The Demand Response Potential in Electricity System

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Abstract: With the increasing scale of new energy access grid and the continuous construction of smart grid, the demand for demand-side response and flexible dispatching conditions are becoming more and more urgent and mature. As a demand-side resource, demand response has the characteristics of economy and flexibility. As one of the key technologies, demand response plays an increasingly important role in maintaining the economic, reliable and efficient operation of power system. Demand response is one of the core technologies of smart grid. It can not only serve as a low-cost capacity resource for scheduling when the power system is facing an emergency, but also affect the pricing of the electricity market. It plays a role in reducing electricity price fluctuations and curbing market power. When the active power shortage occurs in the power system, the power system frequency will decrease. If the demand side and the power generation side cannot be treated equally, it is impossible to form a truly benign power market.

1. Introduction

With the development of economy and society, the problems of resources and environment are becoming increasingly prominent, and the development of power grid is facing a series of new problems and challenges [1]. With the development of intermittent renewable energy and electric vehicles, as well as the advancement of global energy transformation process, power systems are facing new opportunities and challenges. Demand response is an interactive activity between demand side and supply side of power grid [2]. It guides users to adjust the mode of electricity consumption through various price incentives. Demand side management (DSM) is a model of witch baby in the energy management system of smart grid in the future. It can provide technical support for smart grid in many fields. While the power system provides clean electrical energy, the volatility and intermittent nature of the power system itself poses a huge challenge to the power system scheduling of power systems [3]. Controlling and guiding energy demand can reduce the peak load of demand, reshape the load curve, and increase the level of sustainability of the grid by reducing total cost and carbon emissions [4]. The mechanism of demand response refers to the power user responding to the price signal or the stimulus signal. Rules and principles that change the inherent power usage to affect the overall system load characteristics.

The frequency of the power system reflects the balance of the active power of the power system. The frequency stability of the power system is of great significance to the operation of the power system [5]. When the supplier and the demander can trade freely in the market, and the price is jointly determined by both the supply and demand sides, the total return of the market transaction is the largest. Demand response changes power system load, which has a greater impact on system reliability [6]. The influencing factors of power system reliability generally include system load fluctuation, component reliability pillar energy, electrical characteristics and network structure. When smart electricity price is applied to demand side management, the demand of users will be affected by price incentives or penalty schemes according to the real-time change of the cost of the whole network, so as to make corresponding adjustments [7]. The traditional frequency modulation method tracks the varying load by changing the active power output of the generator. When the active power shortage occurs in the power system, the frequency of the power system will decrease [8]. If the demand side and the generation side cannot be treated equally, a truly benign electricity market will not be formed.

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2. Demand Response Participates in System Standby Capacity Provision

2.1. Demand response uncertainty

The traditional frequency modulation method tracks the varying load by changing the active power output of the generator. When the active power shortage occurs in the power system, the frequency of the power system will decrease. By improving the responsiveness of power demand to market price, the total power supply cost can be reduced to meet the same level of power supply reliability. It can also reduce the spot price level and price fluctuation during the peak demand period of the system, and bring enormous comprehensive benefits to the whole market and system operation. It takes a period of recovery for the grid to return to a new equilibrium state. If the method is not used properly, it will even cause a more serious grid power imbalance than before. Determining the alternate allocation by a fixed percentage in the deterministic criteria may result in inconsistent risk for each program.

Most current demand response studies focus on static characteristics of demand response. Such as load rate, peak-to-valley difference, load transfer rate, etc. The time span of these indicators is generally large, and is based on a summary of load curves based on days or even years. When the system voltage level is lowered, the reactive power demand of the power system and the reactive power loss of the line will lead to the lack of power of the power grid, further deteriorating the voltage level. The output characteristic equation of the generator can be obtained by fitting the output characteristic curve by least squares method. In order to ensure the accuracy of the fitting, the curve can be divided into three parts, and each part is fitted by the binomial. Figure 1 shows the generator output characteristics.

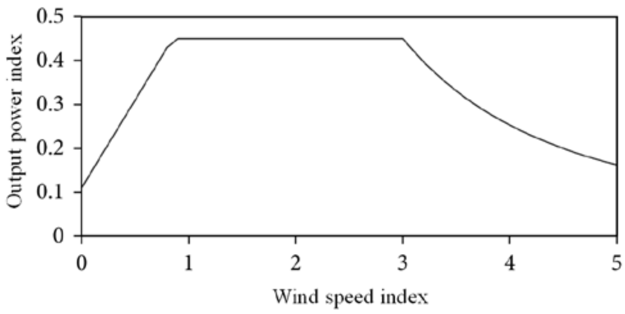

Fig.1. Generator output characteristics

2.2. Statistical-based demand response

The significant difference in physical load and usage habits of the terminal load enables the demand side users to have diverse responsiveness and response characteristics. If the user's satisfaction is not considered, the optimization result may damage the user's interests. The user is not satisfied, and it is difficult to achieve the purpose of coordinating the user's electricity to adapt to the power system. There is a minimum sensible difference in the incentive effect of the price change on the user, that is, the difference interpretation value. In this wide range, the user basically does not react to the price change [9]. Price-based demand response refers to the implementation of changing electricity prices to enable users to adjust electricity demand spontaneously, so as to achieve power load reduction or transfer. In the behavioral model of multi-period response, the elastic coefficients are divided into self-elastic coefficients and cross-elastic coefficients. The output and consumption of electric energy are increasing day by day. A large capacity battery can be used to adapt to and absorb the supply and demand relationship of electric energy for seed delivery. Comparatively speaking, the multi-time response is more in line with the actual situation.

3. Uncertainty Modeling of Demand Response

In the implementation process of demand response project, there may be a series of reasons, such as lack of attention to incentives, communication delay and changes in consumer behavior. The actual responsiveness of users to incentive or price signals is often uncertain. When the power supply exceeds the demand, the storage battery can store the overflowing power by charging and feed back the stored energy to the power grid to meet the user's demand at peak demand. Requirement response to participate in FM needs to be based on a faster real-time measurement and communication mechanism than traditional DLC. When the frequency deviation occurs in the power system, the controller can quickly control the shutdown of the power equipment or adjust the power of the power equipment. Demand response participates in system backup resources, and its reliability is an important indicator. The demand response can replace a part of the rotating unit capacity.

In the smart grid, the establishment of a two-way real-time communication system ensures that users actively participate in the operation and management of the power system. Real-time notification of the cost of power consumption and the status of the grid and planned power outages. If the power generation power can be accurately predicted, that is, the prediction error is small, it is beneficial for the power system dispatching department to adjust the dispatching plan in time, thereby effectively reducing the impact on the power grid, reducing the operating cost of the power system and rotating the standby. When the influence of the valve point effect is ignored, the total cost of power generation is reduced. Accounting for 4.46% of the total cost, regardless of the cost of the valve caused by the valve point effect, the scheduling result is very error. Table 1 is an optimization result before and after considering the valve point effect.

Table 1 Optimization results before and after considering the valve point effect

Optimization model	Optimizing target (10,000 yuan)
Ignore the valve point effect	18.436
Consider the valve point effect	20.267

In the power system, demand side resources are ubiquitous, and demand response participation in power system frequency modulation has great development potential. Demand response refers to the power user consciously adjusting its power usage behavior and changing its power demand according to the price or incentive signal issued by the power grid company. Because it cannot be stored economically, the production cost of electric energy is significantly different from that of other traditional commodities [10]. This characteristic determines that power demand has always played a pivotal role in the market. Demand side electrical equipment can change its power consumption time according to energy constraints, and can automatically measure the frequency of power system, and change its switching state according to the measured frequency. Although the traditional demand response projects have achieved some results, the dynamic demand response adjusted in real time according to price or incentive information in the market environment can participate not only in the main energy market, but also in the capacity market and ancillary service market. It is the trend of development in the future. Demand response has played a significant role in stabilizing electricity prices in the wholesale market and curbing market power on the generation side.

4. Conclusions

With the continuous development of smart grid and demand response, the research of dynamic demand response is gradually emerging. Compared with the traditional power system frequency modulation, demand response participation frequency modulation has the potential of faster response and no additional coal consumption. Demand response resources can improve the reliability and flexibility of the system by participating in the power ancillary service market. Accurate modeling of demand response is helpful to optimize decision-making and provide more credible analysis results. By analyzing the dynamic characteristics of the system frequency, the relationship between the disturbance and the maximum frequency deviation is obtained. Constrained by a frequency limit under a hypothetical disturbance, the inequality relationship between the combination of the generator set and the total capacity of the demand response resource is obtained. Due to the diversified influence of users participating in the demand response project and the weak mandatory specialization demand side response of the demand response itself, there is a large uncertainty. In the future, the application of demand response in operational optimization and simultaneous optimization of electrical energy should be considered to optimize both the power generation market and the standby market. And a variety of demand response resources are simultaneously involved in the power generation market and the standby market, giving full play to the potential role of demand response.

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