can not describe the effect of terrain and landform on wind speed in detail, which leads to the low accuracy of wind speed prediction. Considering the effect of terrain and ground roughness on wind speed, a hypothetical model reflecting terrain and ground roughness is constructed in [33]. The influence of terrain and ground roughness on atmospheric physical evolution is analyzed. The prediction results of wind speed data show that the wind speed prediction considering terrain and ground roughness model is improved and and the relative error is less than 30%.

Aiming at the problem that the resolution of the atmospheric physical model is large and the accuracy of wind speed prediction is affected. Some literatures revise it with intelligent algorithm to improve the prediction effect of wind speed. For example, in [34], the nearest node to the wind field in the multi-scale model of global environment is processed by linear interpolation, and the wind speed data is processed by combining Kalman filter and neural algorithm, which achieves the purpose of improving the accuracy of wind speed prediction. [35] uses the fourth order polynomial as Kalman filter polynomial to revise the data of numerical weather forecast, and constantly updates the observation data to revise the weight coefficient of the model, which also achieves the result of improving the prediction accuracy.

It can be seen that the prediction accuracy of wind speed can be improved by using some intelligent algorithm combined with numerical weather prediction model, but this kind of model needs real-time processing of a large amount of meteorological observation information, which is difficult to realize on a small computer, and to some extent limits the wide application of this kind of model.

Key Research Directions of Wind Speed Prediction

In view of the fact that the current research results of wind speed prediction cannot fully meet the actual needs, there are some shortcomings, such as large training samples, low accuracy of dramatic changes in wind speed and long calculation time. In the future research of wind speed prediction, we should focus on the following directions.

1) How to minimize the number of training samples on the basis of ensuring the prediction accuracy to meet the engineering needs.

2) How to improve the prediction accuracy of drastic change wind speed without occupying too much machine memory.

Conclusions

In view of the fact that the current research results of wind speed prediction cannot fully meet the actual needs, there are some shortcomings, such as large training samples, low accuracy of dramatic changes in wind speed and long calculation time. In the future research of wind speed prediction, we should focus on the following directions.
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