Demonstration of Friendly Interactive Grid Under the Background of Electricity Market Reform in China

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***Abstract*—The Friendly Interactive System of Supply and Demand (FISSD) is a large-scale demonstration project supported by *Ministry of Science and Technology of the People's Republic of China*, which provides an effective solution towards the problems in the development of future electric power systems, such as the increasing penetration of renewable energy sources (RES), the growing peak-valley difference of loads and the development of ultra-high-voltage (UHV) power grid. The FISSD project will take advantage of the advanced information and communication technologies (ICT) to achieve an effective interaction between customers and the power grid. Moreover, some innovative business models will be put forward and implemented in the demonstration area under the new round of electricity market reform in China. The objectives of the FISSD are to reduce the peak-valley difference of loads by 5.8% and the comprehensive energy consumption of residential customers by 5.5% at the end year of the project in 2020, compared with the start year 2016. The FISSD project will be demonstrated in two cities of Jiangsu Province, Suzhou and Changzhou, where the resident population is 2.38 million. Around 110,000 residential customers will be selected and equipped with smart devices to participate in the project. This paper provides an overview of the FISSD project and the launched pilot policies.**

Keywords—demand response; flexiable loads; smart grid; electricity market

NOMENCLATURE

RES	-	Renewable energy sources
UHV	-	Ultra-high-voltage
ICT	-	Information and communication technologies
DR	-	Demand response
DRP	-	Demand response provider
DSM	-	Demand side management
EMS	-	Energy management system
FISSD	-	Friendly Interactive System of Supply and Demand

I. INTRODUCTION

Renewable energy sources (RES) are paid more attention to deal with the environmental pollution. However, the RES power generations are intermittent, which bring fluctuations to the electric power system [1]. Therefore, the balancing services between supply and demand become more important. Moreover, the peak-valley difference of loads is growing continually in China due to the high proportion of air conditioner loads [2]. In general, the balancing services and peak-load regulation services are provided by traditional power generators, e.g. thermal power units and gas power units. However, it may not be sufficient in the future because the non-RES power generations probably are phased out gradually.

Intelligent household appliances become widespread and easy for customers to monitor and control remotely [3]. The advanced information and communication technologies (ICT) make it possible for these intelligent appliances to assist system balance from demand side, which is called demand response (DR) [4]. Some researches of DR have been made. For example, the transmission system operator can utilize thermostats as regulating resources with little negative impact on device performance [5]. Customer's satisfaction and system's operation cost are optimized based on a fuzzy logic approach in [6]. Moreover, some projects of DR have been implemented, for example, the emergency response service in ERCOT Region and the heat pump project in Denmark [7], [8].

With the release of "No. 9 Government Document" in 2015, a new round of electricity market reform was launched in China [9]. The DR is paid more attention in this document for increasing the flexibility of the power system. Following on this country's document, several provincial documents about specific implementation details of DR are also launched. Moreover, a large-scale demonstration project—Friendly Interactive System of Supply and Demand (FISSD)—was started in 2016 in Jiangsu Province, which aims at reducing the peak-valley difference of loads and the comprehensive energy consumption of residential customers. In addition, the FISSD also provides an effective scheme of enhancing the system reliability to the provinces that act as the receiving end of ultra-high-voltage (UHV).

The rest of the paper is organized as follows. Section II analyzes the new challenges of smart gird in China. Section III demonstrate the launched pilot policies about DR and the obtained beneficial effects to the system. The FISSD project is introduced in Section IV. Finally, the conclusions are presented in Section V.

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II. NEW CHALLEGNES OF SMART GRID IN CHINA

A. The Increasing Penetration of RES

The development of RES starts relatively late in China compared with the developed countries. However, the deterioration of environment and the shortage of energy resources make Chinese Government pay more attention to RES in recent years. For example, the installed capacity of wind power and photovoltaic power are booming in the past few years, as shown in Fig. 1 [10]. It can be seen that the average growth of these two main RES are 36GW per year. China already has the largest installed capacity of wind power generations since 2012 and the largest installed capacity of photovoltaic power generations since 2015.

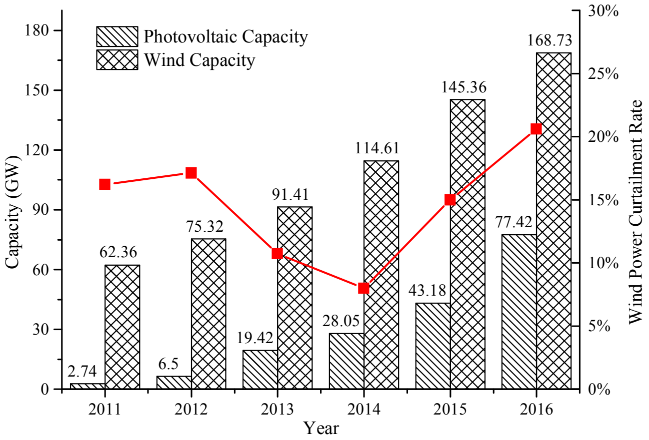

Fig. 1 The installed capacity of wind power and photovoltaic power in China from 2011 to 2016 [10]

However, there are some problems in the consumption of RES power. As shown in Fig. 1, the wind power curtailment rate is over 20% in 2016 and takes on ascend trend. The uncontrollable intermittence, which is the natural characteristics of RES power, is considered to be the main reason. Because power generation in China is dominated by coal-fired power, which is insufficient to provide deep peak-load regulation capacity. Therefore, DR may be an efficient way to reduce the abandoned wind power by regulating the period of power consumption.

B. The Growing Peak-valley Difference of Loads

The peak-valley difference of loads is keeping expanding, which reaches 1/4 of the maximum loads in some provincial grids in China. Moreover, seasonality is one of the typical characteristics of peak loads. Because air conditioners account for around 35% of the total power consumption in these provinces, which is the main reason to create peak loads in summer.

The accumulated time, when loads reach 95% of the maximum load, is only 70~80 hours of the 8760 hours in 2015 in Jiangsu Province. It is a huge waste to build so many power plants and grids for the short-time peak loads. Therefore, coping with the load spikes from the power supply side is not cost-effective. Correspondingly, DR is more effective to reduce load spikes by transferring the time of power consumption, which contributes to upgrade deferral of power plants and transmission & distribution lines.

C. The Backward Management Methods

Demand side management (DSM) has been implemented for decades in China by some ways, for example, rationing electric power, orderly electricity consumption and peak-valley price policy [11]. However, all the above methods are implemented by administrative regulations, not by the market methods.

A new round of electricity market reform has been launched in China in 2015. The power grid companies are required to make a marketization transformation and provide better electricity services for the customers. Compared with DSM, DR is a more market-oriented way to carry out reduction of electric power and customers will receive subsidies.

III. PILOT POLICIES OF DEMAND RESPONSE

A. The Business Model of Demand Response

Some pilot policies of DR has been released in China, of which Jiangsu Province is currently at the forefront of the pilot provinces. As shown in Fig. 2, a new business model is proposed for the first time.

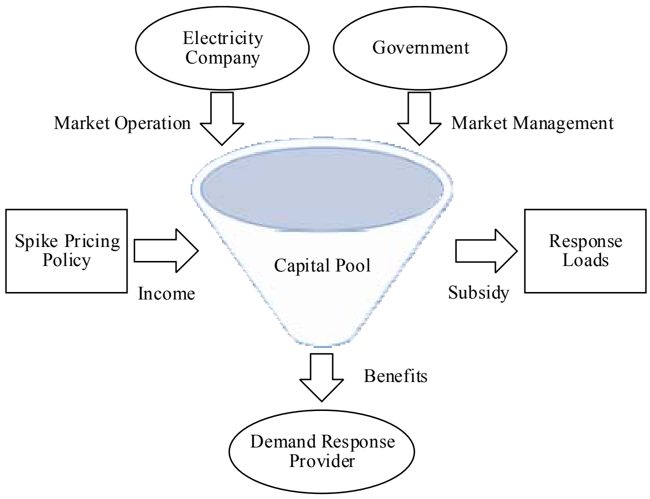

Fig. 2 Business model of demand response in Jiangsu Province

The business model includes three entities: Government, Electricity Company and Demand Response Providers (DRP):

- The government has no income in the market, whose main duty is making price policies. Moreover, the government offers services of optimizing the energy allocation, promoting economic development and improving the social efficiency.
- The electricity company is responsible for maintaining the electric power system's operation and providing technical platform for DRPs. The electricity company cannot participate in the market competition and only get fixed service revenues.

- DRPs are entities to provide capacity of DR. They sign contracts with the electricity company and reduce the consumption of power when needed by the load dispatch department. DRPs will receive subsidies after performing the response in accordance with the contract.

B. *The Spike Price Policy*

As shown in Fig. 2, a capital pool is built for the DR projects. The capital pool is a sum of funds for the subsidies to the customers or aggregators who successfully implement DR. It gets funds in two ways: the overcharged money by spike price policy and the specific funds from the government.

- The spike price is based on the peak price and increases 0.1 Yuan/kWh for the large industrial customers, whose apparent power are above 315 kVA, as shown in Fig. 3(2). The spike price policy will be carried out when the outside temperature is over 35 degrees Celsius in summer (July and August). That is, the price policy remains as the original peak-valley price policy in other months, as shown in Fig. 3(1).
- The specific funds from the government is financial support for encouraging the customers and aggregators to participate in DR. The specific funds will gradually disappear when DR has been promoted widely.

C. *The Effect of Demand Response*

Around 56,000 large industrial customers were implemented the spike price policy. Compared with the original peak-valley price policy, the income of electricity increase 32 million Yuan and 45.51 million Yuan in 2015 and 2016, respectively. All the increased income were used to subsidize the customers or aggregators who successfully implemented DR. This paper takes two typical days as examples, as shown in Table I.

- In August 4, 2015, there were 513 industrial customers and 8 aggregators participating in DR. The reduction of loads reached 1,887MW, which made the peak-valley difference of loads reduce 10.59%.
- In July 26, 2016, more customers participated in DR. Some commercial customers and residential customers were also included besides industrial customers. Therefore, the reduction of loads increased to 3,520MW and the reduction of peak-valley difference reached 18.47%. Moreover, air conditioners' capacity accounted for 210MW among the total capacity of load reduction.

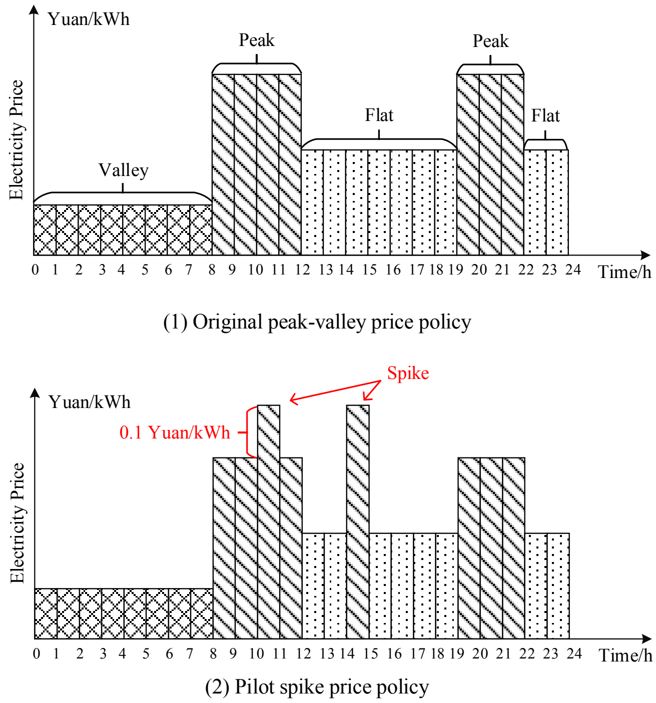

Fig. 3 Electricity price policy in Jiangsu Province

Some DR projects about residential customers were first implemented in 2016 in Jiangsu Province. Around 13,600 residential customers have satisfied the requirement of controlling air conditioners remotely and signed contracts with the electricity company. According to the measured data in August 2016, each residential customer's response capacity have reached 540W~590W.

IV. Demonstration of Friendly Interactive Grid

Even though the business model in Section III has achieved good effect of peak-load reduction, there are still some problems: (1) all kinds of loads are managed indiscriminately and lack of the cooperative operation mechanism; (2) the system operator is not able to achieve hierarchic management to the loads; (3) the two main DR modes (price-based DR and incentive-based DR) cannot cooperate perfectly.

In order to solve the above problems and do further study on DR, a large-scale demonstration project of DR—Friendly Interactive System of Supply and Demand (FISSD)—is approved and supported by *Ministry of Science and Technology of the People's Republic of China*.

TABLE I. The Effect of Demand Response

Typical days	*Number of industrial customers*	*Number of commercial customers*	*Number of residential customers*	*Number of aggregators*	*Reduction of Loads (MW)*	*Reduction of Peak-valley difference*
August 4, 2015	513	0	0	8	1,887	10.59%
July 26, 2016	1283	1526	321	24	3,520	18.47%

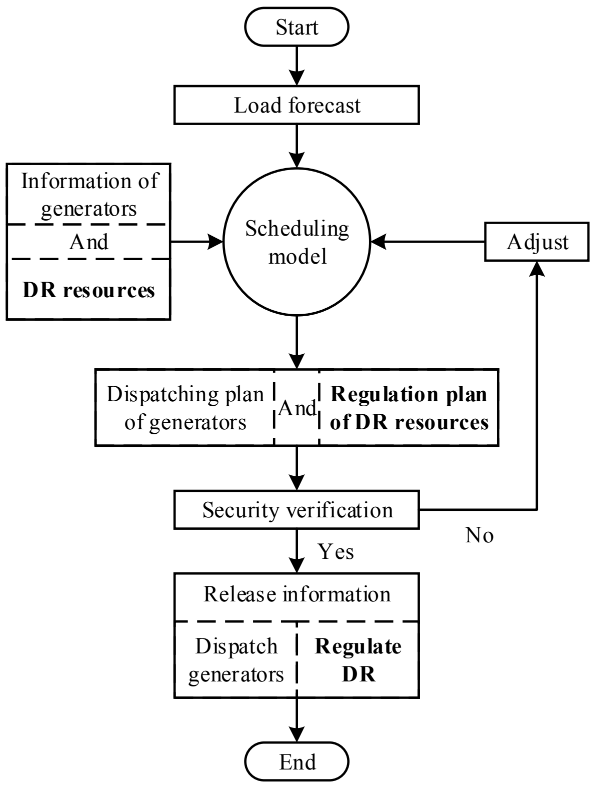

Fig. 4 The implementation process of demand response

A. The Implementation Process of Demand Response

The FISSD is designed to provide effective technical solutions and policy solutions towards the problems in the development of future electric power systems. The technical problems include the increasing penetration of RES, the growing peak-valley difference of loads and the increasing capacity of ultra-high-voltage (UHV). As the receiving end of UHV, it is estimated that 45% electricity power in Jiangsu Province will come from outside during peak period in summer in 2020. UHV will be a serious threat to the power system's safety and reliability because the power from outside generally cannot be regarded as the peak-load regulation units.

In traditional electric power system, system operators schedule generators to maintain the system balance between supply and demand. Loads are not responsible for the balance. Therefore, generators have to provide sufficient regulating capacity. However, in the system which has DR resources, the system operator can dispatch both generators and DR resources, as shown in Fig. 4.

The scheduling model has three inputs: load forecasting curve, status information of generators and DR resources. The optimization objective of the model can be minimizing the operation cost. Then the model outputs the dispatching plan of generators and the regulation plan of DR resources. The dispatching information will be released if the results satisfy the security verification. Otherwise, the scheduling model have to calculate again.

B. Introduction of the Demonstration

The FISSD project will be demonstrated in two cities of Jiangsu Province, Suzhou and Changzhou, where the resident population is 2.38 million. As shown in Fig. 5, the participants in the project include:

- More than 1,000 large industrial customers, which are mainly high energy-consuming enterprises.
- Commercial customers, including more than 250 malls, 300 hotels, 150 office buildings and 30 schools.
- Around 110,000 residential customers. They will be equipped with smart devices to realize the remote monitoring function. Moreover, at least 22 aggregators will be promoted in the demonstration area.
- Distributed generations. For example, 200 residential customers will install photovoltaic power generation system and energy storage system.
- Charging stations. Some residential communities will construct charging stations for electric vehicles. The scale of these charging stations will cover 30,000 houses.

In order to achieve the above goals of the project, intelligent devices, software systems and business models are necessary, as shown in Fig. 5.

- The energy management system (EMS) is the control terminal of the loads which participate in DR. It makes the house appliances be "smart" and achieve energy-saving operation according to the orders or electricity price. Moreover, the EMS can assist customers to manage distributed generation system and charging stations.
- The interaction platform can monitor the operation of electricity system and make decisions of DR. It can also communicate with all kinds of customers, send signals to each terminal EMS and calculate subsidies for DRPs.
- The business model is a market structure of DR, which accords with the existence of Chinese electricity market. Moreover, this business model should be able to motivate customers to participate in the project actively.

The objectives of the project are to reduce the peak-valley difference of loads by 5.8% and the comprehensive energy consumption of residential customers by 5.5% at the end year of the project in 2020, compared to the start year 2016.

V. CONCLUSIONS

The future power system will be more fluctuating due to the high penetration of RES. Moreover, air conditioners are accounting for a larger proportion in the total power consumption of the system, which expands the peak-valley difference of loads. All the above challenges put forward higher requirements for the traditional generators to provide balancing services and peak-load regulation services. With the

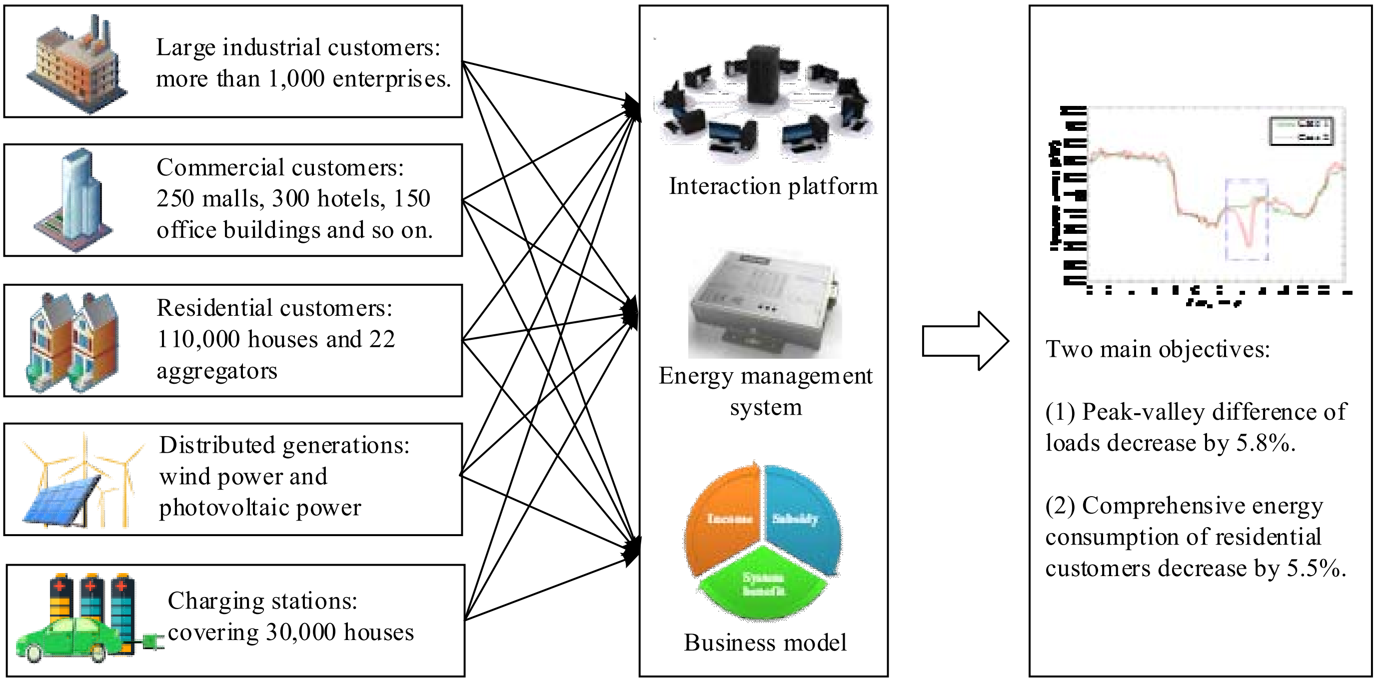

Fig. 5 The demonstration of *Friendly Interactive System of Supply and Demand*

development of ICT, it is efficient for customers to assist system balance from demand side. The pilot policy in Jiangsu Province in China verifies the effectiveness of spike price policy and DR. The reduction of peak-valley difference can reach 18.47% and the average response capacity of residential customers can reach 590W. In order to do further study on DR, a demonstration project of DR—Friendly Interactive System of Supply and Demand (FISSD)—was implemented to test the feasibility of DR in a larger area, Suzhou and Changzhou. The participants include industrial customers, commercial customers and residential customers. Moreover, distributed generations and charging stations will be built in the demonstration area. Some intelligent devices and software systems will also be developed. The FISSD will be one of the largest DR project in the world and make significant progress toward DR's study.

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