

Reserve Demand Determination Method Considering the Different Time Periods Uncertainty of Wind and Solar

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Abstract: With the gradual realization of China's 14th Five-Year Plan, the proportion of installed renewable energy capacity in all regions has increased significantly. The access of a high proportion of renewable energy has brought serious challenges to the safe and stable operation of the power system. The uncertainty of wind power and photovoltaic output makes it difficult for the traditional reserve demand determination method to economically and effectively calculate the reserve capacity required by the system, so it is urgent to propose a reasonable reserve capacity demand determination method. On the one hand, it ensures that the reserve capacity needed by the system is sufficient to cope with real-time active fluctuations, and on the other hand, it improves the economy of the reserve capacity. The reserve demand determination method considering the different time periods uncertainty of wind and solar in this paper is able to meet the reserve demand of new power system. At last, the article proves the benefits of Reserve Demand Determination Method through a numerical example.

1. Introduction

1.1 Background

With the development of economy and society and the pressure of environmental protection, the proportion of renewable energy such as wind power and photovoltaic in the power system is increasing. According to the international renewable energy agency (IRENA) released "2022 renewable energy capacity statistics" report, China by 2021 photovoltaic installed capacity reached 306.4GW, an increase of nearly 50GW compared with 2020, domestic wind power installed capacity reached 328.97GW, an increase of 40GW compared with 2020^[9]. The 14th Five-Year Renewable Energy Plan also states that annual renewable energy generation will reach 3.3 trillion kilowatt-hours by 2025^[10]. Due to the special output characteristics of wind power and photovoltaic, the net load of the power system will change beyond the forecast, which may lead to insufficient reserve of the power system.

1.2 Definition of operational reserve and its existing reserve requirements determination method

Operational reserve means a reserved capacity arranged by the power dispatching department to ensure the safe operation and reliable power supply of the power grid, and to balance the power shortage of the power grid caused by future uncertain times such as power grid load deviation, unit trip, DC block, and power grid accidents. Operational reserve can be subdivided into spinning reserve and negative reserve^[2].

Spinning reserve: During the real-time operation of the power grid, in order to cope with the load fluctuation, the trip of a single large unit, the loss of multiple large units caused by the failure of a single grid component, and the impact of a single DC bipolar blocking, the power dispatching department arranges for all of them to be transferred out within 10 minutes. Reserved capacity is not subject to grid stability limits and can last at least 1 hour^[6]. Its source is, in principle, the remaining power

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generation capacity of the operating units [8].

Negative reserve: In order to cope with unexpected situations such as load downward deviation, clean energy generation exceeding expectations, and sudden loss of external transmission channels, the negative capacity of units arranged by the power dispatching department is reserved. It generally consists of the power generation capacity that can be adjusted between the output of the operating unit and the minimum adjustable output. Under special circumstances, it can be incorporated into a pumped storage unit with a pumping space and an emergency adjustable shutdown unit.

At present, the determination of the demand for spinning reserve and negative reserve is mainly reserved by the power dispatching department according to corresponding principles.

The requirement for spinning reserve capacity is reserved according to the following three principles: 1) The spinning reserve is greater than the sum of the maximum single-unit capacity and the maximum DC bipolar transmission power. Ensuring the safe, stable and reliable operation of the power grid, adapting to UHV DC and high-power electricity is the primary goal of spinning reserve. The disconnection of the largest single-unit capacity unit and the disconnection of the largest tributary bipolar power transmission may have a huge impact on the power grid. The principle is to ensure that the rotating reserve capacity is sufficient to deal with an important guarantee for emergencies. 2) The spinning reserve is greater than 2% of the predicted maximum load of the entire network. Fully consider the impact of the whole network load fluctuation on the reserve demand. 3) The spinning reserve is greater than 95% of the historical prediction error of the net load (load deducting new energy output). The fluctuation in the existing system is mainly caused by inaccurate load forecasting and load fluctuation. This part of the deviation is the part that the spinning reserve needs to cover. Therefore, the current spinning reserve retention method stipulates that the spinning reserve shall not be less than 2% of the current load. The flow chart is as follows:

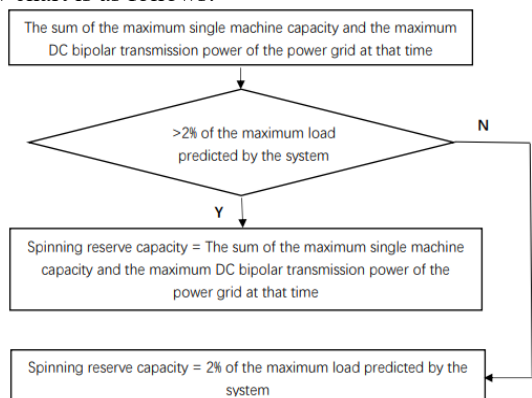


Figure 1. Traditional reserve demand measurement process

Negative reserve capacity requirements are reserved in accordance with the following two principles: 1) Negative reserve is greater than 2% of the predicted maximum load of the entire network. Fully consider the impact of the

whole network load fluctuation on the reserve demand. 2) Negative reserve is greater than 95% of the historical prediction error of the net load (load deducting the output of new energy).

1.3 Weaknesses of existing methods

With the increasing penetration of new energy in the power system, the uncertainty of wind power and photovoltaic output greatly increases the uncertainty of the power supply [3,4]. The existing reserve retention method mainly considers the load side fluctuation, and the power side generally only considers the influence brought by unit trip, grid component fault and DC transmission line fault, but does not consider the uncertainty of wind power and photovoltaic output. As a result, when the output uncertainty of wind power and PV is further increased, the fluctuation of the supply side of the system is beyond expectation, and the shortage of spinning reserve and negative reserve may lead to serious consequences of power abandonment or load cutting, even affect the safe operation of power system [7]. Therefore, the method of reserve demand determination considering uncertainty of landscape time sharing is introduced in this paper.

2. Design of Reserve Demand Determination Method Considering the Different Time Periods Uncertainty of Wind and Solar

Under dual carbon background, the proportion of renewable energy in the power system has increased significantly, and the uncertainty of wind and solar output has increased the uncertainty of the power supply side [8]. However, the existing capacity reserve method mainly considers the load side and the power supply side, in which the load side only considers the load fluctuation, and the power supply side generally only considers the influence of the unit trip, grid component failure and DC transmission line failure, but does not consider the uncertainty of photovoltaic and wind power output. This makes when the uncertainty of wind and solar output increases further, the supply side of the system fluctuates more than expected, and there may be insufficient spinning reserve, which in turn leads to serious consequences of power abandonment or load shedding. Therefore, it is necessary to study a method for determining the rotating reserve capacity of the power system that can take into account the uncertainty of wind power and photovoltaic output.

By analyzing the historical output data of wind power and solar, the uncertainty of wind and solar output at different time scales in the future is predicted, and the rotating reserve capacity and negative reserve capacity required by the system are determined based on the prediction results, taking into account the uncertainty of wind and solar. The following steps describe the specific determination method:

Step 1: Calculate the sum of the maximum single-unit capacity and the maximum DC bipolar transmission power

in the power grid at the time of operation.

Step 2: Calculate the maximum predicted load of the power grid and calculate 2% of the maximum predicted load.

Step 3: Compare the sum of the maximum single unit capacity and the maximum DC bipolar power transmission power with 2% of the maximum predicted load, and take the larger value of the two as the reserve capacity considering the unit, DC line faults and load fluctuations, denoted as A.

Step 4: Generate the probability distribution function of wind and solar output uncertainty.

The processing method for the uncertainty of wind and solar output is: based on the assumption that the probability distribution characteristics of future forecast errors and historical forecast errors are the same, the forecast errors of the simulated days are generated. The generated forecast error is added to the forecast wind power output on the simulation day, which is the actual wind power output on the simulation day.

First, data statistics are made on the historical wind power、 solar output forecast and actual output in the calculation area, and the historical forecast error is calculated.

Secondly, comprehensively considering the randomness of the output of new energy at each moment and the correlation between adjacent moments, the difference sequence is formed by the difference between the prediction errors of adjacent moments D_t :

$$D_t = e_t - e_{t-1} \quad (1)$$

$$e_t = P'_{w,real} - P'_{w,fest} \quad (2)$$

$P'_{w,real}$ and $P'_{w,fest}$ respectively means the actual value and predicted value of wind power output at t moment, e_t express predicted error at time t .

For the difference series, T location-scale distribution with shift factor and stretch coefficient is used to fit the probability distribution function. Based on its distribution characteristics, the difference series of forecast errors D_t in the simulated day are generated, and then the prediction errors e_t at the first moment of the simulated day are determined by sampling the historical forecast errors. The prediction error sequence e_t at time t can be obtained by stacking the difference value D_t of the prediction error at time t and the prediction error e_{t-1} at time $t-1$ in turn.

Finally, the forecast error sequence e_t and the forecast curve $P'_{w,fest}$ at each time were added to obtain the day curve of wind power output forecast in the simulated day, and a large number of probability distribution functions were generated to fit it.

Step 5: Envelope the generated probability distribution function according to a certain degree of confidence. The difference between the upper bound of the envelope and the predicted curve corresponds to the spinning reserve capacity taking the uncertainty of wind and solar output into account, denoted as B. The difference between the lower bound of the envelope and the predicted curve corresponds to the negative reserve capacity that takes the uncertainty of wind and solar output into account, denoted

as C.

Step 6: Compare the sizes of A and B, and take the larger one as the spinning reserve capacity required by the system.

Step 7: Compare C with 2% of the maximum predicted load of the system, and the larger one is taken as the negative reserve capacity required by the system. The flow chart is as follows:

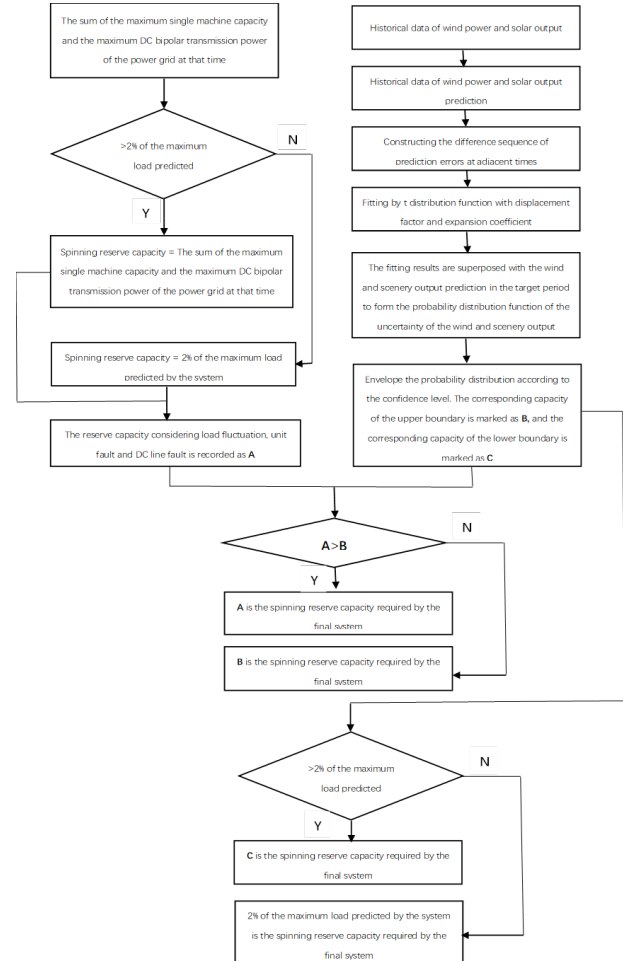


Figure 2. Flow chart of reserve demand calculation taking into account landscape uncertainty

3. Example

3.1 Simulation method

Aiming at the current energy structure with the increasing penetration rate of renewable energy in my country, this paper proposes a method for determining the reserve demand that takes into account the different time periods uncertainty of wind and solar. In order to verify the feasibility and superiority of this method, various probability distribution functions are simulated for the forecast errors of wind power, solar and load, and they are enveloped with a certain degree of confidence. The difference between the upper bound of the envelope and the forecast curve corresponds to Taking into account the spinning reserve capacity of wind and solar output uncertainty, the difference between the lower bound of the

envelope curve and the corresponding prediction curve corresponds to the negative reserve capacity taking into account the uncertainty of wind and solar output. Finally, the simulation calculation is compared with the existing methods.

3.2 Parameter preparation

This example includes the annual load forecast data, actual load data, wind power forecast data, wind power annual forecast data, solar annual forecast data, and solar annual actual data of a province in China in 2020. The prediction errors of load, wind power and photovoltaic are obtained by differentiating them respectively, and the total prediction error is obtained by adding the three. At the same time, in 2020, the province's traditional spinning reserve reserve capacity is known to be 1603MW, and the traditional negative reserve is reserved at 2% of the maximum predicted load, that is, 954.4MW.

3.3 Comparison of measurement results

Through the simulation calculation of the above-mentioned spinning reserve demand determination method that takes into account the different time periods uncertainty of wind and solar, the results are as follows:

First of all, the province's annual reserve demand forecast taking into account the uncertainty of wind and scenery is compared with the traditional reserve capacity:

TABLE 1 the Comparison Between the New Reserve Capacity and Traditional Reserve Capacity

	Spinning Reserve (MW)	Negative Reserve (MW)
Taking wind and solar uncertainty into account reserve capacity	1875	1957
Traditional spare capacity	1603	954

It can be seen from the results that after taking into account the uncertainty of wind and scenery, the demand for rotating reserve and negative reserve in the province has increased, which improves the safety and reliability of the power system.

Next, compare the calculation results of spare demand for wind and solar uncertainty in each quarter of the province:

TABLE 2 Calculation Results of Reserve Demand in Each Quarter Taking into Account the Uncertainty of Scenery

	Spinning Reserve (MW)	Negative Reserve (MW)
Spring	1356	2742
Summer	1248	1285
Autumn	998	1108
Winter	1932	2120

It can be seen from the above results that, affected by the seasonal characteristics of wind power and photovoltaics, the method proposed above also has

obvious seasonal characteristics. Among them, the autumn spinning reserve and negative reserve demand are the smallest, the winter spinning reserve demand is the largest, and the spring negative reserve demand is the largest, reaching 2742MW.

Finally, the comparison between the calculation results of the reserve demand during the day and night in the province in winter is as follows:

TABLE 3 Estimated Results of Reserve Demand During Daytime and Night in Winter

	Spinning Reserve (MW)	Negative Reserve (MW)
daytime	2169	1967
night	1938	2214

The province's daytime and nighttime reserve demand differs, with higher spinning reserve demand during the day and less negative reserve demand, while nighttime is the opposite, where spinning reserve demand is smaller and negative reserve demand larger.

4. Conclusion

With the continuous increase of the proportion of renewable energy, the existing methods of spinning reserve demand and negative reserve demand are difficult to meet the demand of power system economically and effectively. This paper not only proposes a set of wind and solar output deviation prediction method based on the historical output of wind power and photovoltaic, but also a determination method of time-sharing spinning reserve based on output deviation prediction method of wind power and photovoltaic, which solves the time-sharing demand analysis problem of reserve under the condition of high proportion of renewable energy. Through the calculation of the example, it can be seen that the reserve demand calculation method proposed in this paper can improve the security and reliability of the power system and avoid load shedding caused by wind power and photovoltaic fluctuations, when the reserve demand is urgent, the reserved reserve capacity is larger than that of the current method. When the reserve demand forecast is small, the reserved reserve capacity is smaller than that of the current method on the premise of ensuring the system security, which improves the economy of the reserved reserve capacity. The influence of different time-sharing methods on the amount of reserve will be further discussed in the subsequent study.

Acknowledgments

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