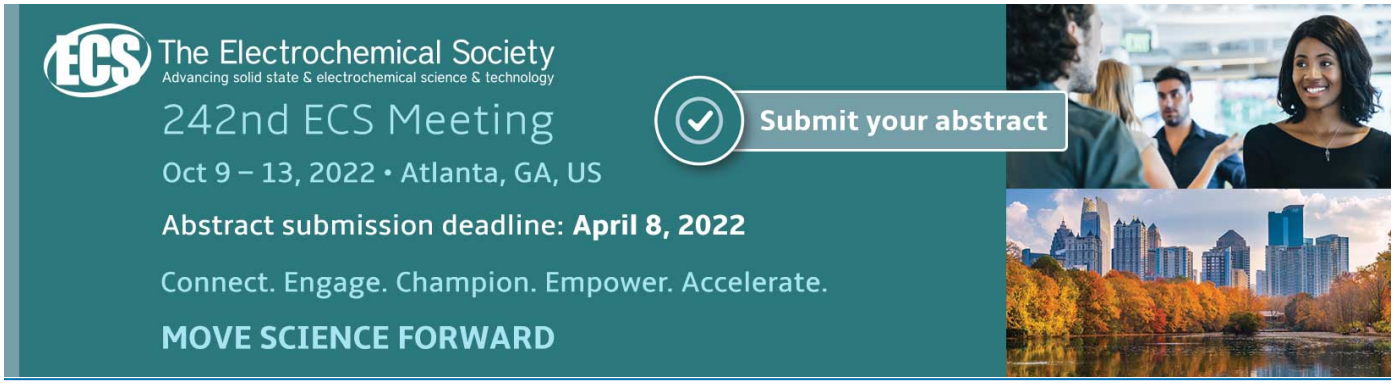
Research on Flexible Interaction Mechanism of Source-Grid-Load-Storage Based on Customer Ubiquitous Electricity Internet of Things Technology



Research on Flexible Interaction Mechanism of Source-Grid-Load-Storage Based on Customer Ubiquitous Electricity Internet of Things Technology

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Abstract: The use of customer-side flexible and controllable load resources to respond to the consumption of clean energy dispatch can significantly reduce the amount of wind abandoning. In this paper, based on Load Segmentation technology, intelligent energy gateway technology, intelligent matching technology, and customer-side flexible load management platform technology, effective practices have been implemented in the aspects of the interaction mechanism， electricity market transaction mechanism and intelligent dispatch response mechanism. It has a good effect on the consumption of clean energy in Jilin Province.

1.Introduction

Flexible load refers to a load with flexible characteristics that can actively participate in grid operation control and interact with the grid appropriately. At present, the flexible load that can be adjusted in Jilin Province is mainly electric heating load. Electric heating flexible loads include water storage, solid storage, direct heating electric boilers, electric radiators, heat pumps, and geothermal cables. As of the end of 2018, there were a total of 53,232 electric heating users in the province, with a total electricity capacity of 2.0348 million kilowatts and heating area reached 24.98 million square meters, accounting for 2.58% of the province's total heating area, of which the total capacity of thermal storage electric heating accounted for about 20 %, about 400,000 kilowatts.

In recent years, relevant scholars and experts have done a lot of research on demand response, load aggregator operations, and DRA control strategies. Literature [1] selects ice storage air conditioners as the research object. Under the concept of load aggregators, it analyzes the scheduling potential of controlled users, and builds a scheduling model, which is based on an incentive to purchase abandoned wind power at low prices and minimize the operating costs of aggregators. Literature [2] based on the two-stage interaction model between load aggregators and users and master-slave game to establish the pricing strategy of load aggregator. Literature [3] puts forward a business model which is suitable for China's national conditions and oriented to the demand side active response. Literature [4] summarizes the research and practice of developing LA business abroad, summarizes the definition and role of LA from the perspective of integrating demand response resources, and classifies its control resources, including simple adjustable load, energy storage device and distributed generation. Literature [5] proposed the specific interaction between DRA and system operators, retailers, and end

users, and put forward the high-level operation process of DRA marketization. The model of DRA control strategy considering the uncertainty of load response is established. Literature [6] established a load aggregator bidding decision optimization model based on two demand response contracts, load reduction and load shift, so that the aggregator can effectively dispatch the user's controllable load. Literature [7] proposed an evaluation method of household electric heating load adjust-ability based on temperature forecast. Based on realizing the evaluation of electric heating load adjust-ability, it proposed a cluster processing method for electric heating load and homogenized aggregation based on parameters. Based on the model's electric heating load cluster control strategy, it is convenient to study the electric heating load aggregation control mechanism.

2.Flexible interaction system between source, network, load, and storage

The load-storage flexible interactive system of Jilin power source network mainly includes "1 process, 3 mechanisms". A process mainly refers to the process of customer-side flexible load participation in the power market. The three mechanisms are flexible load aggregation management mechanism, source network load-storage interactive transaction mechanism, and intelligent dispatch response mechanism.

2.1Customer-side flexible load participation in the power market

The process of customer-side flexible loads participating in the power market mainly includes: 1) Decentralized flexible load aggregation, which aggregates flexible loads such as buildings and homes through the load aggregation management mechanism; 2) Participating in market quotations. Electric heating users and load integrator make quotations for abandoning wind and light through the electricity trading platform;3) Market clearing. The power trading center shall make clear according to the quotation and network constraints of both parties; 4) Issue market orders. According to the information provided by the trading center, the power grid dispatching center issues control instructions; 5) Flexible load response. Electric heating users or load integrator participate in the response through remote automatic control, manual control, etc.; 6) Market settlement. According to the interactive situation of flexible load, the system automatically calculates the response incentive, and settles the incentive expenses through "daily settlement", "daily settlement" and other methods.

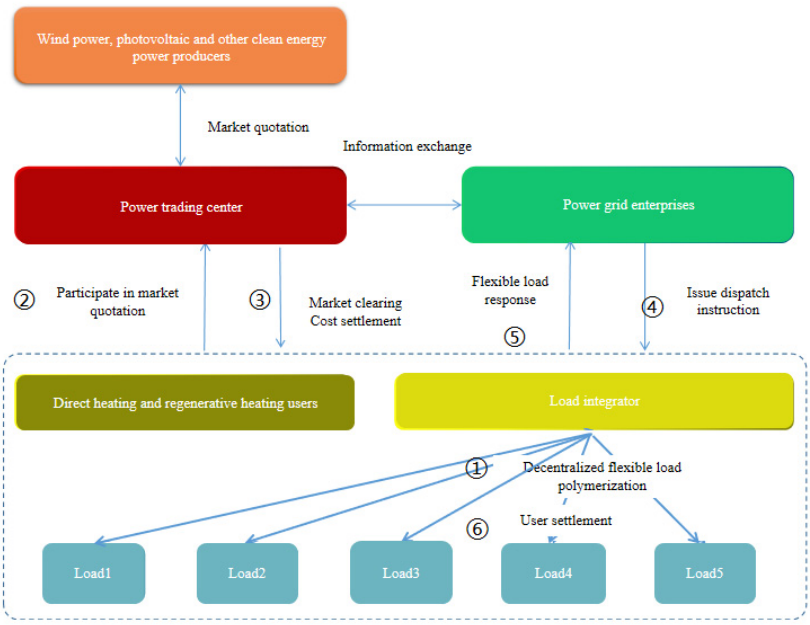

Figure1 Customer side flexible load participating in power market process

2.2Flexible load aggregation management mechanism

Flexible load aggregation management mainly refers to the use of market-oriented methods through online service channels such as integrated energy service platforms, green state grid, online state grid, offline service channels such as gateway account managers, grid managers, and electric heating equipment providers, building property management and other customer-side ecological customer channels. Learning from the Internet thinking, carry out the design of emergency, economic, auxiliary service, and other flexible interactive products, promote multi-channel access to all kinds of flexible load users to make users have the willingness to participate in the interaction, sign an interactive agreement with power grid enterprises, obtain incentives through participation in the interaction, and then continue to actively participate in the interaction of a set of management mechanism.

Figure2 The framework of Jilin Electric Power Flexible Load Aggregation Management System

2.3Source network load-storage interactive transaction mechanism

The source network load storage interactive transaction is mainly to promote the clean energy consumption capacity in the province. Combined with the characteristics of the large inertia of the cold and thermal systems, it can provide energy storage standby services, and is suitable for participating in various auxiliary service market operation mechanisms. By establishing the energy market and auxiliary service market optimization model including different energy flows such as electricity and heat, the power trading center organizes the monthly transaction, D-3-day transaction, spot trading within days, which is carried out by the buyer (direct heating and regenerative electric heating users, power selling companies) and the seller (wind power and photovoltaic power generation enterprises) through the support system of the power trading center (hereinafter referred to as "power trading platform") . The buyer and the seller voluntarily participate in the market, determine the transaction power and price according to the priority of the main quotation of the market, and pay the price through centralized bidding, which can significantly improve the acceptance capacity of clean energy such as scenery.

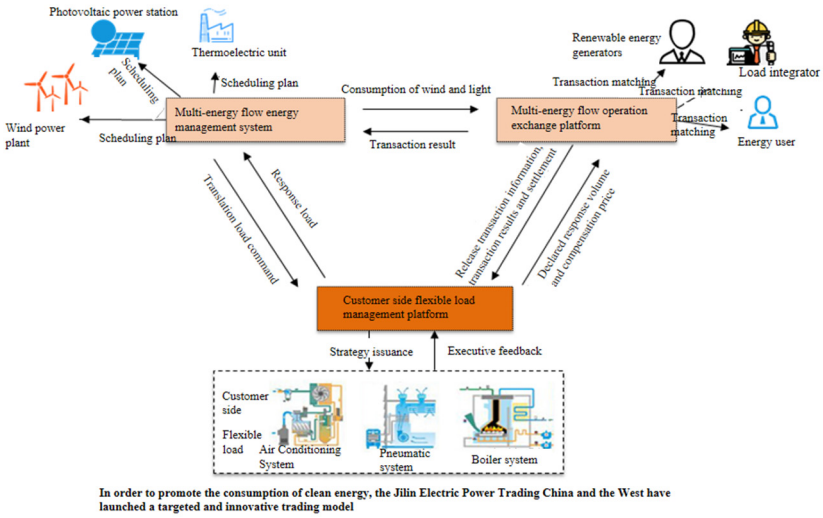

Figure 3 Schematic diagram of the interactive transaction mechanism between source network and storage

2.4Intelligent dispatch response mechanism

Intelligent scheduling response mainly refers to the real-time scheduling of flexible load to realize the absorption of abandoned wind and light (Load following network dynamic). The basic mode of load following network dynamic mechanism is as follows: the index of wind abandoning and light abandoning consumption is determined by dispatching platform data, and the index of wind abandoning and light abandoning consumption is distributed to each flexible load user through the intelligent load distribution strategy set by the system. The formulation of load distribution strategy should consider not only the scalar but also the priority of load distribution.

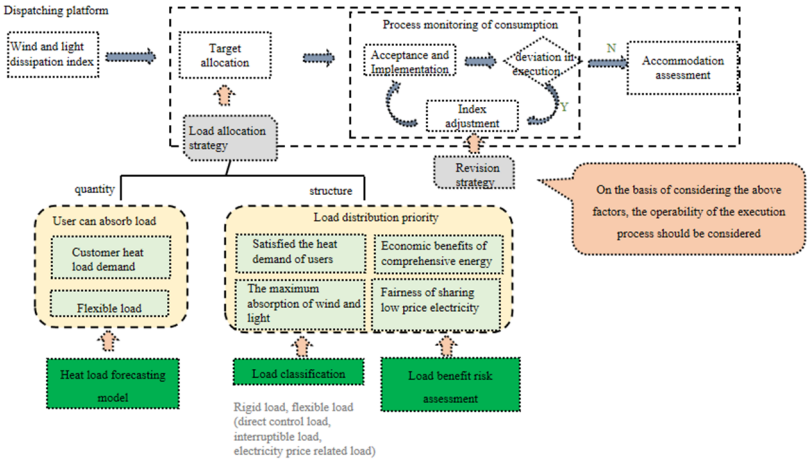

Figure 4 Schematic diagram of intelligent scheduling response mechanism

3.Key technologies of flexible interaction of source network load storage

3.1Flexible load subdivision technology

Flexible load subdivision technology mainly refers to the use of AI technology BP neural network algorithm to analyze massive information and build electric heating data analysis model based on the basic information of urban electric heating users such as natural conditions, equipment operation and equipment construction cost, so as to comprehensively and objectively reflect the suitable population and optimal use mode of electric heating market, so as to achieve the purpose of tapping potential

users and precision marketing. Basic information includes customer type, heating area, use type, electric heating capacity, installation time, implementation price and other basic customer information; The operation cost, service life, suitable place and other electric heating construction cost information of different heating modes; Outdoor temperature change, customer's temperature demand, customer's heat habits, energy use site category and building energy saving and other information outside the system affect the use of electric heating.

In the actual modeling process, through the data analysis of electric information acquisition system and marketing business application system, we can obtain the characteristics of user type, average indoor heating temperature, indoor area, monthly heating time, heating power consumption, current year electricity price, heating equipment investment, average total investment, etc. These features are used as the input of PCA algorithm. These features are combined into a high-dimensional vector and projected into a low dimensional vector space through a special eigenvector matrix U. Low dimensional vector is the input of BP neural network, that is, the main feature vector. After dimensional reduction, the remaining features are housing area, user density, electricity price, demand temperature, heating time, construction cost, external temperature and so on.

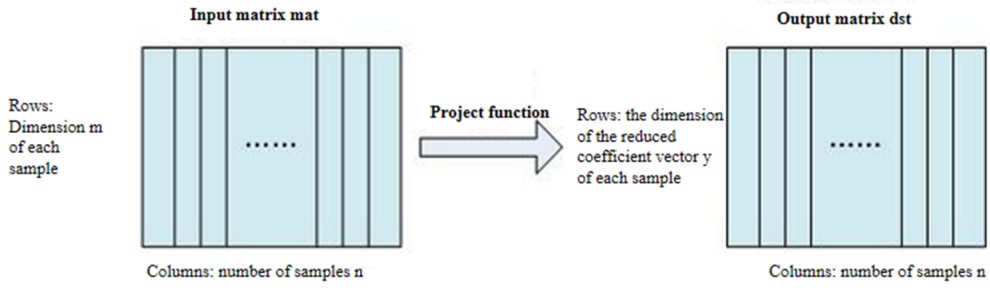

Figure 5 Projection of high dimensional vector to low dimensional vector

In the process of modeling using BP neural network, a single sample has eight inputs and six outputs, and there are usually several hidden layers between the input layer and the output layer. Therefore, the BP neural network is divided into input layer, output layer and middle layer, which is an 8-dimensional to 6-dimensional mapping. BP neural network can be trained by inputting training set, which plays an important role in subsequent user recommendation.

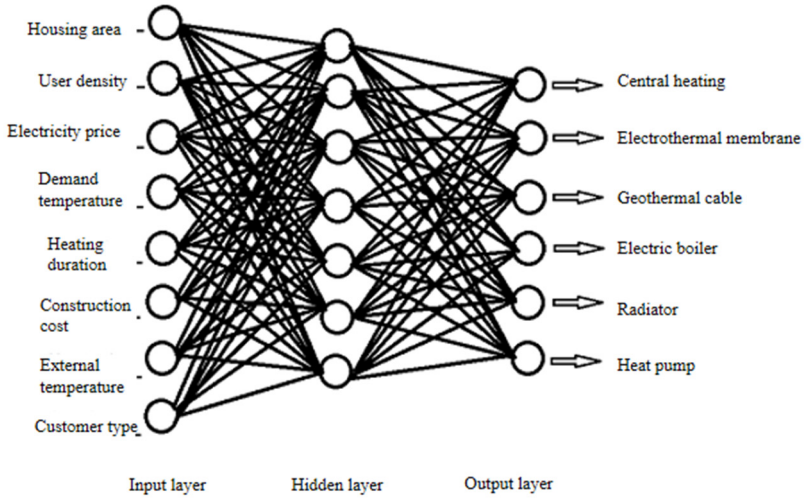

Figure 6 Mapping of BP neural network

3.2Flexible load forecasting technology

Flexible load forecasting technology is to build multiple user's load forecasting models by analyzing

the information data of flexible load (equipment file information, equipment historical operation status, historical gateway load), meteorological data, holidays, and other information data. According to different algorithms to construct multiple user's load forecasting models, then use the optimized combination forecasting technology to weighted average the prediction results of multiple models to forecast the load at 96 points on the next day.

At present, electric heating load is the main flexible load in Jilin Province, including water storage, solid storage, direct heating electric boiler, electric radiator, heat pump, geothermal cable. The working principle and operation condition of different loads are different, there are six types of models according to the equipment type. Take a certain type of equipment as a demonstration to build a model. When the model reaches a certain accuracy, other types of equipment will be optimized based on this model and combined with their own characteristics. The specific implementation process is as follows:

Data processing. According to the collected flexible load information data, meteorological data, holidays, and other information data to construct characteristic. Through the correlation coefficient, information entropy, mutual information, and other methods to analyze the correlation between each characteristic index and the gateway load, select the characteristic index used to build the model.

The ARIMA algorithm is used to construct a time series model based on the gateway load, and the parameters suitable for the model are determined by analyzing the trend and changing law of the total data. The full name of the ARIMA model is the Auto-regressive Integrated Moving Average Model (ARIMA), which is a Time-series Approach prediction method proposed by Box and Jenkins in the early 1970s. AR is auto-regressive, p is auto-regressive term; MA is moving average, q is the number of moving average terms, and d is the number of differences made when the time series becomes stationary. The ARIMA model is a model built by transforming a non-stationary time series into a stationary time series, the dependent variable only regresses its hysteresis value and the present value and hysteresis value of the random error term. For non-stationary time series, it can be converted into a stationary series by difference, which is to replace each observation in the time series with .In a p-order auto-regressive model, each value in the sequence can be represented by a linear combination of the previous p values. is any observation in the time series, μ is the mean value of the sequence, β is the weight, and t is the random disturbance.

$$AR_{(p)}: Y_t = \mu + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t$$

Using the neural network algorithm to build a regression model (characteristic indicators as independent variables and gateway load as dependent variables). Take the appropriate training sample set and test set, input the sample set to the neural network, continuously optimize the parameters to improve the output accuracy.

3.3 Intelligent load matching technology

As a generalized energy storage system, regenerative electric boiler is a typical flexible load object. By controlling the operation of electric flexible load such as regenerative electric boiler, it is an undoubtedly effective means to solve the problem of wind abandonment. Based on effective online monitoring and centralized control of user equipment, it is particularly important to formulate a strategy of "not only meeting the heating needs of users, but also achieving the rational use of resource library resources".

Matching strategy 1: Give priority to meet the rigid needs of users

Satisfied users' demand for heat consumption is the basic requirement of policy matching. Therefore, the load of users' needs to be decomposed reasonably. It can be divided into two categories: the first is rigid load, which refers to direct heating to meet the heat demand of users. The second type is flexible load, which refers to the heat storage capacity of thermal storage boiler. The user's thermal load forecasting model is as follows:

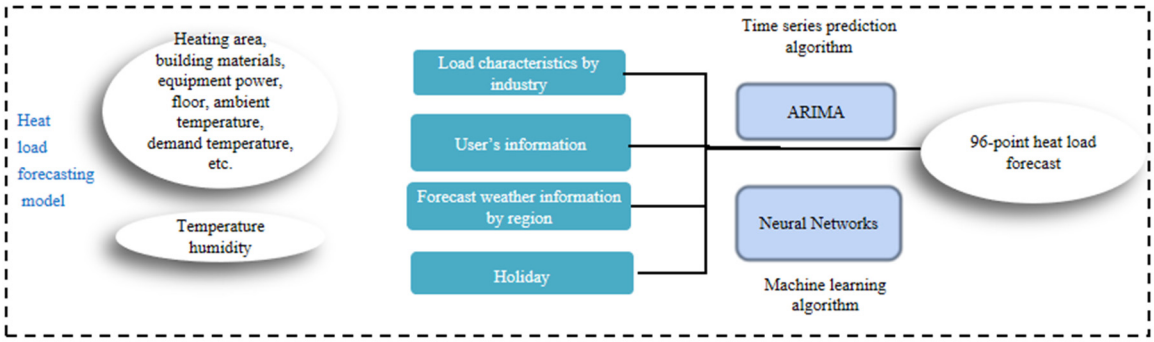

Figure7 Schematic diagram of user heat load forecasting model

Matching strategy 2: Flexible load is based on direct control load

The remaining load after the rigid load is allocated is stored in the form of thermal energy and matched according to the characteristics of each flexible load type. It can be divided into 3 types: the first type is direct control of load. It refers to the user equipment which can be directly remote controlled and belongs to the high reliability controllable load; The second type is interruptible load. It refers to the manual operation of the user, but it needs to pay liquidated damages for breach of contract, and the reliability is slightly low; the third type is the electricity price related load. It refers to the operation of users according to price stimulation, without penalty, and the lowest reliability. Considering the short-term nature of wind and light curtailment, the matching strategy is based on direct load control, supplemented by interruptible load, and the load related to electricity price is not involved. In order to ensure the stability of wind and light dissipation and keep the load stable, the principle of direct control load distribution is to ensure that the same level of heat storage capacity is fully stored at the same time, the schematic diagram is as follows:

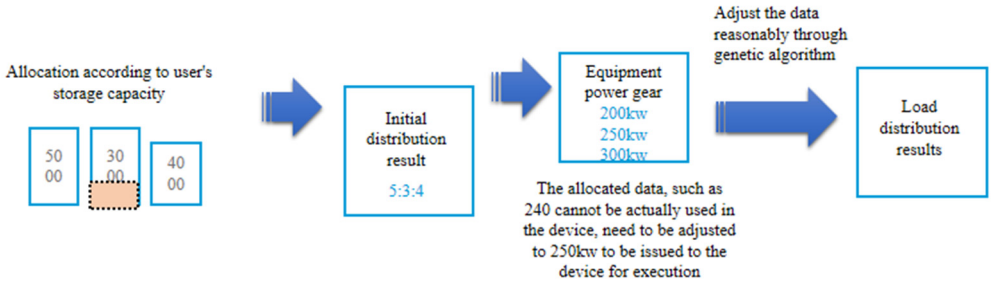

Figure 8 Schematic diagram of the principle of direct control load distribution

Matching strategy 3: Economy and fairness of flexible load

Economy refers to the price of contracts signed with users while considering the balance of load matching as mentioned above, while maximizing the economic benefits of the comprehensive energy company and the fairness of users' perceptions.

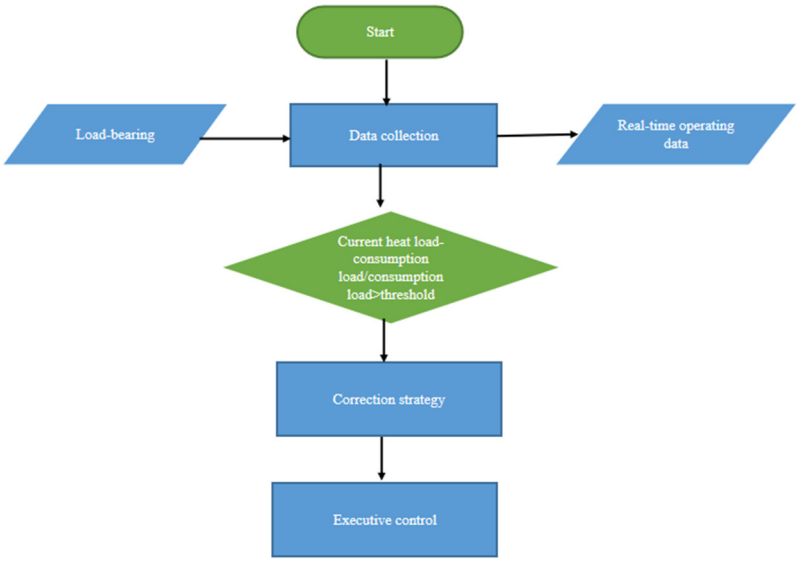

Figure 9 Schematic of the implementation of the correction strategy

3.4Customer side flexible load management platform

Customer side flexible load management is based on the strategic deployment requirements of the State Grid Company to build the ubiquitous power Internet of things, expand customer side energy service and transform comprehensive energy service providers, through the flexible load management platform on the customer side, it can realize the aggregation management, energy consumption data acquisition, real-time monitoring and load optimization control of the adjustable load on the customer side of electric heating. According to the market-oriented trading system, release the clean energy output curve, and guide the users to use the abandoned wind and light power during the low period according to the user's adjustable situation, to promote the consumption of clean energy. The overall architecture of customer side flexible load management platform is as follows:

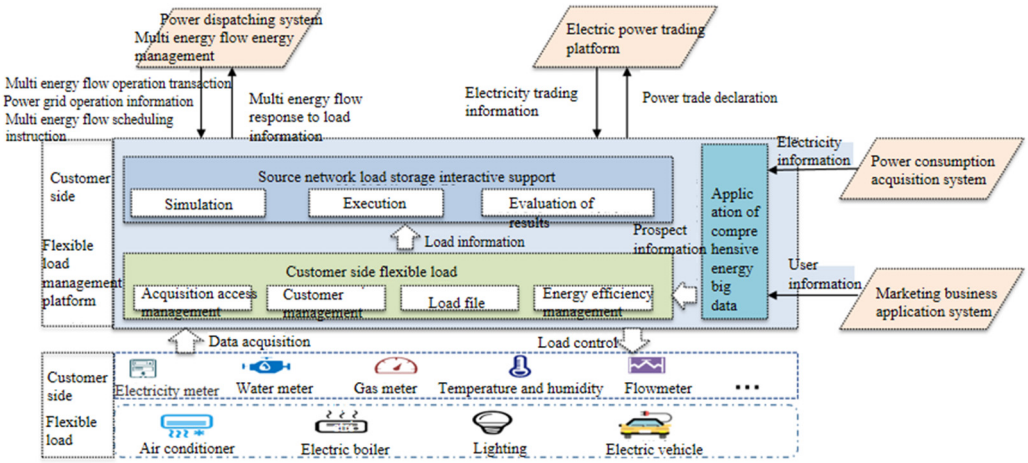

Figure 10 Architecture of customer side flexible load management platform

The overall architecture of customer side flexible load management platform includes the following three main parts:

Based on the marketing business application system, electricity information collection system of customer information, electricity information, through big data mining analysis, realize electric heating, electric energy substitution and other potential customers mining.

4.Summary

Since the construction of load storage flexible interactive service system of Jilin power source network, great management, economic and social benefits have been achieved. In 2018, the annual electricity consumption of electric heating will be 1.293 billion kWh, which will increase the power consumption of the whole province by 1.72%, improve the on-site consumption capacity of clean energy, and boost the decline of wind curtailment rate by 4%. It is estimated that the wind curtailment power consumption will be 109 million kWh. Through the implementation of flexible load management project, the effective generation hours of power generation enterprises are improved, and the generation income is increased by 10 million yuan. It is verified that the "Load following network dynamic" is effective, which plays a significant role in promoting the development and consumption of new energy and responding to the national clean energy heating. In the next five years, the electric heating area is expected to increase to 42 million square meters. At the same time, it also has a significant effect on environmental optimization. It is estimated that within five years, through the implementation of clean energy projects, the cumulative emission reduction of sulfur dioxide 4841 tons, nitrogen oxides 4215 tons and dust 387300 tons, it will play a positive role in improving the air quality of the whole province.

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