Concepts and Framework of Controllable Characteristic Evaluation and Bidirectional Interaction Technology of Flexible Load

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INTRODUCTION

At the power consumption side, with the emergence of energy storage, electric vehicles, microgrids with bidirectional regulation ability, and flexible loads such as translational load and interruptible load with certain response ability, more schedulable resources are provided for the power grid (Jiang et al., 2020). Through the interaction between the network and load and between the source and load, users give up the control of load to a certain extent. By dispatching this part of resources, the power grid reshapes the demand curve to match the supply curve, which is beneficial for ensuring the stable operation of the power grid, and provides a new means of support for stabilizing the volatility and peak shaving caused by large-scale clean energy access (Wang et al., 2021). However, the load-side resources are distributed in a large number, and the massive distributed schedulable resources are limited by communication, which makes it difficult to control accurately and directly, increasing the difficulty of power grid control. Nevertheless, with the rapid development of cloud computing (Geng et al., 2021), big data, Internet of Things (Cao, 2021), 5G mobile communication, and other technologies, the adjustable control characteristics of flexible load based on real-time data can be accurately predicted. Therefore, a large number of flexible loads are aggregated into one or more schedulable wholes according to certain criteria. Through sufficient real-time data mining (Xu et al., 2019), two-way interaction with the power grid is carried out, and active participation in power grid dispatching is carried out, which are beneficial for fully tapping the distributed resources, achieving higher economic benefits, and improving the stability of power grid operation. In this paper, the problems of flexible load controllability evaluation and bidirectional interaction technology based on real-time data are clarified, and some views on relevant technical elements are put forward.

FLEXIBLE LOAD CONTROLLABLE CHARACTERISTICS

In terms of the potential of flexible load response, Goldman et al. (2007) proposed a potential evaluation method for large industrial and commercial users to participate in demand response. The main steps include determining the research object and the type of demand response items, clustering analysis of user groups based on electricity characteristics, identification of the participation rate of the classified demand response items, calculation of price elasticity, and potential evaluation of demand response. The focus is on the calculation method of price elasticity applicable to subdivided user groups. Based on the above-mentioned assessment methodology, the Federal Energy Management Committee assessed the demand response potential of the United States for 2010 to 2020 from four scenarios: conventional operations,
of each user load, the load aggregator comprehensively evaluates the adjustable potential value, adjustment speed, adjustment cost, and complementarity of user load, completes the calculation of adjustable potential of user aggregation, and participates in market bidding. According to the scene requirements of peak regulation, frequency regulation, and clean energy consumption, the dispatching layer of the power grid generates day-ahead, day-in-day, and real-time regulation requirements based on the real-time operation status data of the power grid and the load storage prediction of the source grid and forms market information and releases it; according to the situation of load aggregators participating in market bidding, the load curve and flexible controllable margin reported by load aggregators are checked, and the market rules are precleared. The plan control target curve and baseline load curve of each load aggregator are issued. In addition, users perform autonomous control according to the control strategy and monitor and track the environment, operation parameters, and disturbance according to human behavior.

**BIDIRECTIONAL INTERACTIVE NETWORK ARCHITECTURE**

Based on real-time data of the power grid, flexible load can realize bidirectional interaction with the power grid. Li et al. (2016) proposed a bidirectional interactive network architecture between a smart park and a power grid system. The author believes that it can realize the interaction between the power grid and users, mainly in two aspects. The first aspect can use smart meters and implement dynamic real-time electricity price, and the power consumption period can be selected by the users themselves. The second aspect of the smart park power system allows users to have distributed power, including electric vehicles and energy storage devices to power the grid. The smart park grid system can make the energy flow and information flow between the grid and the load interact bidirectionally. The premise of realizing bidirectional interaction is to have a perfect power transmission and information communication system. Based on the traditional power transmission and distribution network, the construction of the smart grid should establish a powerful interconnected communication system that can realize communication between the power supply, power grid, and load. Ning et al. (2020) proposed a full process interaction system based on real-time data. The author divided the communication link between the dispatching automation system and the aggregator operating platform into uplink and downlink channels. The downlink data channel includes the control instruction and instruction time issued by dispatching, the day-ahead/day-in-day plan value, and the market clearing information. The uplink data channel is the real-time data of the aggregate total power, the number of load terminals, the power of load cells, the adjustable upper and lower limits, the AGC switching signal, the maximum step length of the acceptable instruction and other real-time data of the adjustable load cells sent by the aggregator, and the static model ledger information and market declaration information of the adjustable load cells.
Flexible load resources can participate in the regulation of the power grid at the beginning of the province peak shaving auxiliary service market as the entry point as the peak shaving market price recipient is not involved in quotation. With the gradual deepening of business participation, they participate in market quotations in an appropriate form and even in the interprovincial market. At the day-ahead/day-in-day global optimization level, the minimum call cost of the whole network market can be taken as the optimization objective. According to the short-term/ultra-short-term load forecasting, based on the comprehensive consideration of the conventional constraints such as system balance constraints, unit operation constraints, and grid operation constraints, combined with the actual quotation reported by the load aggregator and the actual available capacity of the load users after aggregation, the constraints of peak regulation of thermal power units and the energy consumption or battery power of adjustable load resources are introduced to optimize the preparation of the ideal charging and discharging plan of flexible load in the future for a period of time, as shown in Figure 1.

**DISCUSSION AND CONCLUSION**

In order to fully realize the flexible load resources responding to the real-time control instructions of the power grid and participating in the flexible adjustment and realize the real load dispatching control of the multiple coordinations of the source network, load, and storage, it is necessary to continuously study and explore to realize the large-scale real-time measurability and real-time controllability of the flexible load resources. There are still many technical problems to be further explored, as follows:

(a) In terms of device performance, there is still a certain gap between the power data acquisition accuracy and real-time performance of flexible load resources and the demand of regulation business. It is necessary to continue to improve the technical level of load terminal equipment, increase the transformation of device acquisition and control performance, improve the real-time data upload frequency and tracking response ability, expand the number of load resources that can participate in real-time control, and increase the investment and construction of load terminals with strong regulation ability such as V2G and orderly charging piles.

(b) At the aggregator level, realization of the accurate rolling calculation of the security region of controllable power according to the needs of a large number of load users and the state of equipment in the operating platform so as to maximize the aggregation of the regulating space of decentralized load resources according to different optimal
strategies according to different resource characteristics is needed.

(c) In terms of interruptible load, further optimization and transformation of the current marketing demand response system and scheduling precision load shedding system in various regions, expansion of the control ability of the system platform, and its integration into the overall technical architecture in this paper so as to transform a large number of interruptible load attributes that have been gathered in this part of the system into adjustable attributes and fully release the load-side adjustment potential are needed.

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Conflict of Interest: Authors ZT, BL, ST, and CD were employed by the Electric Power Research Institute of Guizhou Power Grid Co., Ltd.

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