Power grid automatic dispatching method considering renewable energy fluctuation

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Abstract. In the process of power supply, the abnormal fluctuation of renewable energy leads to the increase of economic cost of power grid dispatching. Therefore, this paper proposes a power grid automatic dispatching method considering the fluctuation of renewable energy. According to the fluctuation of renewable energy, the power of renewable energy is predicted, and the power balance is judged by combining with other power related parameters in power grid operation. According to the change of peak load regulation, the power grid control center issues dispatching instructions and adjusts power related parameters to achieve the purpose of power automatic dispatching. The experimental results show that the proposed power grid automatic dispatching method considering renewable energy fluctuation has small operation delay and low economic cost, the economic benefit of which is higher than that of the traditional dispatching method.

1. Introduction
The impact of energy on social development is obvious to all. With more and more energy consumption, social development is increasingly restricted. As one of the important energy sources, power generation brings more and more serious energy and environmental problems.[1] With the international community’s attention to energy and environmental problems, large-scale application of renewable energy to power generation is an effective measure to solve the shortage of power and environmental problems [2]. In the safe operation of power grid, the power automatic dispatching method is one of the important guarantee for its safe operation. With the continuous innovation of power technology and the expansion of application scope, renewable energy can not be stably supplied for a long time due to the limitation of natural conditions. It is necessary to integrate renewable energy into the power grid. After interconnection, it can maximize its own advantages of ensuring effective power supply for a long time through reasonable dispatching[3].

At present, the development of power automatic dispatching method has experienced four times of innovation. The first time was in the 1970s when computer technology was introduced into power dispatching. The second time was in the 1980s when the dual machine hot standby system of dispatching host appeared, and part of EMS application software was put into practice. The third time was in the 1990s, the graphic display technology and relational database were added to the power automatic dispatching method, which further enriched and improved the power grid automatic dispatching method.[4-6]. In recent years, the research on power automatic dispatching method has not stopped. With the continuous development and progress of computer technology and network technology, the power automatic dispatching method is also constantly improving. At present, the more widely used dispatching methods include the automatic power dispatching method based on...
energy hub and the dispatching method considering incentive mechanism. These two dispatching methods use renewable energy as the main power supply mode, the economic benefit of which is relatively low [7-9]. Therefore, this paper proposes a power grid automatic dispatching method considering renewable energy fluctuation to solve the problems existing in the above-mentioned traditional power automatic dispatching methods.

2. Design of power automatic dispatching method considering renewable energy fluctuation

2.1. Predicting renewable energy power

Wind power generation and solar power generation are common ways to generate electricity by renewable energy. In the design of power automatic dispatching method, taking wind power generation as an example, the power peak is balanced through forecasting the power of wind power. Then the power grid automatic dispatching is realized. Because the wind speed is unstable and intermittent, support vector machine is used to predict the power of renewable energy. In the prediction of support vector machine, it is mainly to find a function \( f \in \{ f(u,v) \} \) to minimize the expected risk function value \( E(f) \) [10]. Considering that the process of using support vector machine to predict the power of renewable energy is to take the energy generation data as the input data and mine the functional relationship between the input data \( u \) and the output data \( v \). Therefore, the prediction problem can be regarded as a function approximation problem. Then the loss function of renewable energy power prediction problem is shown as formula (1).

\[
H(y, f(u,v)) = |v - f(u,v)| \quad (1)
\]

In formula (1), \( r \) represents a positive integer, which is determined according to the actual situation. According to the principle of structural risk minimization, the calculation process of formula (2) is carried out.

\[
E(f) < E_{\text{emp}} + E_{\text{gen}} \quad (2)
\]

In formula (2), \( E_{\text{emp}} \) represents the empirical risk. \( E_{\text{gen}} \) represents a measure of complexity \( f(u,v) \). \( E_{\text{emp}} \) and \( E_{\text{gen}} \) determines the upper limit of \( E(f) \). Given that the probability of wind speed series observation sample set is \( \{ (u_1,v_1),(u_2,v_2),\ldots,(u_n,v_n) \} \), the regression function is set as formula (3),

\[
G = \{ f | f(u) = vu + v \in E \} \quad (3)
\]

In formula (3), \( b \) represents the constant deviation of calculation. The structural risk function is introduced to make learning and prediction trade-off between empirical risk and model complexity. The kernel function and a nonlinear mapping \( \xi \) are used to map the input \( u \) in low-dimensional nonlinear space to high-dimensional feature space. Finally, the regression function is obtained.

\[
\begin{align*}
\xi(v) &= \sum_{i=1}^{n} (\alpha_i - \alpha_i^*) \xi(u_i) \\
f(u) &= \sum_{i=1}^{n} (\alpha_i - \alpha_i^*) (u_i u) + b
\end{align*}
\]

In formula (4), \( \alpha_i \) and \( \alpha_i^* \) represent Lagrangian multipliers. Based on the calculation results, the influence of large-scale renewable energy access on the peak power balance of power grid is studied.
2.2. Balancing peak power
According to the calculation results, the peak shaving balance state of renewable energy power is judged. The projects involved mainly include peak regulation surplus capacity during peak load period of power grid, peak regulation surplus capacity of power grid in low load period, maximum and minimum output of storage power station, minimum and maximum output of energy generation, daily maximum and minimum generation load, adjustable maximum provided by all conventional motor units and minimum processing and reserve capacity for positive and negative rotation. When the surplus capacity of peak load regulation is greater than or equal to 0, the peak regulation capacity is balanced. The balance calculation process is shown in Figure 1.

![Fig. 1 Flow chart of peak load balancing calculation](image)

In the balance calculation, the power change of renewable energy and the corresponding load characteristics of power grid are taken as the basis. According to these two parameters, the equivalent load is calculated. The maximum and minimum adjustable output of the controllable power supply is calculated after the peak load regulation parameters are obtained. The above calculation results are brought into the peak shaving balance discriminant to judge whether it meets the balance conditions. If the conditions are not met, the peak shaving scheme is modified until the peak shaving is balanced. If the balance conditions are met, the peak shaving surplus is calculated to generate the power dispatching scheme.

2.3. Dispatching power grid
In order to minimize the operation cost of renewable energy power station and power grid in a certain period of time, the mathematical model is established as formula (5).

\[
H = \min \sum_{i=1}^{n} e_i (q_{i1} - q_{2i}) s_{REGi}^{CUP} - \sum_{t=1}^{T} s_{ot}
\]  

(5)

In formula (5), \(H\) represents the objective function. \(n\) represents the total number of renewable energy REG to be selected. \(e_i\) represents 0-1 variable which is related to the number of REG installation. \(q_{i1}\) represents the unit investment cost of renewable energy power generation. \(q_{2i}\)
represents the replacement cost of unit capacity of renewable energy power generation. \( s_{\text{REG}}^{\text{cap}} \) represents the capacity \( REG_i \) of renewable energy generation \( i \). \( s_t \) represents the grid price of the grid in the period of time \( t \). \( s_{\text{eg}} \) represents the power supply power of the grid. The constraint conditions of the data model are equality constraints. The sum of the output power of the grid and the output power of renewable energy is equal to the total load demand of the corresponding period. Under the inequality constraint, the capacity of renewable energy power station cannot exceed its maximum capacity, and the transmission power of the grid cannot exceed the maximum allowable transmission capacity of the grid.

Considering the economic input of grid power generation, the output of grid connected inverter with renewable energy must be the same as the parameters of grid with the same frequency, phase and voltage. Since the grid connected inverter has the function of breaking away from the power grid and automatically cutting in, after the power generation equipment is started, the real-time operation parameters of RTU are collected. The power dispatching request is sent to the dispatching execution level according to the dispatching scheme and the actual situation of power supply. Considering that the renewable energy used by different power stations may be different, in order to improve the grid connection efficiency, different grid connection dispatching strategies are adopted. For solar power stations, grid connected inverter devices are arranged in the way of multi-branches, and energy conversion links are set up in each branch. After energy conversion, the power of each branch is collected and the centralized inverter operation is conducted, which are more convenient in power dispatching. For the wind power station, considering the influence of wind speed change on the power output, the generator is switched according to the change of generator output power, so as to improve the grid connection efficiency of the generator set. During the power generation period of small generator, the output power is detected. If the instantaneous power exceeds 20% of the rated power within 1s, the small generator will be switched to the large generator to ensure the real-time and effective power dispatching.

3. Experimental study

In order to verify the reliability of the proposed power grid automatic dispatching method, the power automatic dispatching simulation platform is built based on OPNET software in the experiment. In the simulation platform, 8 IED devices have the ability of sending and receiving messages at the same time, and support dual full-time communication. The transmission packets are all kinds of messages following the rules of IEC 61850. The parameter information of each equipment in the simulation platform is shown in Table 1.

| Equipment name          | MAC address | Destination address | Contract Law                        | Priority | Investment time |
|------------------------|-------------|---------------------|-------------------------------------|----------|-----------------|
| Intelligent operation box | 0x000n      | 0x0020/0x0030        | heartbeat (5s) /tripping operation (2ms-1s) | 1/7      | 120s            |
| Merging unit           | 0x001n      | 0x0020/0x0030        | period (0.25ms)                     | 1        | 0s              |
| Measurement and control IED | 0x0020      | 0x000n              | Event triggering                    | 3        | 0s              |
| Protection IED         | 0x0030      | 0x000n              | Event triggering                    | 1        | 0s              |
In the configuration information displayed in Table 1, \( n \) represents the label of the same kind of equipment.

Based on the above-mentioned simulation platform, the simulation case of normal communication network of power automatic dispatching method is designed. The normal operation scenario of communication network of power automation dispatching method includes two working conditions, steady-state operation and sudden operation. In these two cases, the traditional power automatic dispatching method is used to calculate the operation cost and transmission delay of each method in the above cases. The specific experimental results are shown in Table 2 and Table 3.

### Tab. 2 Experimental results of operation cost of different power automation dispatching methods

| Power automation dispatching method | Power automation dispatching method based on energy hub | Power automatic dispatching method considering renewable energy fluctuation |
|-------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------|
| Operation cost                      | 85637.14                                               | 70241.62                                                                  |
| Start stop fee                      | 300.00                                                 | 300.00                                                                    |
| Incentive load cost                | 0                                                      | 393.72                                                                    |
| Interruptible load cost            | 207.4                                                  | 0                                                                         |
| Total cost                          | 86144.54                                               | 70541.62                                                                  |

### Tab. 3 Transmission delay test results of different power automatic dispatching methods

| Power automation dispatching method | Power automation dispatching method based on energy hub | Power automatic dispatching method considering renewable energy fluctuation |
|-------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------|
| 0s                                  | 0.192                                                  | 0.012                                                                     |
| 60s                                 | 0.198                                                  | 0.028                                                                     |
| 120s                                | 0.206                                                  | 0.016                                                                     |
| 180s                                | 0.214                                                  | 0.025                                                                     |
| 240s                                | 0.369                                                  | 0.021                                                                     |

From the data in Table 1 and Table 2, it can be seen that the data in Table 1 show the statistical results of various costs in the operation process of power automation dispatching method. The operation cost of dispatching method considering incentive mechanism is relatively high, and the cost of incentive load is low. The overall cost is as high as 86144.54 yuan. Compared with the previous group, the overall cost of dispatching method based on energy hub is lower. But compared with considering renewable energy, the cost of dispatching method considering renewable energy fluctuation is obviously lower than the other two groups. The results show that the proposed dispatching method considering renewable energy fluctuations is more economical. The data in Table 2 show that with the increase of simulation running time, the delay of dispatching method considering renewable energy fluctuation is minimal. The other two groups of results have higher delay, which indicates that more resources need to be consumed to maintain the normal operation of the dispatching method in actual operation. Combined with the cost statistics results, the proposed power grid automatic dispatching method considering renewable energy fluctuations has higher economic benefits, which is better than the traditional power automatic dispatching method.

### 4. Conclusion

The development of renewable energy is of great significance to the adjustment of energy structure. Improving the energy utilization efficiency and improving the energy structure is the main
development trend of all countries in the world. For power energy, it is very important to ensure the safe operation of power grid while ensuring the energy utilization efficiency. This paper focuses on the research and discussion of power grid automatic dispatching method. After studying the influence of renewable energy fluctuation on power grid operation, this paper puts forward a power automatic dispatching method considering renewable energy fluctuation. After the design of the method is completed, the simulation platform of power automatic regulation is established. A number of comparative experiments are designed, which is in-depth with the traditional power automatic dispatching method. The reliability of the proposed power automatic dispatching method is verified by many comparative experiments. At the same time, it is proved that the method has high economic benefits, which can meet the actual demand of power automatic dispatching method at present stage, and provide reference for the safe operation of power grid. Limited by personal technical ability and knowledge level, there are still some problems to be solved and improved in the research, such as the response characteristics of load side control and the influence of different load control methods on power dispatching. In the follow-up study, more effective solutions will be developed for different problems, and a higher level of power automatic dispatching method will be designed.

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