A Business Service Model of Smart Home Appliances Participating in the Peak Shaving and Valley Filling Based on Cloud Platform

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SUMMARY With the development of power market demand response capability, load aggregators play a more important role in the coordination between power grid and users. They have a wealth of user side business data resources related to user demand, load management and equipment operation. By building a business model of business data resource utilization and innovating the content and mode of intelligent power service, it can guide the friendly interaction between power supply, power grid and load, effectively improve the flexibility of power grid regulation, speed up demand response and refine load management. In view of the current situation of insufficient utilization of business resources, low user participation and imperfect business model, this paper analyzes the process of home appliance enterprises participating in peak shaving and valley filling (PSVF) as load aggregators, and expounds the relationship between the participants in the power market; a business service model of smart home appliance participating in PSVF based on cloud platform is put forward; the market value created by home appliance business resources for each participant under the joint action of market-oriented means, information technology and power consumption technology is discussed, and typical business scenarios are listed; taking Haier business resource analysis as an example, the feasibility of the proposed business model in innovating the content and value realization of intelligent power consumption services is proved.

key words: power system, peak shaving and valley filling, home appliance business resources, business model, load aggregator

1. Introduction

Due to the influence of holidays, seasons and regional factors, the electricity demand of users in different regions in different periods has a huge fluctuation of peak valley difference. During the National Day holiday in 2019, the maximum peak valley difference of Jiangsu is 16.163 million kW [1], and that of Northeast China during the Spring Festival is 11.46 million kW [2]. In order to reduce the impact of unbalanced power supply and consumption on the stability of power grid operation and the reliability of power users, the power system adopts peak shaving and valley filling (PSVF) to establish demand response. In August 2020, Shanghai electric power company joined 304 customers to participate in the first PSVF demand response in summer, with a daily response load of 218700 kW [3].

At present, the main measures of PSVF include capacity allocation optimization of energy storage system, power dispatching optimization and combined price incentive. Through the power storage in the valley period and power generation in the peak period, the generator set can reduce the start-up and shutdown frequency and alleviate the power load fluctuation [4]. Through load forecasting and load pattern recognition, the generator dispatching data can be modeled to alleviate load mutation [5], [6], but the dispatching strategy needs to comprehensively consider the economy, system reliability and load smoothness [7], [8], the application of energy storage system in individual user is very limited [9]. With the improvement of intelligent power consumption level, the utilization of user side business resources has been paid more and more attention. It includes a series of load data, operation log and picture resources generated by the user side power generation, power consumption and energy storage devices that are installed on the user side and belong to the user. It is a flexible business resource that can participate in the dispatching. Based on the characteristics of users and load response, some studies put forward novel electricity price mechanism [10], [11], and dynamic combination of multi prices [12], [13], so as to guide users to participate in peak load regulation and scientific power consumption, and deal with different power demands. Some researchers also proposed personalized smart home appliances scheduling [14], [15] and home energy management scheme [16], [17] for these resources, so as to improve the home intelligence level and the household energy efficiency.

In order to break through the demand response main body mode of single industrial user, collect various load types such as commercial buildings and households, and solve the problem of insufficient response of individual users, load aggregator [18] appears. It signs an agreement with users to obtain the decision-making power of aggregatable load and provide economic incentives and auxiliary services to users [19], and brings the dynamic liquidity and business transfer value of the power market [20]. Multiple load aggregators coexist in the electricity market [21], [22], and participate in the load cluster scheduling of the power market, such as single load scheduling of
electric vehicles and air conditioning [23], [24], multi equipment load cluster scheduling of water heaters and air conditioning groups [25], and multi energy flow scheduling of heating and power supply [26], [27]. Load aggregator can connect the power grid platform and demand side management platform upward, and connect the IOT platform and big data platform downward. It has great advantages in integrating platform resources, accelerating information transformation, and driving business innovation. At present, Zhejiang, Jiangsu, Shandong and other places actively call for expanding demand response subjects, exploring the role of market-oriented means in tapping the potential of non-productive load, and encouraging load aggregators to carry out professional, personalized and diversified service innovation in energy trusteeship, comprehensive energy saving and energy optimization. Among them, load aggregators represented by smart home appliance manufacturers, relying on their business resources and information technology in the construction of smart home appliance and cloud service platform, can integrate resources, analyze data, innovate services and expand business. According to statistics, as of 2016, about 700 million smart meters have been installed in the world, and nearly half of them are deployed in China. The International Energy Agency estimates that by 2040, about 1 billion households and 11 billion smart appliances will be connected to the interconnected power system, saving more than 270 billion US dollars in investment for new infrastructure [28]. The deployment of smart devices brings together a large number of individual user resources, which will undoubtedly greatly promote the development of auxiliary service market such as PSVF.

However, with the diversification of power demand and the increasing volume of business resources, how to realize the efficient aggregation of load resources of small and scattered users, fully tap the value of business resources, and cultivate new business forms of power service still need to be further explored.

2. Peak Shaving and Valley Filling Process of Smart Home Appliances

It is estimated that about 1/3 of the peak load in summer is generated by air conditioning [29]. With the rapid development of IOT, cloud computing and big data in recent years, large enterprises in the home appliance industry and even some Internet enterprises are speeding up the layout of IOT home appliances. Accordingly, the cloud service platform for smart home appliances has attracted the attention of major smart home appliance manufacturers.

The cloud service platform for smart appliances is usually composed of IOT platform, big data platform and interactive platform, which has rich and complete business resources of household appliances. Relying on the cloud service platform, load aggregators can deeply connect and accurately access smart home appliances, realize the aggregation, coordination and optimization of a large number of fragmented loads. Figure 1 shows the overall framework of device regulation of cloud service platform. By collecting and integrating the data of networked appliances, user data and other production and marketing data, it can not only guide users to regulate electricity consumption behavior, but also realize remote regulation of equipment clusters.
Fig. 2 The relationship of participants in electricity market

with different electricity consumption modes, so as to improve the level of demand response. Taking Haier Group as an example, as of 2017, networked household appliances accounted for 23% of Haier appliances, and the number of intelligent household appliances users has exceeded 60 million. The Haier U + smart life platform (U + platform) intelligently connects more than 80 kinds of household appliances, which has generated 600 + billion big data and received 100 million pieces of data reported by devices every day [30]. The data range has covered 443 cities and 63483 residential areas in China. Among them, the daily load difference between peak and valley of Haier’s interconnected electric water heater is at least 245000 kW. Assuming that the operation time and operation mode of the electric water heater are adjusted, the daily peak power can be reduced by 830000 kW, equivalent to about 280000 yuan of electricity.

3. The Relationship among the Participants in the Process of PSVF for Smart Home Appliances and the Current Power Market Business Model

3.1 The Relationship among the Participants in the Process of PSVF for Smart Home Appliances

In the process of PSVF of smart home appliances, the participants include power generation enterprises, power grid enterprises, load aggregators, power users and social government (see Fig. 2). Under the policy and legal environment permitted by the social government, smart home appliance manufacturers, as load aggregators, sign load control agreements with power users to obtain the control right of household appliances terminals, match the dispatching plan of power grid, and transmit price signals and incentive measures to users.

As shown in Table 1, there are expectations on the comprehensive value of economy, security and environmental benefits of all participants. However, in the end, the government, power plants, power grid companies, end users and related industries should form a multi benefit pattern.

3.2 The Current Power Market Business Model

At present, the power market is still in the process of realizing the value conversion of power load. The power grid enterprises and other participants are in the dominant subordinate relationship. The former dominates the decision-making and benefit distribution of power load in PSVF. The participation of load aggregators is not high, and the form of participation is limited. Although there are hot topics such as virtual power plants, they mainly focus on the collection of industrial power resources, and they do not pay much attention to small and scattered household users, resulting in weak user stickiness, and the demand response construction from the user side is very limited. For consumers, they only benefit from electricity subsidies and tariff cuts.

4. Business Model of Power Market Based on Home Appliance Business Resources

In order to fully understand the process of value transformation of business resources and clarify the value flow relationship of each participant in the new business form of electric energy service, the development of business model of power market is divided into three stages: load response realization stage, scene consumption stage and flow realization stage.
Table 1  The value expectation and interest concerns of all participants in the process of smart home appliances PSVF.

| participants                  | value expectation                                                                 | interest concerns                                                                 |
|-------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| power grid enterprises        | Realize PSVF to ensure process balance; Improve load response level; Improve load smoothness; Realize load tracking; Realize energy fine management; Optimize power dispatching; Increase the stability of power generation, transmission, transformation, distribution and utilization; | Allocation of peak load reduction tasks; Planning of demand response scheduling; The monitoring, evaluation and feedback evaluation effect of demand response; Compensation and incentive of demand response; Power grid operation burden, maintenance cost and failure rate; Service life of power grid equipment; |
| load aggregators              | Obtain the economic benefits of participating in the load response of power market; Obtain power big data and its value; Develop new products, new businesses and new services based on power big data; | The cost and benefit of electricity market bidding; The cost and benefit of electricity subsidy; Energy management system development and maintenance costs; User data management costs and benefits; R & D and production cost of smart home appliances; The development value of new products, new businesses and new services; |
| power users                   | Obtain response compensation and incentive benefits (economic benefits); Realize the fine management of power consumption; Obtain the auxiliary value-added service of demand response; | Electricity cost; Electricity subsidy income; Electricity experience (power reliability, power quality); Comfort degree of household appliances; The right to control household appliances; |
| power generation enterprises  | Increase the complementarity of multi-energy integration of power supply; Develop distributed energy system; Improve the utilization rate of renewable energy; Optimize power quality; Coordinate the allocation of generation capacity; | Investment and construction cost of standby power plant; Fuel cost of generator set; Operation and maintenance cost of generator set; Environmental governance costs; The cost reduction of investment, fuel and environmental treatment formed by peak valley load transfer; Extension of equipment life; |
| social government             | Expand the new commodity form of electric energy; Reduce environmental pollution; Increase the reliability of social power consumption; Enhance the support of power big data for the development of other industries; | The impact of power grid operation risk on the market; Load resource utilization rate; The social benefits of power quality to social life stability. The economic benefits provided by electricity big data to the response data demander; |

according to the service development depth and value transformation mode. As shown in Fig. 3, the framework mainly includes equipment layer, load layer, data layer, demand response layer, business layer and application layer. With the support of information technology, power consumption technology and market-oriented means, equipment, load resources and data together constitute business resources to support demand response and business development, and finally transform into a variety of scenario applications.

Among them, the combination of energy utilization technology, information technology and market-oriented means is the main driving force to promote the development of power market business model. Energy utilization technologies include energy conversion, energy storage configuration and optimization, load flexible regulation and control, dispatching management and collaborative control, smart microgrid protection and control, which are used to promote the development of power grid in transmission, generation, distribution and transmission; information technology includes IOT, cloud computing, integrated communication, equipment monitoring and diagnosis, energy consumption detection and diagnosis, load forecasting, load response evaluation, demand response resource combination optimization, multi-functional system evaluation optimization and other technologies, which are used to promote the development of equipment centralized control, data fusion and mining, user demand analysis, resource optimization evaluation and other aspects; marketization means include market operation technologies such as combination pricing mechanism, demand response market transaction mechanism and settlement system, which are used to promote the innovation of market operation form and the customer satisfaction of market entities.

4.1 Stage 1: Business Model of Load Response Realization

1) Value flow relationship
With the transformation of electrical appliances to the grid, distributed energy storage equipment and power terminals can be centralized control and operation and maintenance. The current electricity market is also heading for the first stage of development in the first stage, namely the business model of load response realization. All participants in the electricity market mainly aim to complete the peak valley load transfer, investment income and government subsidies, and users are in a passive state of participation. Power load flow is the main value carrier (see Fig. 4).

Through flexible regulation of smart appliances and centralized management of regional electric energy, virtual power plants are formed for power grid burden reduction. Power generation enterprises can reduce the investment cost of physical standby power plant, the power grid can reduce the investment cost of transmission lines and supporting equipment, and power users can get red packets of electricity charges and deduction subsidies of electricity charges.

2) Typical application scenarios
Scenario 1: centralized control of smart home appliances cluster. Based on the analysis of the electricity consumption data of intelligent electric water heaters, the U + platform found that 80% of the households had the phenomenon of no power supply all day, and the actual water consumption time of users was 1-2 hours later than the scheduled water use time, which resulted in serious waste of energy consumption. Therefore, the U + platform can remotely power off the equipment cluster or switch to standby mode outside the reservation period.

Scenario 2: power dispatching based on power consumption law. Washing, cleaning cooking and other living habits
Fig. 3  Business model development architecture of power market based on business resource integration solution.

Fig. 4  Value flow relationship under the business model of load response realization.
change with the seasons, U+ platform found that users use kitchen appliances earlier in winter than in summer; due to the cold weather, the frequency of using electric water heater in winter morning and evening is higher. Based on this finding, different power dispatching plans are implemented in summer and winter, and the time interval setting of time of use price is adjusted to encourage users to use electricity at off peak.

4.2 Stage 2: Business Model of Scenario Consumption

1) Value flow relationship
With the mining of power consumption data and user data, user needs can be perceived in advance, and the service based on energy consumption scenario can be realized actively. In the stage of scenario consumption, through in-depth mining of user needs and pain points in various life scenarios, the user needs are perceived in advance, and a demand response scheme integrating smart home appliances hardware, accessories infrastructure, household electricity management system and power maintenance services is provided for users. Users are in the active participation stage. Power load flow and scenario driven business flow are the main value carriers (see Fig. 5).

By analyzing the behavior path and electricity consumption law of users in different regions and families in the process of demand response, the user portrait is constructed and the typical scenes are analyzed to realize fault prediction, personalized power consumption regulation, personalized product promotion, upgrading and maintenance of household electricity management software system and personalized settings. The power grid improves the collection mode of power consumption information, centralized control frequency, the form of power subsidy and the evaluation standard of energy efficiency. Power users receive software services, content services and data services developed under the power consumption scenario.

2) Typical application scenarios
Scenario 1: fault prediction and active repair of smart home appliances. U+ platform found that the actual water output of a household electric water heater is smaller, the heating efficiency is lower, and the holding time is shorter. Therefore, possible fault information is pushed to users through WeChat and SMS, and active repair order is generated.

Scenario 2: diversified forms of subsidies for home appliances. Targeted power compensation services to specific users (such as families with children, elderly families, and individual users) are provided. For example, for the elderly families, free air conditioning cleaning service and intelligent upgrade of household appliances system load response are given to realize automatic operation; for families with children, upgrade the safe operation mode of electric water heater.

4.3 Stage 3: Business Model of Flow Realization

1) Value flow relationship
With cross brand and cross category resource access, the platform can realize interconnection, finally, the electricity market has entered the stage of flow realization, and the value brought by user flow is sustainable and will exceed the benefits brought by power load regulation. Platform based user access flow and power load flow are the main value carriers (see Fig. 6).

With the accumulation of massive data, it is necessary to establish algorithm platform, general technology platform and application platform, increase its access to other financial, Internet and We Media platforms, and realize the mutual transformation of user traffic of major platforms. The social government obtains the data of power, energy, finance and other aspects through various platforms, which are used for urban planning, such as precision marketing and commercial location. Load aggregate business user traffic, obtain revenue from content services, data value-added services, advertising fees, keyword sales, and share traffic, bonus exchange and commodity sharing with power grid or other platforms. Power users get points to exchange gifts, content free subscription, exclusive rights and interests and
other compensation.

2) Typical application scenarios
Scenario 1: Users use power points to enter the point mall, such as Haier Haibei mall, to exchange for equivalent gifts, and increase the click through, exposure and repurchase rate of other products on the platform.
Scenario 2: Through the opening advertising business, Haier carries out advertising placement in Haibei mall and obtains advertising fees. The power grid can divide the flow, or sell the keywords searched in the platform to the browsing interconnection platform to obtain data revenue.

5. Feasibility Analysis of Business Model Development Based on Haier’s Smart Home Appliance Business Resources

Based on the power consumption data analysis, smart appliance clusters with different power consumption modes have great power saving potential. Through learning and modeling of user behavior, equipment operation and scheduling records, load response can be realized. Haier user interaction software provides full scene intelligent appliance integration solutions for users, which can realize scene-based business innovation and value realization. In addition, Haier Haibei online mall has further expanded the interface of other platforms, which makes it possible for users to realize their traffic.

5.1 Value Realization of Power Load Flow Based on Smart Home Appliance Load Data

Smart home appliances are divided into continuous power consumption and indirect power consumption according to the power consumption mode. For the continuous electrical equipment, such as air conditioning, it must operate continuously when the user needs it, and the operation energy consumption can be reduced by adjusting the operation mode; for the indirect electrical equipment, such as electric water heater, it can support the operation in idle time, and the energy consumption and waste can be reduced by adjusting the operation time to maximize the operation effect.

Intelligent electric water heater belongs to indirect electrical equipment, continuous start-up is easy to heat repeatedly, resulting in energy waste and other contradictions. According to statistics, 80% of households have the habit of not cutting off power all day. In addition, as shown in Fig. 7, the actual water consumption time of households is significantly delayed compared with the scheduled water consumption time. The delay time is generally 0.5 to 2 hours, and some even 4 hours, which leads to serious energy consumption restriction and waste. The U+ platform can learn the heating and water consumption by establishing the water use learning model, and obtain the water use law, so as to accurately predict the user’s future water use time, water consumption, heating mode, etc. (see Fig. 8), so that users can automatically shut down or reduce the set temperature when they are used to heating well at the right time. The platform supports 2 million water heaters online calculation at the same time, the preheating time of the equipment is shortened to 5 minutes, the hot water output rate is as high as 90%, the online time of electrical appliances is reduced by 2.5 hours/day, and the power consumption of a single unit is saved by 6kWh/day.

According to statistical, the domestic market of house-
hold air conditioning products is about 400 million, with an annual increment of 40 million. In 2020, intelligent air conditioners account for 70% of the total number of air conditioners in China [31]. Through the data analysis of the monthly operation frequency, time period, wind speed and temperature setting (see Fig. 9), it is found that July is the month with the highest operation. Winter is the second peak of the whole year. Therefore, we choose to start automatic energy-saving equipment in summer and winter for energy-saving intervention (see Fig. 10). In August, each equipment participated in energy-saving 21 times on average, and in November 74% of users started energy-saving equipment. In the summer of 2017, a total of 1453756 kWh was saved, reducing 31.6% of the power consumption for users on average.

5.2 Value Realization of Business Flow Based on Haier Zhijia App

Haier Zhijia App is a user interaction platform for smart home appliance management, real-time monitoring, scene management and active service.

For users, by registering on the app, filling in user information and connecting Haier smart appliances with Bluetooth, they can obtain device operation information, centralized intelligent regulation and control, and obtain home full scene intelligent device regulation and control solutions. In addition, by participating in load demand response, users can obtain cash bonus or user points.

Haier, as load aggregator, guides users to buy home appliances by linking smart home appliances in different scenarios, or exchange cash red packets and user points for home repair and other services (see Fig. 11).

5.3 Value Realization of User Flow Based on Haier Haibei Online Mall

Haibei mall is an online platform for all users to exchange Haibei points for rewards. It is composed of Haizhiyou, Haier community, Haier marketing activities and other Haibei points from Haier’s interactive channels.

For users, Haibei can be used to exchange for physical gifts, cleaning and maintenance of Haier products, extended service, and other value-added services.

For Haier, as load aggregator, thanks to the user flow drainage of Haier Zhijia app, the B2B2C model of Haibei mall not only makes profits in the sales of Haier related products, but also cooperates with several consumer brands to earn the entry fees and sales commissions of brand merchants, as well as the revenue of advertising space in the
mall (see Fig. 12).

6. Conclusion

In the context of power market reform, load aggregators have brought the possibility of innovative business model in the power market. Among them, smart home enterprise, as load aggregator, has rich and complete user-side business resources. Its participation in the construction of PSVF demand response can promote the realization of business resource value, innovation of service mode and service content. Based on the analysis of the relationship between the participants in PSVF and the development of the current business model of the power market, a business service model of smart home appliances participating in PSVF based on cloud platform is proposed, the market value created by the business resources of home appliances is explored, and typical business scenarios are listed. Finally, taking Haier’s business resource analysis as an example, it proves that the development model of each stage is feasible.

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