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Study on the evaluation index of active power reserve

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Abstract. Based on the role of active reserve at different time scales, divides the evaluation dimension of active reserve. Analysis the calculation principle of traditional reliability index such as probability of system safety, lack of power shortage and electricity shortage expectancy, and studies the applicability of these indicators to evaluate the reserve capacity on different dimensions. Resolves the evaluation index of active reserve capacity from the dimensions of time dimension, spatial dimension, system state, risk degree and economy, then construct evaluation index of active reserve capacity.

1. Introduction
The actual operating system must have a certain amount of active reserve capacity to protect the power supply reliability. Domestic regional power grids of China generally tend to be in accordance with the "power system technical guidelines", divide operation reserve into load backup and accident reserve, or according to the generator operating state divide it into spinning reserve and non-spinning reserve [1]. In addition, some regional power grids take the load side resource into account, specify the response time for the load side resource to participate in running the reserve [2-7]. Foreign grid agencies highlight the specific requirements for the performance of the reserve power supply [8], including the response time, adjust speed, auxiliary service type and so on.

At present, the research on the reserve is still under development. With the large-scale intermittent new energy penetration rising, large-capacity UHV DC density, flexible load gradually involved in grid interaction and other new features appearing constantly, the balance of power resources and the power balance characteristics of the power grid have undergone significant changes, and it is urgent to study the system reserve capacity optimization technology in current environment. This paper analyzes the applicability of the traditional reliability index to the evaluation of the active reserve capacity, and constructs the multi-dimensional active reserve capacity evaluation index considering the demand of the active reserve under different scenes.

2. Evaluation dimension division for active reserve

2.1. Time dimension
From the time dimension, the grid reserve has gone through three stages, namely, primary reserve, secondary reserve, tertiary reserve. The process is as shown in the figure1.
When the power imbalance occurred due to load fluctuations or equipment failure, the power generation can adjust the output power to suppress the power according to the frequency difference automatically. This process is called primary frequency control (FC). It can be done in dozens of seconds. This ability to adjust to the range of the system's requirements is usually called primary reserve, which is used to prevent the frequency of the system from fluctuating when the power is out of balance.

Primary reserve prevents frequency changes. The system will call part of generator automatically by adjusting the active power to restore the system frequency to the planned value, this process is usually referred to as the secondary frequency control, usually completed within 10 minutes (15 minutes). This part of the power generator adjustment is usually referred to as secondary reserve, its role is to restore the system frequency.

The system frequency is restored after the secondary adjustment. In order that the quick adjusting unit could continue to deal with the next power imbalance of system, its frequency regulation capability need be replaced by other slow adjustment unit, the process is often referred to as tertiary frequency control.

The process of using system reserve to cope with power imbalance make use of primary reserve to prevent the frequency fluctuation firstly, then make use of secondary reserve restoring system frequency planning value, and finally make use of tertiary reserve restoring fast frequency control capability of the system.

2.2. Spatial Dimension

![Fig. 2 Schematic of interconnected system](image-url)
As shown in figure 2, regional interconnection, UHV AC / DC transmission is the main pattern for the future development of the power grid. Now, China's major power grids have already realized the national interconnection, which mainly formed five synchronous power grids such as east, south, northeast, northwest and north China. When there is a severe shortage of electricity in one area, reserve can be provided from other areas, this part of the reserve is the sharing reserve which can improve the system reliability [9-15].

Thus, from the spatial dimension, the reserve can be divided into the network reserve, partition reserve, sharing reserve.

3. Research on the applicability of reliability index

The reliability indicators in common use include the loss of load probability (LOLP), expected energy not supplied (EENS), frequency and duration (F&D), margin capacity (Mk), etc. LOLP and EENS are often used to measure the abundance of active reserve capacity. However, the active reserve capacity refers to the difference between the capacity of the system and the system load. It includes spinning reserve capacity, thirty minutes reserve, sixty minutes reserve and more than sixty minutes reserve. So, these indicators cannot directly represent whether the spinning reserve capacity meets the requirements. It is specific to the following aspects.

3.1. Different research time scales

The traditional indexes are usually used for the average reliability of the long-time running of the power system, and the time scales are usually measured in years. For example, the spinning reserve capacity is used for dampening the power imbalance quickly, usually working in ten minutes. So when evaluating spinning reserve, it needs to be time-bound, such as ten minutes LOLP, ten minutes EENS and so on.

3.2. Different component reliability model

Let's still take the spinning reserve as an example. The model of component failure rate used in traditional reliability assessment is the average of long-term historical statistics. As the spinning reserve capacity is the problem of the system running reliability in short time, the reliability model is the instantaneous state probability model, and it is affected by various conditions at run time. So, there need to do the following two things:

First, calculate the forced shutdown probability of the unit. In the traditional reliability index calculation, the forced shutdown probability of the unit is usually obtained by equivalent shutdown time divided by equivalent running time. But in practice the effect of the system power supply reliability is different in the short time, so when evaluating spinning reserve, it needs to be use instantaneous state probability model of the unit to calculate the reliability index.

Second, the operating conditions affect the failure rate of the system. Weather factors have a certain effect on the failure rate of electrical equipment, especially for dc systems. The failure rate of dc system in thunderstorm and other bad weather is much higher than that of dc system in normal weather. Therefore, it is necessary to calculate the influence of weather factors on the calculation of fault state probability of dc system

3.3. The impact of intermittent new energy sources on reserve

In traditional grids, the share of new energy is lower, and when calculating the reliability index the power supply is usually assumed to be deterministic. This approach will change as massive wind power and other intermittent new energy sources access in. Like the load model, it need to be planed the influence of the prediction deviation of the force model of the intermittent new energy.

3.4. The impact of demand response on reserve

Through designing appropriate demand response mechanism, power users who have ability to regulate can cut part load when the system need reduce system energy gaps. This is equivalent to provide the
active reserve capacity to the system. The results from the Lawrence Berkeley national laboratory also show that some demand response resources can respond with a speed of minutes or even seconds, and the response can be completed without human intervention with the support of relevant automation technology. In other words, it can even be used as spinning reserve in some applications.

But above all, the traditional reliability evaluation index (such as LOLP, LOLE, EDNS, EENS, F&D, $M_k$) can be used to evaluate the active standby capacity. However, it is necessary to constrain the time scale of reliability evaluation and adopt the instantaneous state probability model which is involved in the index calculation when it is used to evaluate different reserve types. Meanwhile it is necessary to increases the consideration of various factors such as risk of load forecasting error, risk of wind forecast error, risk of transmission equipment failure, uncertainty about demand response and so on.

4. Construction of reserve indicator

The evaluation index of active reserve capacity is one of the important criteria to measure the adequacy of reserve, which is an important basis for calculating the demand of active reserve capacity. With the development of power grid technology, there is a wealth of active reserve types in power grids. Different categories of active reserve in power grid play a role in the operation on different time scales. The traditional reliability evaluation cycle is long and difficult to achieve effective for some short time active reserve capacity evaluation. From the grid risk perspective, active reserve capacity adequacy not only affects the system's risk probability, also affect the risk grade and risk range so on. The single dimension reliability evaluation index cannot fully measure the abundance of active reserve capacity.

In this paper, the reserve index system is constructed from multiple dimensions such as the time dimension, spatial dimension, system status, risk grade, economic and so on (as shown in Figure 3).

![Fig. 3 Evaluation indicators of Operation Reserve](image)

4.1. Time dimension indicators

The time dimension indicators describe the principle indicators (primary/secondary frequency control performance indicators) and investigative indicators (primary / secondary / tertiary reserve recovery rate) that need to be retained at different stages of development of the grid.

4.2. Spatial dimension indicators

The spatial dimension indicators show the characteristics of relative independent and mutual support of each sub-region of the network. It can leave the total amount of the net reserve (Total reserve capacity/Reserve coefficient), and leave the reserve capacity of each partition (Partition reserve capacity/Partition reserve coefficient). At the same time, it inspects the mutual support capabilities between partitions from the perspective of alternate sharing (Reserve sharing rate).
4.3. System state indicators
The system dimension indicators are used to plan (Non-accidental reserve demand/Accidental reserve demand) and predict (LOLP/LOLE/EENS) the network security of the system in future from a reliability point of view.

4.4. System risk indicators
The system risk indicators are supplement to the system state dimension index. It can not only reflect the load loss of the system (Risk of load reduction/Risk of bus load reduction), but also can reflect the safety margin of the system (Risk of system frequency overload), as well as the line current overload and node voltage limit (Risk of component overload/Risk of transmission line overload/Risk of bus voltage overload), etc.

4.5. Economic indicators
Economic indicators describe the cost of the system reserve, including total reserve cost of purchase, reserve capacity cost of power generation, reserve capacity cost of electricity load, partition reserve cost of purchase and rate of assessment for reserve cost.

5. Conclusion
Combined with the problems of power reserve in the new situation, the active reserve is divided into primary/secondary/tertiary reserve in the time dimension, and is leaved according to a mechanism that partitions are retained and shared across the net in the spatial dimension. Countering the application of traditional reliability index in reserve, put forward the improvement direction of reliability index from several aspects such as time scale, component reliability model, the access of intermittent new energy sources and demand response. At last, Construct the evaluation index of active reserve capacity from time dimension, spatial dimension, system status, risk grade, economic.

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