Optimal Dispatch Strategy of Renewable Energy Power System Based on Wind Power Forecasting

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Abstract: China's electric power system is undergoing a drastic change in which new energy gradually replaces traditional fossil energy. New energy generation represented by wind power has the characteristics of randomness and volatility, which brings challenges to maintain the power balance of the power system, and the problem of new energy consumption is increasingly serious. This paper focuses on the optimization dispatch of new energy power system based on wind power short-term forecast. Under the current situation of increasing proportion of new energy, the power system is stable and the new energy is absorbed as much as possible through optimal dispatching.

Keywords: Power System, Wind Power Forecast, Optimal Scheduling, Renewable Energy

1. INTRODUCTION

Energy is an important resource for economic and social development and an important guarantee for healthy economic development. Developing the economy, reducing energy consumption, reducing greenhouse gas emissions, protecting the environment, vigorously developing renewable energy and finding alternative energy sources have become major issues of universal concern to the international community. Due to the increasing population base in China and the prominent pollution problem, the development of new energy industry is an inevitable choice to change China's energy structure, reduce the dependence on fossil energy and reduce environmental pollution.

Wind power and photovoltaic power generation continue to develop rapidly. By the end of 2014, the grid-connected capacity of wind power and photovoltaic power reached 87.9GW and 24.5GW, respectively, accounting for 8.0% and 2.3% of the total installed capacity of the State Grid. The annual wind power generation was 145.2TW·h, and the photovoltaic generation was 22.7TW·h.

With the increasing proportion of new energy in the power grid, the research on the prediction of wind power generation at home and abroad continues to deepen. In China, literature [1] proposed a layered model to predict large-scale wind power grid connection. Literature [2] introduced an ultra-short-term wind power prediction model combining CNN and GRU, and filled in more wind power prediction methods. Compared with China, foreign researches on wind power prediction started earlier. As early as 1990, Denmark developed a forecasting system[3], and later Germany, the United States, Spain and other countries also developed wind power forecasting systems[4].More and more people are thinking about how to optimize the dispatch of the high proportion of new energy power system. In literature [5], the optimal dispatch considering the flexibility of the photothermal power station and the DC connection line is proposed. This is the most typical research case for the optimal dispatch of the high proportion of new energy power grid at present.

2. WIND POWER FORECASTING

2.1. Wind Power Forecasting model construction

It is well known that neural network has good learning and analysis ability for data, and can realize the prediction of wind power by constructing neural network. However, it is difficult to achieve good results for wind power data with strong randomness only by using neural network, so a training network model with fuzzy neural network structure can be constructed to realize the prediction of wind power. According to the needs of the final selection of SVM function to achieve the construction of the training network model.

Obviously, the wind power data as input cannot exactly meet the requirements of the linear training data set, so we should treat it as a nonlinear data set, and use the SVM kernel function to replace the inner product in the linear problem to obtain the nonlinear support vector machine learning problem. Therefore, it is determined to construct a nonlinear SVM learning algorithm. This algorithm is based on the linear problem. After some optimization, the basic principle is similar to that of the linear problem.

Its classification decision function is:

$$f(x)=\mathrm{si\,gn}(\sum_{i=1}^{N}a_i^{*}y_iK(x,x_i)+b^{*}) \qquad (1)$$

Then the convex quadratic programming problem is constructed and solved according to the principle of linear problem:

$$\min\frac{1}{2}\sum_{i=1}^{N}\ \sum_{J=1}^{N}a_ia_jy_iy_jK(x,x_i)\text{-}\sum_{i=}^{N}a_i \qquad (2)$$

In the formula, $K(x,x_i)$ is the kernel function of SVM function, b^{*} is the parameter that can be obtained by kernel function and training data set through the built-in operation of SVM function in MATLAB. After the convex quadratic programming problem is constructed, the separation hyperplane can be solved through calculation, and then the required learning algorithm can be obtained by the established classification decision function. Finally, the training model is established.

After the SVM function is called and the parameters of its kernel function are set, in order to improve the construction speed of the training network and increase the training speed of the training data, the sample data should be normalized. In this paper, the Mapminmax function is used to convert all the sample data into decimals between [-1, 1].Normalization can not only accelerate the training speed, but also improve the accuracy of prediction.

2.2. Predicted Results

By adjusting the parameters of the kernel function, the prediction model of wind power is obtained through training. The selected sample data can be used as input. After the prediction data is obtained, A testable prediction analysis can be made by drawing to analyze whether the prediction model meets the expected results. The forecast results are shown in the figure below:

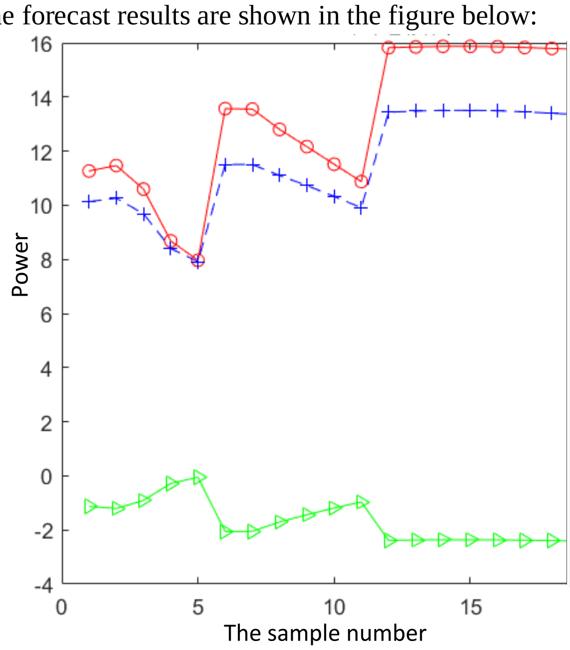

Fig. 1 Comparison of prediction results

Firstly, it can be clearly seen from the figure that the blue line is the forecast result. The final result is the forecast value of wind power for each hour of the next 24 hours in the next day, with 24 output values accumulated. We also put the actual data of the day in the test data in the chart for a clear comparison. The actual data are shown in red. Obviously, there is a certain error between the predicted value and the actual value, which is in line with expectations. As for the wind power prediction, since this kind of data is very random due to the weather and other conditions, it is inevitable to make the prediction with errors. We can only reduce the errors as far as possible to control them within an acceptable range.

The green line in the figure is the error, and it can be seen that the overall error is not very good, basically less than 20%, which basically meets the requirements. In the subsequent optimization scheduling, a certain amount of rotation reserve can be set to deal with it.

3. OPTIMAL SCHEDULING MODEL

3.1. Objective function

The fixed proportion of rotation reserve can be determined by the above error analysis. Under the common constraints of this constraint and other constraints, the safe and stable operation of the power system can be guaranteed. And considering the actual situation of new energy power generation of the unit cost will be lower than the conventional unit, we only need to pass to conventional units and new energy units according to the actual cost, set up different cost coefficient, using the objective function to solve the minimum generating cost, can be given to maximize under the condition of the security and stability of new energy. The expression of the objective function is as follows:

$$\min\ F = \sum_{t=1}^{m} P_C(t) \cdot \Delta t \tag{3}$$

Where $P_C(t)$ is the generation cost of all generator sets in time period T, and a time period in this paper is one hour.

The expression of $P_C(t)$ is as follows:

$$P_C = \sum_{i=1}^{N} \omega_i P_i(t) \tag{4}$$

Where ω_i represents the cost coefficient of the ith generator set, N represents all generator sets, and b represents the output of the ith generator set at time t.

The objective function is a relatively simple linear function, which can quickly calculate the cost of each generator set for the optimization solver. The minimum cost of all generator sets is the optimal economic benefit under the condition of safety and stability, which is in line with the purpose of optimal dispatch of power grid.

3.2. Variables and processing

In the optimization scheduling model that needs to be studied in this paper, the optimization variables that need to be taken into account are divided into two categories: conventional generating unit output and new energy generating unit output. Set these two types of variables to:

(1) The generating output of the conventional unit at each node $P(t)$.

(2) Power generation output of new energy units at each node $P_r(t)$.

Therefore, in the whole power system, when all variables are combined as a column vector, there should be n*m dimensions, where n is the number of power generation nodes and m is the number of time periods. In this paper, the prediction of wind power is the output of 24 hours in the next day, so m is 24.

The power generation output of conventional units is naturally a controllable variable and does not require additional output. The power generation output of new

energy sources is mainly discussed as wind power output, which accounts for a high proportion in the power system, and is determined by wind power prediction, so there is no need for specific modeling.
Therefore, the load power of each node is the only variable that needs specific processing. Since the load is an uncontrollable variable, to convert it into a digital variable, it needs to be modeled, and the possible fluctuation and randomness of the load should be converted into a mathematical model.
Power prediction of wind power forecasting is 24 hours a day in the future, so the load would need to be established in accordance with the time series into a complete a day load characteristic, the construction of the characteristic curve model in the research of new energy power system production simulation there are a lot of ways, one of the most traditional method is the typical daily load curve, this article also USES the method of variable load modeling.

3.3. Constraint

In the consideration of constraints, the most common and basic constraints in the power system are considered first. In this paper, power grid constraints are not considered in the optimal dispatching, and the power grid is regarded as the output and load are all collected as a whole and connected through a single line, and the constraints only need to be considered from the power level.
(1) Active power balance constraints

$$\sum_{n=1}^{N} P_n(t) + \sum_{r=1}^{R} P_r(t) = \sum_{l=1}^{L} P_l(t) \tag{5}$$

$P_n(t)$ is the planned output of conventional unit N in time period T, n is all conventional generator sets; $P_r(t)$ is the planned output of new energy generating set R in time period T, where r represents all new energy generating sets; $P_l(t)$ is the predicted power of load L during time period T, where L represents all loads.
(2) Line power flow constraint

$$-L_{ij,\max} \le L_{ij}(t) \le L_{ij,\max} \tag{6}$$

Where, $L_{ij}(t)$ and $L_{ij,\max}$ are respectively the power of the line between node i and node j at time period t and the maximum power that the line can bear.
One of the most basic power system constraints, the next step is to determine the constraints of conventional unit regular unit belongs to the control unit, the limit of the efforts of conventional generating units only itself output limit and creep speed, conventional generating units with new energy, new energy with stochastic volatility, the conventional unit from one output to another output size. It's a fixed rate change, there's no mutation.
(3) Output upper and lower limits

$$P_{i,\min} \le P_i(t) \le P_{i,\max} \tag{7}$$

Both sides of the inequality are the upper and lower limits of conventional unit output.
The output of new energy in the power system also has a certain range. In this paper, the output of wind power, which accounts for more than the rest, is mainly considered. After the short-term prediction of wind power, its output fluctuates around the predicted value with a large probability, which belongs to the output.
(4) Constraints on new energy output

$$P_{r.\text{predicted}}(t) \ge P_r(t) \ge 0 \tag{8}$$

Where $P_{r.\text{predicted}}(t)$ is the predicted value of wind power output, and the planned output of new energy must be limited within such a range.

4. THE SIMULATION RESUALTS

4.1. The IEEE 39 node

The IEEE 39 node is a typical power system structure, which is very suitable for many aspects of research. Based on the high proportion of new energy power system optimization dispatching based on wind power prediction, we also choose this calculation example to analyze the final results.
The proportion of new energy in the power system is not very high at present, and the main power generation is still conventional generator sets. Therefore, we only take 3 of the 10 power generation nodes as new energy power generation nodes, namely 34, 35 and 36 nodes, and the other 7 are all conventional power generation nodes.
In variable processing, we will load as uncontrollable variables, and made a typical daily load curve, said so on the actual load power set, every node must conform to the typical curve, after optimization algorithm, still is not what happens to load, is still comply with the rules of curve.

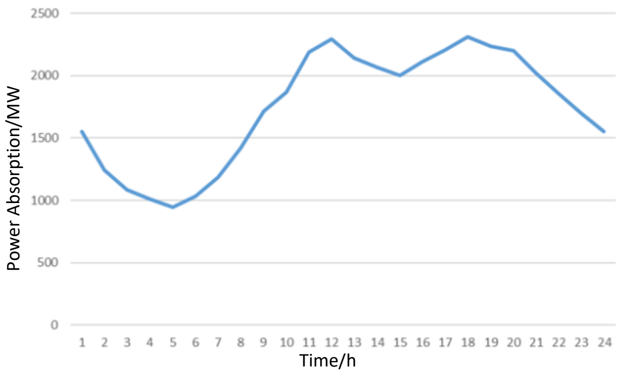

Fig. 2 Daily load curve

As you can see, the load curve is completely in conformity with the typical daily curve, which means in the process of our optimization, load node is consistent with our expectations, also accord with the reality, actually can be seen in the figure, at noon time, load consumption, reached a peak at 8 o 'clock to six o 'clock in the evening, there is also a small peak, this is the same with our actual life habit.

4.2. Results analysis

Through the establishment of the optimal scheduling model, the use of MATLAB programming realize the optimization of the model solution, finally use fimncon function and the final result, in the actual operation in the process of program optimization to solve in order to improve the solving speed, we will all data reduces 30 times, so the ultimate results also narrowed the thirty times numerical results.

Our optimization scheduling purpose lies in under the condition of security and stability, as far as possible, given the new energy (wind) were discussed in this paper, all will be the final result data collection to a given problem do analysis of the wind, the wind of the actual output as the input into the system through program optimization scheduling and real given value of the final system actual make a comparison between drawing.

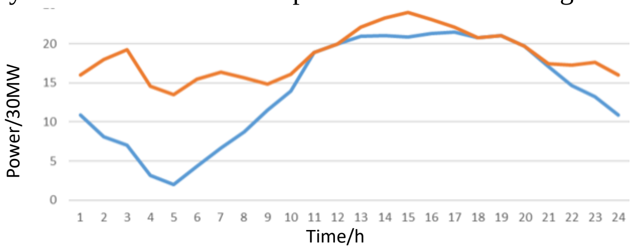

Fig. 3 Comparison of wind Power output and absorption value (initial coefficient)

From the figure, we can see that the two broken lines are partially overlapped, which means that the wind power consumption is maximized during this period, which is in line with the expected goal of our research project. But at the same time, it can be clearly seen that the overlapping parts are basically in the peak period of electricity consumption, but not in the peak period of electricity consumption, and there is also a large gap between the two broken lines.

The overlap of broken lines indicates that the results of optimal scheduling are in line with our expectations, which is to maximize the absorption of new energy (this paper mainly refers to wind power), but there is a big difference at low load, which may be due to the power climbing changes of conventional units that limit the absorption of new energy.

Combining the load curve with this result, it can be seen that in a few time periods after zero point, the load decreases rapidly and enters the lowest point of electricity use a few hours later. However, the response of the conventional unit is limited due to the drastic changes in these hours, and they cannot change as dramatically as the load in a short time. This leads to an increase in the proportion of the power generated by conventional units in the total load consumption, while the actual output of new energy does not decrease much during this period. In order to maintain the power balance and stability of the power system, we can only choose to abandon part of the wind power, resulting in such a big gap in the final result.

To remove this part, however, most of the other line height of overlap, especially in the peak season during that time, the given wind power and the actual output, is still likely to get us through optimization scheduling, make can under the condition of security and stability of power system, achieving the maximum given new energy this conclusion.

5. CONCLUSION

In this article, through wind short-term prediction and the optimization model, IEEE39 node example verified the results analysis, finally realize by wind power prediction and the optimization scheduling model of high proportion of new energy power system optimal operation, make the power system under a certain safety coefficient, every time as far as possible given wind power, improve the economic benefit of power system.

This research topic combines wind power forecasting and optimal scheduling, and makes use of the reference of wind power forecasting to do optimal scheduling for the power system, which is a repetition of the research on the use of wind power forecasting to do optimal scheduling. Based on the predicted value provided by the wind power forecast, a more appropriate rotary reserve can be selected in the optimal scheduling, which makes the conventional unit more flexible in the mobilization, improves the absorption capacity and improves the safety and stability.

In the optimization scheduling modeling, by borrowing the relationship that the actual conventional unit power generation cost is higher than the new energy power generation cost, the maximum consumption of new energy under the condition of safety and stability is realized by finding the lowest power generation cost, which is simple and effective, and has certain practical significance.

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REFERENCES:

[1] Boming Zhang, Jianhua Chen, Wenchuan Wu. Autonomous-Synergetic Energy Management System Family for Smart Grids: Concept, Architecture and Cases [J]. Automation of Electric Power Systems, 2014, 38(09): 6-14.

[2] Yang Xue, Lin Wang, et al. An ultra-short-term wind power forecasting model combined with CNN and GRU networks [J]. Renewable Energy Resources, 2019, 37(03): 456-462.

[3] BOSSANYIE A. Short-term Wind Prediction Using Kalman Filters[J]. Wind Engineering, 1985, 9(1): 1-8.

[4] ACKERMANN T. Wind Power in Power System[M]. Chichester, England : John Wiley & Sons, Ltd, 2005.

[5] Jingde Xia, Liyuan Chai, et al. Optimal Operation and High Consumption of Renewable Energy under Market Environment[J]. New Energy, 2019, 47(01): 19-25.