Research on Simulation Requirements and Business Architecture of Automated Demand Response in Power Sales Side Market Liberalization

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Abstract. With the gradual reform of the electricity market, the power sale side liberalization has become the focus of attention as the key task of reform. The open power market provides a good environment for DR (Demand Response). It is of great significance to research the simulation requirements and business architecture of ADR (Automatic Demand Response) in power sale side market liberalization. Firstly, this paper analyzes the simulation requirements of ADR. Secondly, it analyzes the influence factors that the business development of ADR from five aspects after power sale side market liberalization. Finally, Based on ADR technology support system, the business architecture of ADR after power sale side market liberalization is constructed.

1. Introduction

DR refers to the power user's electricity behavior, that is, the user according to Grid Company issued by the price or incentive signal, consciously adjust the electricity behavior to change the demand for electricity and to achieve peak load [1-3]. At present, with the development of China's electricity market reform, power sale side market liberalization has a certain promotion for ADR [4-6]. Therefore, in order to promote the promotion of ADR in China, it is very important to research the simulation requirements and business architecture of ADR. The concept model of ADRS (Automatic Demand Response System) is proposed in document [7], and the key technologies of business requirement and system construction are analyzed. Document [8] designed an ADRS architecture based on IoT (Internet of Things) technology, and realized the monitoring of power equipment according to different modes of power consumption behavior.

Based on this, this paper studies the ADR simulation requirements and business architecture from the perspective of power sale side market liberalization. First of all, simulation requirement of ADR is analyzed from the aspects of government, enterprise and teaching research. Secondly, from five aspects respectively analyzes the influencing factors of ADR services, that is, load adaptability and user response mode, cost of user demand response, user type and its electrical characteristics, user demand response time and user load emergency, and proposes the ADR technology support system. Finally, the business architecture of ADR after power sale side market liberalization is proposed.

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2. ADR Simulation Requirements Analysis

The ADR simulation requirements is diverse. Through the establishment of simulation system platform for the state or relevant government departments develop DR policy documents, optimize operational management services, and provide decision-making support. The simulation requirements system platform can also serve the power grid development, planning, transaction and dispatching departments, and optimize the investment decision of the centralized and distributed renewable energy sources for the power generation enterprises. At the same time, it can serve teaching research to provide quantitative analysis tools and simulation platform for DR soft science research.

Specifically, ADR simulation platform through the simulation of DR system in various subjects, including it faces different circumstances and needs, and simulate the response business implementation process of renewable energy consumptive demand situation. In the simulation process of DR business, changes in the supply area of power flow based on the DR user analysis and the DR resource equipment power absorption or release situation analysis, to provide decision-making basis for the relevant government departments to formulate relevant policies. The simulation platform can also provide services for DR Service providers, DR aggregators and power users, such as simulation, organization implementation, simulation participation, implementation effect simulation and evaluation. Through simulation platform for DR implementing agency carry out simulation deduction and personnel training. At the same time, through simulation and validation of implementation effect and strategy function of the DR plan, the system provides a systematic simulation test tool for universities and research institutes engaged in DR research.

3. Factors Affecting the Development of ADR Services

The factors affecting ADR business development in power sale side market liberalization include the following.

3.1. Load Adaptability and User Response mode

The possibility of power users' participation in ADR (provide DR resources) depends on the ability of users to maintain the comfort of terminal requirements and the ability to use electricity at a certain level in the event of power failure or reduced demand. To this end, the following factors are used to measure the capacity of the user: the ultimate service (such as heat energy, kinetic energy, electronics, etc.) provided by the power load; the energy storage capacity; the load scheduling device; the cost of changing demand. The first three items are the technical requirements for the user to adjust the mode of power consumption, and the last one is the economic requirement. The technical and economic differences between user loads determine the response to different incentives. The user's response to the excitation signal is not limited to load shedding. If only the power supply is cut off, it will have a great impact on industrial production and residents' electricity comfort. In order to avoid bad influence behavior, the user can make corresponding response according to the electricity price information by using the electric power mode, such as interruption of power consumption, transfer of electricity, alternative energy, energy storage.

3.2. Cost of User Demand Response

Cost of user demand response refers to the user's response to the needs of the incentive signal to make changes in their own electricity costs generated by the way. Demand side resource is an equivalent supply resource, which is used to meet the demand of electricity consumption by reducing the power consumption of demand and demand side. The calculation formula of the cost of user demand response is shown in (3-1).

$$C = C(\lambda, P, \eta, t_d, t_{di}, f_i) \tag{1}$$

Among them, $C(\bullet)$ represents the user's power demand response cost; λ represents type data of the user; Q indicates the power consumption of user interrupts; η indicates type of time that the interrupt occurred; t_d indicates the duration of power interruption; t_{di} indicates the time ahead of the load interruption; f_i indicates the number of times the load is interrupted. When the incentive of demand response is price incentive, the latter three physical quantities do not work.
In the case of interruption in unit time, for the same physical condition of the interruption contract (including the user facing the same time ahead of the notice, the duration of the interruption and the time of the interruption), the main factor determining the user terminal cost is the type of user and the interruption of power consumption, that is, $C = C(\lambda, P)$.

3.3. User Type and its Electrical Characteristics

The power users in the power system can be divided into industrial users, urban residents, commercial users, agricultural users and other users. The user's DR capability depends on the electrical characteristics of the user. Taking electricity price incentive measures as an example, this paper analyzes the relationship between the user's electrical characteristics and the demand response capability through the analysis of the user load optimal response model with storage capacity.
Some air conditioners, electric heating units and electric water heating systems in large businesses have certain thermal storage capabilities. Companies with captive power plants also fall into this category. Therefore, the load optimal response model of the user with storage capacity is:

$$C_{opt} = \min_{u_k}[\sum_{k=1}^{N} \rho_k \times E_k] \tag{2}$$

s.t.

$$X_{k+1} = X_k + E_k - W_k \tag{3}$$

$$X_N = X_0 \tag{4}$$

$$0 \le X_k \le X_{\max} \tag{5}$$

$$P_k \ge 0 \tag{6}$$

Among them, C_{opt} represents the total cost of optimization; k indicates the period of change in the price of electricity, and N indicates the total change period of the electricity price; ρ_k represents the price of electricity during the k period; X_0 represents the initial energy storage capacity; X_k represents the energy storage capacity of the k period; X_{max} represents the maximum energy storage capacity; Ek represents the maximum energy consumption; W_k represents the energy consumed by the k period. Formula (3-3) means that E_k is primarily used for energy storage when the system is at a low ebb (k period is at night) and W_k is smaller. When the system is at its peak, the electrical energy E_k is smaller, and the production consumption W_k is taken from the stored energy X_k. According to this formula, it is not difficult for users to determine the optimal use of electrical energy at each price period. Because of the energy storage, users cut back more energy and demand during peak periods, reaching the goal of demand response. This type of load is the most appropriate type of load in an automatic demand response.

3.4. User Type and its Electrical Characteristics

When the power users of different load characteristics participate in the response measures of ADR, the ADR implementing agency will participate with the power users according to the time stipulated in the contract. In the contract, the response time is related to the time of advance notice and the duration of the interruption.

3.5. User Load Emergency

Usually, during the peak hour period, the load of the whole area is ensured by means of shifting peaks and averting peaks. Power rationing measures are based on the nature and reliability of the user's work. When the power supply is in short supply, we must ensure the reliability of the electricity supply of important units and infrastructure such as schools, troops and hospitals. At the same time, we should take into account industrial and commercial electricity consumption, and strictly limit the enterprises that do not meet the national industrial policies and enterprises with high energy consumption and enterprises that have not installed load monitoring devices. Therefore, it is necessary to sort the users according to the importance of the load.

4. ADR technical support system

The automatic demand response is based on an integrated high-speed two-way communication network, through the advanced sensing and measurement technology, equipment technology, control method and application of decision support system, realize the reliable, safe, economical, efficient and environment-friendly target of the power grid. Specifically, the technical support system for demand response is shown in figure 1.

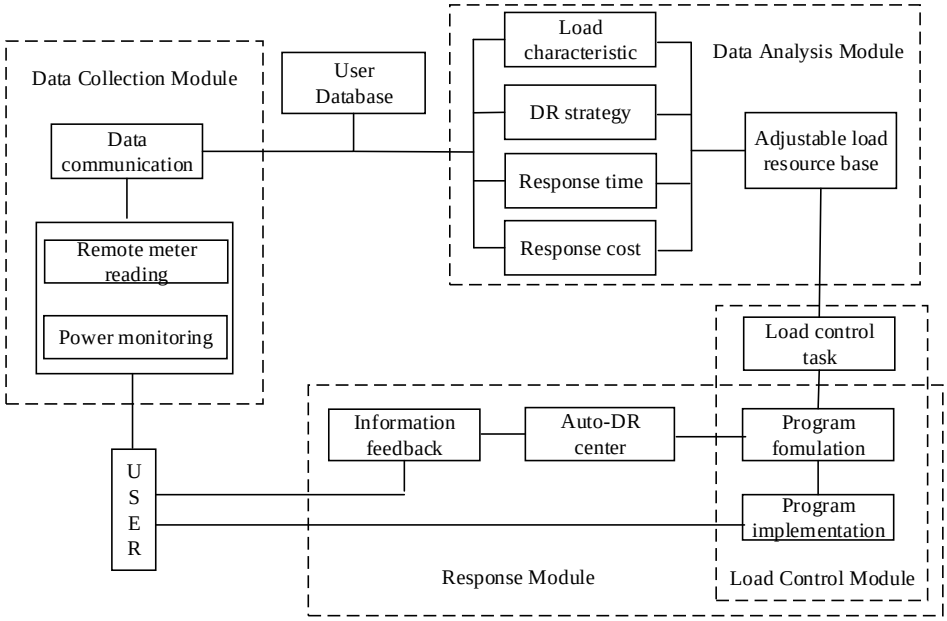

Figure 1. ADR operation flow chart

Specifically, the ADR technology support system can transfer data and organize data after user data collection, thus forming an adjustable load resource library. Secondly, according to the identified load control tasks, formulate and implement the program. Finally, the user's information is fed back to the automatic demand response center, and finally the two-way interaction between the user and the grid enterprise is realized.

In Figure 1, the technical support system of ADR includes data collection, data analysis, load control, and response modules. The modules are functionally independent but supported by information flow.

(1) Data collection

The module mainly includes remote meter reading, power monitoring and data communication. Data collection is automatically recorded and collected by the monitoring equipment installed on the user side, and the user's data is collected, and the user database is formed to provide accurate customer power information for the automatic demand response center.

(2) Data analysis

The module is mainly for information from the user database analysis, including load characteristics, demand response participation potential, acceptable response time, and the estimated cost from the power users. Based on the result of data analysis, the customer voluntarily signed the automatic demand response agreement. The data of the power users signed have been aggregated to form an adjustable load resource repository, which provides the basis for the load control task.

(3) Load control

The module contains four sub modules: load control task, program formulation and scheme implementation. The module sets up load control task and control plan for the adjustable load resource library, and selects the best implementation plan. On this basis, load control information is sent to power users in the adjustable load resource repository for implementation.

(4) Response modules

The module includes four sub modules: program formulation, program implementation and information feedback. As the connection point between the user and the demand response service provider, the response module receives the response information from the user and feed it back to the automatic requirements response center. According to the feedback information, the center decides whether to develop a new load control scheme to realize the interaction between the user and the demand response service provider.

5. Business Architecture of ADR in Power Sale Side Market Liberalization

The main participants in ADR include power suppliers, regulators, load integrators and resident users. Power suppliers are the policy makers and project publishers of demand response, which are the demand side of demand response service. Regulators are generally governments that oversee the process and effectiveness of demand response business. As a third-party service provider, load integrators provide a unified market channel for demand side resources of widely distributed and the individual rarely demand for DR resources.

The business architecture of ADR is shown in figure 2. After analyzing the running status and demand of power grid, the power supplier makes the DR plan and releases the plan to the load integrator and user. The power users with large demand for DR resources can respond directly to the demand response program issued by the power supplier, and power providers evaluate and settle user DR execution results. The power users with less demand for DR resources participate in DR through the load integrator, and respond to the demand response program issued by the power grid enterprise by the load integrator. The load integrator decomposes the execution of the response to the user involved in the aggregation service. In the process of participating in the demand response, there are two kinds of business modes for users, that is, buyer response and seller response. The buyer responds to and purchases a load curtailment, and the buyer needs to cut back on the load. The seller receives the amount of electricity is vacancy.

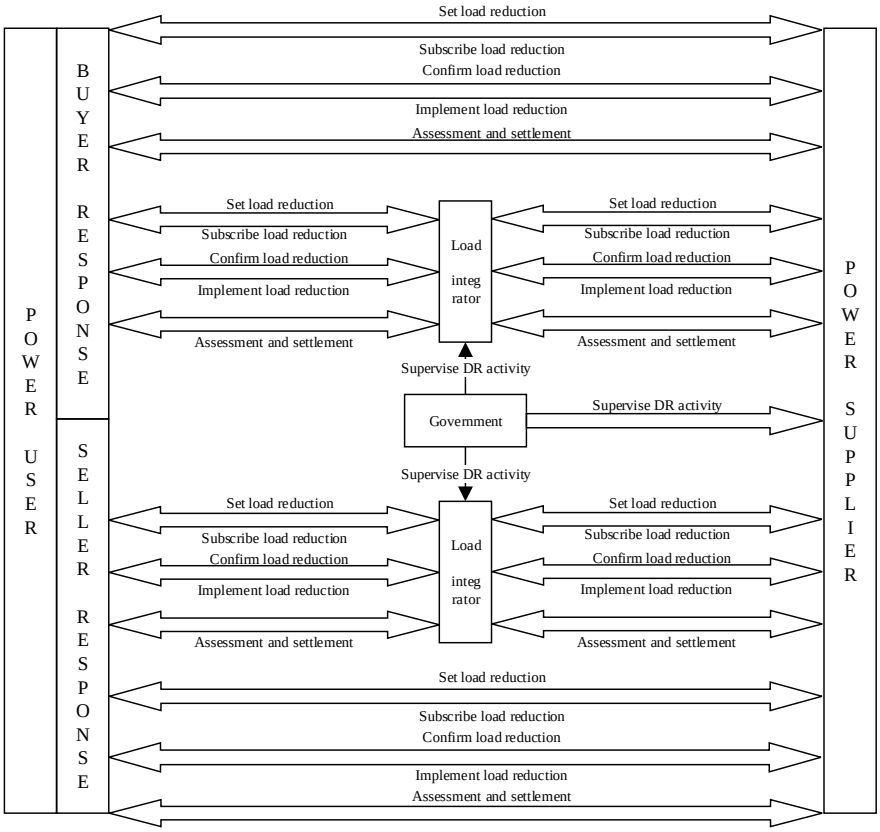

Figure 2. Business architecture of ADR

6. Conclusion

Firstly, this paper analyses the simulation requirements of ADR. Secondly, From five aspects respectively analyses the influencing factors of ADR services, that is, load adaptability and user response mode, cost of user demand response, user type and its electrical characteristics, user demand response time and user load emergency, and proposes the ADR technology support system. Based on this, the business architecture of ADR after power sale side market liberalization is proposed.

Power sale side market liberalization provides a good opportunity for the market and commercial operation of ADR. With the gradual liberalization of power sale side and continuous development of the smart grid, China should build up the business framework and operation mode of the foreign DR technology. Combined with the actual development of China's power market, to promote the maturity of demand response technology. Constantly improve the demand response standards, and rapid development of demand response to new technologies, as soon as possible to achieve automatic demand response in China's application and popularization.

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References

[1] GAO Ciwei, LIANG Tiantian, LI Yang. A survey on theory and practice of automated demand response [J]. Power System Technology, 2014, 38(2):352-359.

[2] LI Yang, WANG Beibei, SONG Hongkun. Demand side response and its application[J]. Power Demand Side Management, 2005, 7(6):13-15.
[3] ZHANG Qin, WANG Xifan, WANG Jianxue, et al. Survey of demand response research in deregulated electricity markets[J]. Automation of Electric Power Systems, 2008, 32(3):97-106.
[4] GAO Ciwei, DONG Li, SUN Lingling, et al. Demand response under deregulated electric power retail market[J]. Distribution and Utilization, 2017, 34(3):21-25.
[5] PEI Haibo, SUN Chang. The influence of the power sale side market liberalization on the demand response implementation model[J]. China Power Enterprise Management, 2016(36):49-50.
[6] LIU Shungui, SUN Chenglong, SUN Jie, et al. Design of agency and participation mechanism of DRRs with sale-market released[J]. Proceedings of the CSU-EPSA, 2017, 29(5):115-121.
[7] ZHANG Jing, SUN Wanjun, WANG Ting. Studies on requirements and architecture for automated demand response system[J]. Proceedings of the CSEE, 2015, 35(16):4070-4076.
[8] SHEN Minxun, SUN Yi, LI Bin, Study on the architecture and application of the automatic demand response system based on the technology of IoT[J]. Electrical Measurement and Instrumentation, 2014, 51(24):96-100.