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Effect on Accommodating Renewable Energy Penetration in the Smart Grid (General Report)

APEC Energy Working Group

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Produced by
China Electric Power Research Institute
Southeast University

For
Asia Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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Foreword

Energy is the mostly basic driving force of world development and economic growth, and the base on which human survives. Rapid development of the economic society results in the increasing growth of energy demand in China. As the restriction on resource environment becomes intensified day after day and in order to cope with the increasingly severe energy environment problems, China is now gradually expediting to exploit and use the renewable energy sources (hereinafter referred to as "RES"). During the "11th 5-year plan" period, China's RES policy system, with the impetus of ***Law of the People's Republic of China on Renewable Energy Resources*** and the guide of government, has been continuously improved; China has incubated and formed the RES market and industrial system to push RES technology get rapid progress by conducting resource assessment, organizing concession bidding, improving price policy and boosting the pilot project construction of major engineering, and thence has boosted its industrial strength obviously.

In sense of the characteristics of RES, namely fluctuation, intermittency and non-schedulability, the issues of its grid-connection and consumption have become the major factors hindering RES from development, and the issue how to improve the consumption capacity of power grid for RES has become the focus and the research hotspot of scholars at home and abroad. According to plenty of researches and practices, the measure to implement demand response can mobilize sufficiently the power demand side resources (hereinafter referred to as "PDSR") to participate in power grid regulation, yield generated output by responding RES quickly, improve system stability and reliability, and boost the consumption of RES to some extent. Therefore nowadays it is very necessary to launch further study on the feasibility to improve RES consumption by participating in power grid optimizing operation initiatively by coordinating demand side resources via demand response, analyze the win-win benefit distribution mode of renewable energy power generation provider, government, power supply company and consumer, and then design the commercial operation model of demand response and multiple demand response projects suiting for different electric power environment.

For this reason, the study of the paper covers three sub-subjects, namely firstly the study on the feasibility and benefit analysis of improving RES consumption by demand response; secondly the study on the business operation mode and policy mechanism of demand response; thirdly the study on the pilot implementation project mode of demand response. This report is rightly prepared on the basis of such sub-subjects.

The report covers mainly the contents as follows. Firstly the research status quo at home and abroad for RES and RES consumption via demand response is sufficiently investigated, which lays basis for the subsequent study; secondly the wind power is used as the representative of RES to establish the model for the wind power consumption by demand response; where the feasibility of two types of demand responses, namely peak-valley time-of-use tariff and interruptible load, for the consumption of wind power is significantly discussed; thirdly the structure and operation of electricity market in China and USA are investigated; fourthly, the demand response commercialization operation modes under two economic systems are designed for the main purpose of boosting the co-ordination of supply and demand of electric power system, energy sustainable development and enhancing the competitiveness mechanism role of electricity market; fifthly the staged development of demand response project mode is considered and the demand response project mode in different electric power environments is discussed. Lastly the supporting policy and mechanism guarantee needed by RES consumption via demand response under smart grid is proposed in the report.

1. Application status quo of RES at home and abroad

RES is an important integral part of energy system, featuring in wide resource distribution, large development potential, good cleanliness, safety and sustainable use. In recent years, the voice to cope with climate change has become increasing day after day; however since the situation of energy shortage and energy supply safety has been becoming severe increasingly, the one to develop and use RES has become the important measure of all economies in the world to guarantee energy safety, enhance environmental protection and cope with climate change.

1.1. Development of RES in USA

1.1.1. Application status quo of RES in USA

(1) Overview for application of RES in USA

In order to cope with climate change, air pollution and other environmental problems, and guarantee energy safety, USA has always kept paying special attention to the development of RES. Featuring in safety and cleanliness and in the form of distribution and diversification, RES is important in the energy system structure of USA, and the wind energy has gotten rapidest growth.

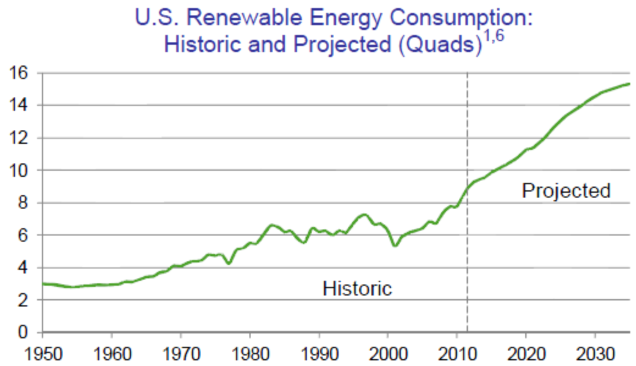

Fig. 1-1 Schematic diagram for development of U.S. Renewable Energy Consumption

Fig. 1-1 shows the schematic diagram for development of U.S. Renewable Energy Consumption[1], which includes the historic and the projected consumption. From the figure, it can be seen the renewable energy consumption fluctuated/fluctuates, but the overall consumption grew/grows; and the overall consumption grew rapidly since the year of 2000.

(2) Overview for application of U.S. renewable electricity

Most of RES are directly used for generating electricity; therefore they are helpful to reduce the coal consumed by electric power generation. In USA, RES electricity develops very well, especially in the field of wind energy. Since the effect of multiple aspects, namely total electric power demand reduces, fuel turns to natural gas, and more compensations are granted to wind power generation, the coal consumed by electric power generation is reduced hugely.

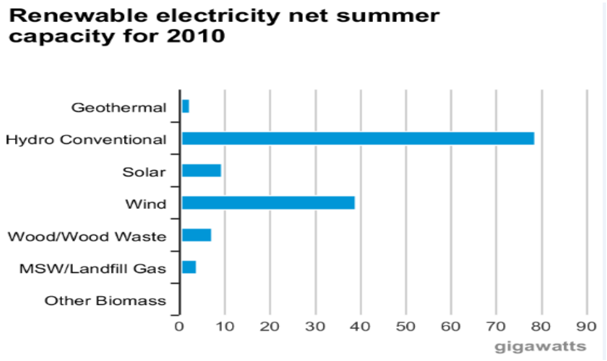

Fig. 1-2 Schematic diagram for renewable electricity installed capacity of USA 2010

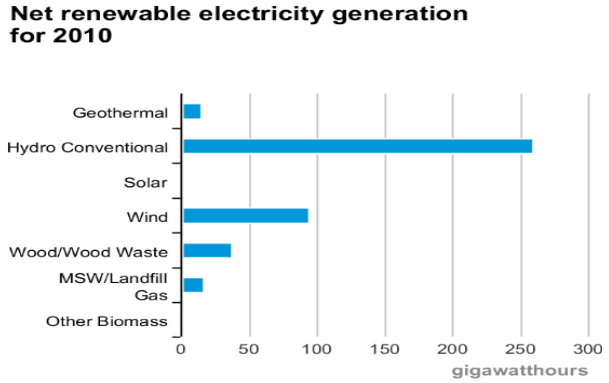

Fig.1-3 Schematic diagram for electric power generation of RES in USA 2010

Fig. 1-2 and 1-3 above shows respectively the schematic diagram for renewable electricity installed capacity and the electric power generation of RES in USA in 2010[2]. From which it can be seen the wind power installed capacity was inferior to that of the hydropower and has become the important integral part of renewable electricity of USA.

1.1.2. RES policy of USA

Upon years' exploration and accumulation, USA has established relatively perfect policy system for supporting RES development, including the administrative policy (such as restrictive indicator) and the incentive policy[3] (such as tax offset and exemption, direct subsidy).

(1) Laws, regulations, standards, restrictive indicators and other administrative policy, including the one to improve laws and regulations, formulate the standards to boost RES development and establish restrictive indicators and quota system.

(2) Economically incentive measures, including tax offset and exemption, direct subsidy for production side and consumption side, facilitate depreciation, foundation support, bond and loan guarantee.

1.1.3. RES development in China

1.1.4. Application status quo of RES in China

In order to cope with the increasingly severe energy environment problems, China is now gradually expediting to exploit and use the RES. During the "11th 5-year plan" period, China's RES policy system, with the impetus of ***Law of the People's Republic of China on Renewable Energy Resources*** and the guide of government, has been continuously improved, China's market size has been kept expanding, and Chin's RES has stepped into the overall, rapid and scale development stage [4].

(1) Development status quo of wind power in China

Since the promulgation of the ***Law of the People's Republic of China on Renewable Energy Resources***, the wind power industry in China has kept high-speed development tendency; as for the detailed development status, see Fig. 1-4 as follows.

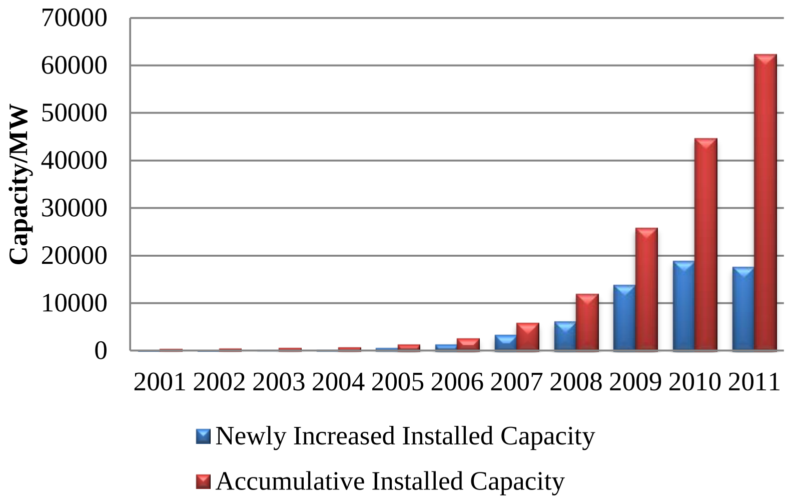

Fig. 1-4 Schematic diagram for wind power development of China

In 2009, the newly increased installed capacity of wind power in China surpassed that of USA and became No. 1 in the world; in 2010, the newly increased installed capacity of win d power in China was 18.93GW, and the accumulated installed capacity of wind power in China was 44.73GW; where the accumulated installed capacity of wind power in China surpassed that of USA and became No. 1 in the world[5].

(2)Development status of photovoltaic power in China

Driven by European market, the photovoltaic power industry in China has realized rapid development since the year of 2004, even China became the largest solar cell manufacturing country in the world in 2007. Till the year of 2010, the solar cell output of China shared the international output by 45% and was ranked top 1 in the world for consecutive four years[6].

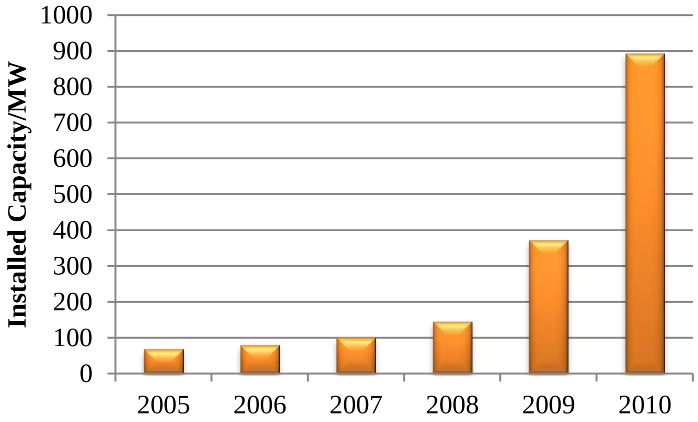

Fig. 1-5 Schematic diagram for photovoltaic power in China

1.1.5. Main concerns to be faced by RES development in China

In recent 10 years, the wind power industry in China has realized its rapid development and a comparatively perfect industrial system has formed, which lays solid basic for the large-sized development of wind power. However as the wind power scale expands, the wind power's development faces with plenty of new challenges. Especially in recent years, as the wind power is transformed, some problems brought by the rapid development of wind power industry in China have gradually emerged, such as the one that there is not available the efficient wind power development and operation mechanism, larger gap between wind power technology and the advanced level in the world, the need to further improve R&D and innovation capacity, the difficulties to connect the wind power with the electric grid and the difficulties to consume wind power, as well as the need to explore efficient wind power consumption ways.

The main concerns to be faced by the development of photovoltaic power are: it is further needed to enhance technical support; the market development is unbalanced; the overseas market is depended on overmuch and the photovoltaic construction and photovoltaic power generation involve in higher cost.

1.1.6. RES policy of China

In order to improve RES development, China has been active to learn the experience of EU, USA and other economies, and has improved its laws and regulations, and has also formulated the active industrial supporting policy, including the financial support, tax preference and online guarantee and etc.

(1) Laws and policy: China has promulgated the ***Law of the People's Republic of China on Renewable Energy Resources*** and its relevant enforcement regulations, and every local government has also promulgated the laws and regulations for RES.

(2) Economic incentive policy: it includes special fund, tax preference and etc.

(3) Industrial support policy: it includes RES development program, grid-connected guarantee policy and etc.

1.2. Analysis on characteristics of RES generated output

1.2.1. Analysis on characteristics of RES generated output

Wind power generation is usually limited by wind speed; however since it is hard to detect the change of wind, the power of wind-driven generator may become unstable. Different from the heat-engine plant with stable output power and schedulability, the wind power output depends on wind, featuring in unstable time, unbalanced space, fluctuation, intermittency and non-schedulability. The wind power output fluctuates hugely and its fluctuation frequency is also irregular.

Fig.1-6 shows the daily output of a wind generator in a wind farm in April 2007; in which the solid lines with different colors are used for showing the power output of the wind generator in different days; the broken lines in bold black show the average power output of wind generator. From which it can be seen the wind power output of wind generator in different days is different hugely; where the wind power output of wind generator was "0" in a whole day during some days, but even near to a rated value for consecutive hours during some other days. In a same day, the wind power of wind power generator changed hugely and its fluctuations were obviously and irregularly.

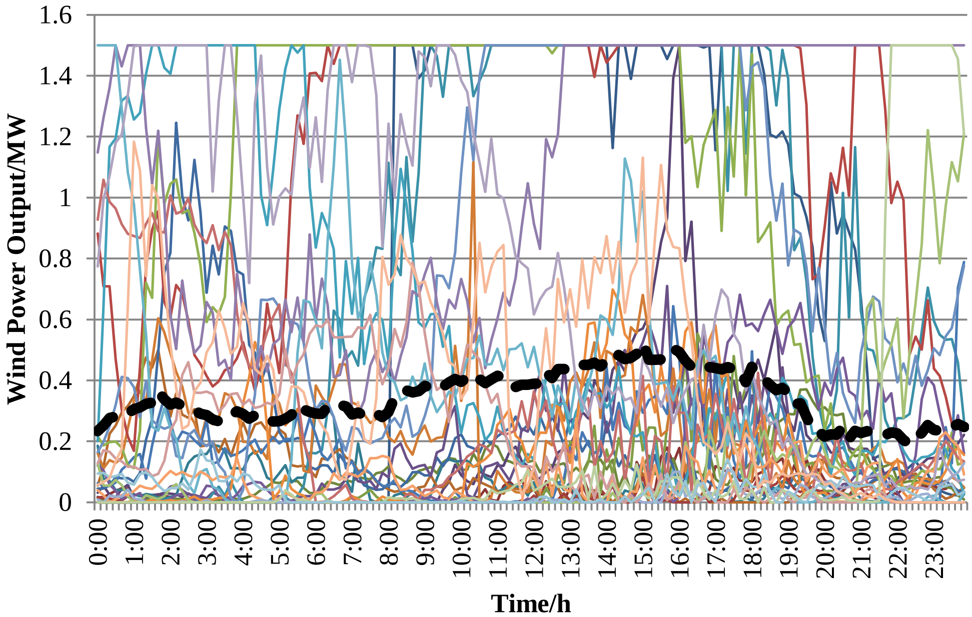

Fig. 1-6 Schematic diagram for daily power output of wind generator (In April 2007)

The reference [7] and [8], upon the wind data measured actually in Jiuquan area, Gansu Province, shows that the wind power output is of fluctuation and randomness, and is of relevance and complementarily. In order to cope with the large-range fluctuation of wind power output, it is needed to provide with a larger variable capacity.

Similar to the wind energy, solar radiation fluctuates out of predictability and suddenly. The actual output power of solar photovoltaic power station varies with the illumination intensity; the output power is positively correlated with the illumination intensity. As same as that of the wind power, the photovoltaic power generation is also featured in intermittency and random fluctuation. The photovoltaic power output is hugely influenced by weather, especially in the cloudy days, the generated power may get rapid and intensive change as the cloud changes.

Comparing with the wind power and other energy featuring in fluctuation, the photovoltaic power generation is regular, is more correlated with load, and can play the role of peak clipping[9] in most cases. In sense of time and area, wind energy and solar energy are complementary each other [10]; however the photovoltaic power generation is featured in intermittency and random fluctuation; therefore it is usually used as the supplementary energy [11] that provides only the power value, but not the capacity value.

1.2.2. Analysis on RES consumption

Renewable energy source ("RES" for short), different from the conventional energy sources, is intermittency and hard to predicate. In summary, the power grid faces with four challenges when the RES is connected to the grid, namely frequent correction demand, large power output change in an hour, surplus generated output (especially for the wind power), and approach to the instantaneous large-range output fluctuation (especially for the photovoltaic power generation).

Currently the tactics to connect RES with the power grid in a large scale are: generation portfolio, energy-storing device and demand response (DR). Among which the generation portfolio refers to the one that combines the other power generation resources with RES (such as the hydro-wind complementary system, wind-fire complementary system [14]). The principle of energy-storing device is similar basically, namely the energy is stored when RES power output is higher (or the electric energy is converted into other energy sources), and the energy is released when RES power output reduces. Nowadays the large-scale store energy is realized via the pumped storage. However as the battery energy storage technology develops, the chemical energy storage will become the main way of RES consumption.

DR resource, since it can be deployed flexibly and can substitute for power generation resources rapidly, and response RES change, has become a new way to cooperate the operation of RES, reduce the impact of RES fluctuation and maintain electric power balance. Additionally, DR resource is more environmental friendly when comparing with conventional power generation technologies and is more economic when comparing with the expensive energy-storing device; therefore DR has become the best RES consumption solution[15] technically and economically.

2. Status quo of RES consumption by demand response at home and abroad

2.1. Overview of demand response

2.1.1. Development status quo of demand response

Demand response (DR) is the development of demand side management in the competitive electricity market, with the generalized concept as follows, namely changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized. DR can increase the role of demand side in market through price signal and incentive mechanism, and make the integrated resource planning for supply side resources and demand side resources so as to adapt to the development requirements of electricity market.

(1)Demand response project

Currently many economies have made extensive researches and practices for DR, and have launched various demand response projects by integrating with the development of electricity market. However the demand response projects are launched by most of economies for industrial and commercial consumers. In accordance with the different response patterns of consumers, the DR project can be divided into two types, namely the price-based DR and the incentive-based DR. As for the former, it refers to the one that consumer responds the change of electric price at the retaining terminal and adjusts electricity demand correspondingly, which includes time-of use pricing (TOU), real-time pricing (RTP), critical peak pricing (CPP) and etc.; however as for the latter, it refers to the one that DR implementer encourages consumers to respond timely so as to reduce load by formulating the deterministic or the time-dependent price when the system reliability is impacted or the electric price is at the higher level, including direct-load control (DLC), interruptible load (IL), demand side bidding (DSB), emergency demand response (EDR), capacity/ancillary service program (CASP) and etc. both of them are internally linked each other and can complement each other[17].

(2)Role of demand response

Demand response improves the service efficiency of system and resources, and optimizes social resource allocation via load adjustment, and plays important strategic role in the field of electric power, economic development and environmental protection. As for the electricity market into which the competition is introduced, demand response is the necessary mean to guarantee system reliability and improve market for efficient operation. The roles of the demand response are: it can help the electric power industry to realize benign market-oriented operation, guarantee electric system to run steadily and reliably, reduce operating cost of system, optimize social resource allocation and consume RES [18].

2.1.2. Analysis on cost benefit of parties who participates in demand response

DR project has great positive function for improving the economic and safe operation of electric power system, where the mostly direct efficacy of demand response construction (or reconstruction) is to save electric power and save electricity. DR is the new resource of electric power system. In addition to the electric power consumers, there are different entities participating in DR project under the different electricity market environments and for the different application purposes. The participating entity in sense of DR-consumed RES mainly includes electric power consumer, RES power generation producer, general power generation producer, grid company (power transmission, distribution and marketing merchants). The table from 2-1 to 2-4 shows respectively the benefit and cost of different consumer who participates in DR project.

Table 2-1 Analysis on cost benefit of electric power consumers who participate in DR project

Cost	Benefit
● Acquisition expenses for electric equipments for production and living; ● Acquisition expenses for terminal load monitoring devices and communication equipments; ● Overhead expense caused by change in electricity consumption plan (personnel, warehouse and etc.)	● Electric charge saved by electricity consumption reduction; ● Electric charge saved by load adjustment; ● Earnings by consuming RES electricity; ● Improvement of electricity reliability and safety

Table 2-2 Analysis on cost benefit of RES power generation producer who participates in DR project

Cost	Benefit
● Acquisition expenses for RES power generation equipments	● Earnings by reducing RES discarding via DR participation; ● Price subsidy or equipment subsidy under different operation modes (electric price subsidy, quota system and etc.)

Table 2-3 Analysis on cost benefit of general power generation producer who participates in DR project

Cost	Benefit
● Reduction in marketing electricity and electricity sales ● Acquisition quota expenses that are possibly produce under the market operation mechanism, benefit to be shared with other principals	● Save the cost of fuel used in the peak season and reduce the operating cost (such as the power generator starts or stops) ● Reduce the construction of some variable load generator units and capacity generator units under long-term planning

Table 2-4 Analysis on cost and benefit of grid company that participates in DR project

Cost	Benefit
● Expenditure for acquisition expenses of consumer side advanced metering Infrastructure (AMI) ● Expenditure for acquisition expenses of grid side intelligent control system (master station) ● Expenditure for acquisition expenses of conducting management and publicity for DR project ● Marketing electricity loss and expenditure of incentive expenses	● Reduce the expenditure for grid purchase price in peak time (the electricity cost is exempted) ● Reduce the expenditure for delaying to construct power transmission and distribution lines (the capacity cost is exempted) ● Reduce the expenditure of auxiliary service expenses by improving system reliability ● Participate in benefit share with

caused by reduction inelectricity purchased by consumers	other principals

Except to the above principals and as for the whole society, DR, by participating in consuming RES, can improve the utilization efficiency of RES, bring outstanding environmental protection benefit, improve system reliability, electric market competitiveness and fairness, and then improve the utilization and development of RES.

2.2. Research status quo of DR-integrated RES Consumption

DR can be deployed flexibly and can respond RES generated output rapidly, and provide more flexible and economic modes[19] for RES grid connection. Different DR projects have different characteristics and have different roles in system, such as reducing peak, providing auxiliary services and others, and thence DR can provide the system with more extensive peak regulation, standby and other resources. Based on the advanced sensor and control technology in the smart power grid, the one to use DR to cooperate RES for operation and improve the utilization efficiency of RES has become the research hotspot nowadays.

2.2.1. Theoretical research status at home and abroad

Overseas researches on DR-integrated RES consumption cover wide aspects, in which the efficacy of complementarily of different DR projects or between different projects in sense of the integrating renewable energy resources (IRR) has not only be analyzed, but also the integration of DR and other means has been discussed, such as the one to improve the wind power predication accuracy and the integration with energy-storing devices.

The reference [20], [21] and [22] , by discussing the relationship between demand side management and integrating renewable resources (IRR) , points out that the responsive load in DSM is the mostly appropriate resource for consuming intermittency electric power, and the participation of demand side resources are becoming more and more important for improving the capacity of system for consuming RES; since the limited technical conditions and the limited flexible coordinating ability of electric grid side, DSM is expected to become the new path to adjust load to adapt to grid development. The reference [23][24] and [25], by establishing the wind power consumption mode on the basis of the real-time pricing system (RTP), analyzes and verifies the load curve on the optimizing day of RTP and the efficiency of improving wind power consumption ability, where the load responds to the change in wind power output through price signal so as to reduce the scheduling cost of system. The reference [26] assesses and polymerizes the potential of different response loads in multiple rate systems, and analyzes the responding load that can improve the safety and economy of the system after the wind power is connected in a large scale. The reference [27] raises a thinking to increase the load elasticity by using the internal storage capacity of load; where the result shows the load response method diverts the peak load efficiently; however as the increase of the wind power connection capacity, especially when facing with the extreme situations of the system, it is needed to increase the kind and quantity of the load in system so as to maintain everlasting electric power balance. The reference [28] points the integration of DR resource and high-accuracy wind power predication can improve the wind power consumption capacity and reduce electric power balance cost. The reference [29] uses the integration of wind-range measuring technology and demand side management to improve the economy and reliability of wind power access system.

Scholars in China have also conducted the relevant researches on DR-based RES consumption. The reference [30], on the basis of the existing DR project research achievement, raises a consumer side demand response incentive mechanism assorted with the large-scale wind power access to improve the wind power consumption ability. The reference [31] establishes an integrated power generation and utilization scheduling mechanism containing the wind power system, which proves that DR can become a feasible pathway to consume wind power and other intermittency energy resources and guarantee electric power balance. The reference [32], from the complementary and matching perspective of demand side and wind power energy, researches the roles of DR-based wind power consumption. The reference [33], by considering the different concerns, namely wind power, thermal power and DR and by researching the combined dispatching of wind farm, DR power generation and carbon emission permit, verifies the fact that DR can obviously improve the wind power consumption ability of system and exert the benefit of wind power (namely energy conservation and emission reduction) after the wind power plant is connected.

All in all, DR resource can be responded rapidly, deployed flexibly and used for substituting for power generation resource rapidly, where its role to reduce the negative effect caused by RES connection has been proved by plenty of literatures.

2.2.2. Key pilot project

(1) IRR Integrating renewable resources pilot project (IRR) by auto demand responses in California

In order to analyze the role of RES consumption by demand response, Pacific Gas and Electric Company (PG&E), Lawrence Berkeley National Laboratory (LBNL), Akuacom and CAISO jointly established and studied the integrating renewable resources pilot project.

As for this project, it was focused on analyzing and verifying the role of RES consumption by auto demand response, and analyzing significantly the strategy of Auto DR for providing auxiliary services, namely regulation down and regulation up.

PG&E formulated certain incentive policy for participating consumers and the demand response control devices were deployed in San Mateo Community College (SMCC), University of California at Merced (UC Merced) and West Hills Farms (WHF) for the project, where the strategy, namely load increase and load decrease, was realized by controlling the air-conditioning temperature and ventilator, and the scheduling department determines if it is needed to call the DR resource and how many DR resource will be called in accordance with the operating status of current grid and the change in RES power output, and then send the call instructions to consumers; after consumers receive the instructions, the auto DR device shall reduce or increase the demand rapidly according to the presetting load reduction and load increase control strategy to follow and respond the change in RES power output and maintain electric power balance, and then consume RES.

The result showed the pilot unit can respond to the requirements of the dispatching centre better, especially that SMCC increased load to meet the requirements of the balanced electric power when the wind power output increases at night, but the load increase can reduce wind consumption, namely the utilization efficiency of wind power can be improved; which shows the efficacy of RES consumption by DR.

(2) Pilot project of Honeywell – Hawaii Electric Power Company

In February 2012, Honeywell Corporation and Hawaii Electric Power Company launched jointly a pilot project. Focused on testing the "quick demand response' technology, the pilot project was conducted to improve the consumption capacity of grid for RES through the demand response technology, and then reduce the independence on fossil fuel whilst maintaining the reliability of Hawaii electric grid.

The project was implemented by two stages. At the first stage, Honeywell Corporation co-worked with Hawaii Electric Power Company to register consumers and connect consumers with the regional operation centre; if the electric power demand surpasses the supply, Hawaii Electric Power Company would send notice to consumers and reduce the electric power consumption demand within 10 minutes. After the project was finished completely, the semi-auto load control over 6MW would be provided. At the second stage, the auto demand response instruments of Honeywell Corporation, including the technologies of Akuacom and Tridium Corporation, would be used. Hawaii Electric Power Company would use the DR automation service software of Akuacom Corporation to management their resources and projects, and the smart grid controller of Tridium Corporation to turn the demand response automation service into the electricity consumption signal. When the electric power company triggers one condition, the controller will receive signal and exchange with the housing management system, and then automatically implement the load off-grid action preset by consumer in advance, such as the one to turn off the important lamp, water pump and motor and etc. Besides, the smart grid controller may send the data of electricity meter to the DR automation service software every 5 minutes to let the electric power company make real-time feedback for demand reduction.

3. Analysis on feasibility of wind power consumption by demand response

In order to show the efficacy of RES consumption by demand response intuitively, the model for wind power consumption by DR will be established so as to make data analyze for the influence of demand response on the premise of hypothesis and verify the feasibility of RES consumption by DR through computation example.

In this report the efficacy of peak-valley time-of-use price (TOU) and interruptible load (IL) for wind power consumption by system will be discussed specially. By guiding consumers to "divert peak and fill up valley" through TOU, especially for the wind power access system, it leaves the load demand increased by consumer at the low valley correspond to the characteristic that wind power generates higher output at night (low-valley period), reduces the adverse impact that wind power access increases the system peak-valley difference, reduces frequent start/stop and output regulation of generator units, reduces the operating costs of system; additionally, the increase of load equals to the increase of system's negative standby and thence it can improve the utilization efficiency of wind power. The IL participates in power generation dispatching in the form of system standby, so it can reduce the number of power generator started for the purpose of standby to reduce the operating costs of system, and realize quick response to reduce electric power demand and improve system reliability when wind power output reduces suddenly. As for the relevant demand response model, see the reference [34] and [35].

3.1. Model for wind power consumption by demand response

3.1.1. Objective function

Wind power access increases the standby demand of system; in this paper the day-ahead scheduling model with the wind power access considered is established, which incorporates the costs arising from the one to provide wind power standby into the objective function, considering to reduce the impact of wind power standby on the cost system and realizing the optimal system economic objective on the premise of consuming wind power as much as possible. See the equation (3.1) as follows.

$$\begin{aligned} &MinF(P_i^t, U_i^t, C_{ILj}^{'t}) \\ &= Min\sum_{t=1}^{T}\left\{\sum_{i=1}^{N}[f(P_i^t) + C_{i,t}(1-U_i^{t-1})U_i^t \right. \\ &\qquad \left. + f'(P_i^{rewindt})] + \sum_{j=1}^{N_{IL}} C_{ILLj}^{'}\right\} \end{aligned} \tag{3.1}$$

Where:

T is the time interval number during the system's scheduling period;

N is the total number of system's generator unit;

N_{IL} is the number of consumers who participate in IL;

$f(P_i^t)$ is the operating costs of the generator unit i at the time of t;

P_i^t is the active output of the generator unit i at the time of t;

$f(P_i^t) = a_i + b_i P_i^t + c_i (P_i^t)^2$;

$C_{i,t}$ is the start costs of the generator unit i at the time of t;

U_i^t is the status of the generator unit i at the time of t;

$U_i^t = 0$ means "stop"

$U_i^t = 1$ means "start"

$f'(P_i^{rewindt})$ is the standby cost that the generator unit i provides wind power standby at the time of t.

3.1.2. Constraint conditions

(1)Power balance constraint

$$\sum_{t=1}^{G} P_{it} + P_{fty} = L_{IL} \tag{3.2}$$

Where:

L_{IL} is the total load at the time t

$L_{IL} = L_t - \sum I_j^t Q_{ILj}^t$,

L_t is the total load at the time t when consumer responds the TOU price

$\sum I_j^t Q_{ILj}^t$ is the load reduction quantity of the interruptible load reserve to be called at the time t

P_{fty} is the forecasted power of wind electricity at the time t

(2) System's positive spinning reserve restraint

$$\sum_{j=1}^{N_{IL}} I_j^t Q_{ILj}^t + \sum_{i=1}^{N} U_i^t P_{szti}^t \geq R_{up}^t + R_{wind,up}^t \qquad (3.3)$$

$$U_i^t P_{szti}^t + U_i^t P_i^t < \overline{P_i} \qquad (3.4)$$

Where:

R_{up}^t is the standby demand for coping with load forecast error and generator unit off-operation at the time of t;

$R_{wind,up}^t$ is the positive spinning reserve needed for coping with wind power fluctuation at the time of t;

Where:

P_{szti}^t is the positive spinning reserve of the power generator i;

$P_{szti}^t = 10\upsilon_i$, υ_i is the creep speed of the No. i generator unit;

$\overline{P_i}$ is the max. output of the generator unit i;

Q_{ILj}^t is the load reduction quantity of consumer j at the time of t;

I_j^t is the call status of IL;

$I_j^t = 1$ means the IL is called;

$I_j^t = 0$ means the IL is not called;

$\overline{P_i}$ is the upper limit of the output power of No. i generator unit.

(3) System's negative spinning reserve constraint

$$\sum_{i=1}^{N} U_i^t P_{sfti}^t + \sum_{i=1}^{N_p} \Delta P_i^t \geq R_{down}^t + R_{wind,down}^t \quad (3.5)$$

$$U_i^t P_i^t - U_i^t P_{sfti}^t < \underline{P_i} \qquad (3.6)$$

Where:

P_{sfti} is the Down-reserve capacity of the power generator i;

$P_{sfti} = 10\partial_i$, ∂_i is the dramp for that No. i power generator unit downward;

ΔP_i^t is the load increment of consumer i at the time of t;

N_p is the number of consumer who participates in DR project;

R_{down}^t is the negative spinning reserve demand of the system at the time of t;

$R_{wind,down}^t$ is the negative spinning reserve needed for coping with wind power fluctuation at the time of t;

$\underline{P_i}$ is the lower limit of the output power of No. i generator unit.

(4) As for the constraint conditions of the power generator unit, see the Reference [34] as follows.

3.2. Case analysis

In accordance with the original load data of an area and the wind speed data of a wind power plant, the scheduling plan of IEEE24-bus 26-generator system is adopted; the installed capacity of the wind power plant is 450MW.

In order to describe the impact of wind power access on system's operating cost, and embody the efficacy of wind power consumption by DR, the day on which there is the higher wind power output (wind power output 1) , the day on which there is the lower power output (wind power output 2), the day on which there is the average wind power output (wind power output 3) are respectively selected as the typical day, see Fig. 3-1 as follows. The Table 3-1 as follows shows the optimal electric price and the called IL of the different systems when the wind power is connected. The Fig. 3-2 shows the load curve under the optimal scheme. By integrating with Table 3-1 and Figure 3-2, it can be seen that the model provided by the paper can adjust the demand side resources called by the system in accordance with the system load and wind power connection status, and then realize the minimal operating cost of the system, which means also that the demand response can coordinate demand side resources to participate in electricity grid to realize optimal operation, and then provide a new feasible way for wind power consumption.

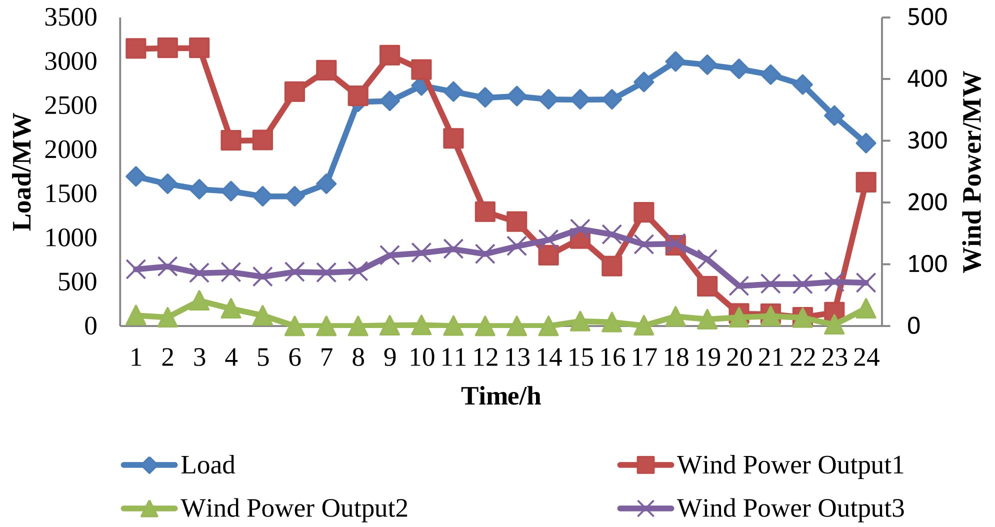

Fig. 3-1 Schematic diagram for load and wind power output

Table 3-1 Optimal electric price and IL proposal

	Optimal electric price (Yuan)			Interruptible reserve capacity (MW)
	Peak time	Usual time	Valley time	
Without wind power access	0.996	0.61	0.199	90

Wind power output 1	0.917	0.61	0.183	120
Wind power output 2	0.924	0.61	0.184	120
Wind power output 3	0.909	0.61	0.181	130

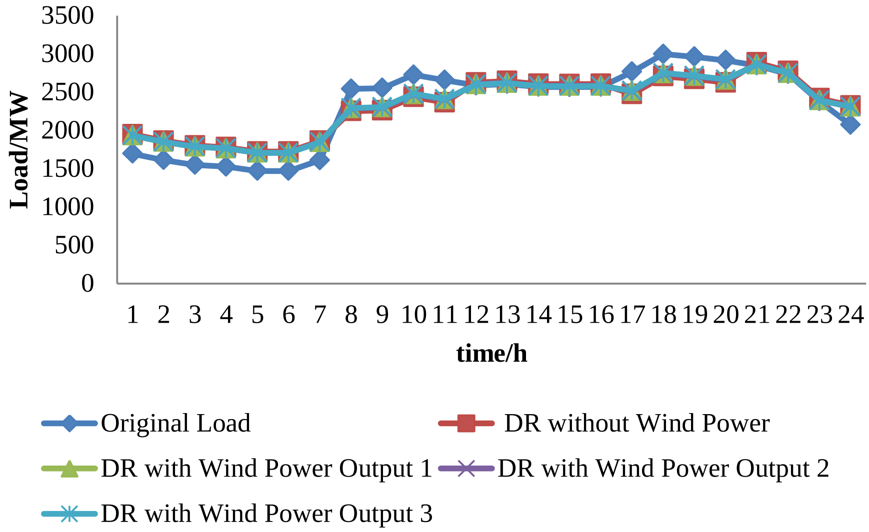

Fig. 3-2 Comparison on load curves under the optimal scheme

(1)Cost analysis

Table 3-2 Comparison of costs

Calculation scenario \ Cost		Generating cost	Start-up cost	Standby cost	IL cost	Total cost
Without wind power access	Without DR	757161.27	4407.68	80439.00	0	842007.95
	Integrated with DR	728363.70	1884.11	33823.17	15439.98	779510.96
Wind power output 1	Without DR	659291.58	4612.10	65994.30	0	729897.98
	Integrated with DR	631843.24	968.52	27755.47	21094.06	681661.29
Wind power output 2	Without DR	722294.81	3417.52	92169.12	0	817881.45
	Integrated with DR	678373.72	1028.77	29038.69	24560.53	733001.71
Wind power output 3	Without DR	753644.56	4407.68	81263.97	0	839316.21
	Integrated with DR	724715.73	1053.61	27010.68	21264.98	774045.00

The Table 3-2 shows the operating cost comparison after the system is connected with the wind power with/without DR. After the wind power is connected, some thermal power generator units are substituted and generating cost, comparing with the one that no wind power is connected, declines accordingly. All costs for integrating with DR in the 4 scenarios are lower than that of the one there is no DR; the DR integration reduces the impact of the wind power integration on system’s operating cost.

(2)Reliability analysis

In order to display the contribution of the wind power generator units to the reliability of electric power system directly, the wind power capacity credit (CC) and the contribution coefficient of wind power for expected energy not supplied (EENS) (or WEENSB, Wind generation EENS Benefit) [36] are respectively calculated.

$$CC = \frac{\Delta P_{CG}}{P_{WTG}}\Big|_{LOLE\ is\ \text{invariant}} \quad (3.7)$$

Where:

ΔP_{CG} is the routine generator unit's capacity subsituted by wind farm in the condition the system reliability level is maintained;

P_{WTG} is the rated capacity of wind farm.

$$WEENSB = \frac{EENS0 - EENS1}{P_{WTG}} \quad (3.8)$$

Where:

$EENS0$, $EENS1$ shows respectively the EENS before and after the wind power is connected to the grid.

Table 3-3 Comparison on benefit of wind power generator unit to reliability of electric power system

	Without DR	DR integrated
ΔP_{CG} (MW)	46	83
CC	0.102	0.184
WEENSB	0.096	0.0418

From the Table 3-3 above, it can be seen that the integrated DR makes the credit of wind power capacity improved and the WEENSB reduced, namely DR reduces the impact of wind power's intermittency and fluctuation on system's reliability.

(3) Analysis on impact of wind power fluctuation on system

In order to analyze the impact of wind power's random fluctuation on system, it is preferred to make the operation simulation analysis. Use Monte Carlo to simulate multiple actual output conditions of wind power; the specimen number is 1,000; analyze the EENS and wind power curtailment of the system; the analysis is conducted on the basis of the optimal scheme of average wind power value.

Table 3-4 shows the comparison on EENS in the condition with or without DR. From the table, it can be seen the IL reduces the impact of wind power's negative fluctuation; in the condition there is no power shortage, the maximum interruptible cost is RMB17555.68; which means the economy is still better than the condition without DR whilst the IL is called to improve the system's reliability.

Table 3-5 shows the comparison on wind abandon conditions. From the table, it can be seen the integrated DR improves the wind abandon conditions of the system obviously.

Table 3-4 Comparison on power shortage

	Without DR	Integrated with DR
Average power shortage value (MW)	19.87	0
Max. power shortage value (MW)	88.06	0
Total time intervals of power shortage (hours)	62	0
Average interruptible standby cost (Yuan)	0	3139.2
Max. interruptible standby cost (Yuan)	0	17555.68

Table 3-5 Comparison on wind power curtailment

	Without DR	Integrated with DR
Average wind abandon (MW)	7.0165	0
Max. wind abandon (MW)	84.25	0
Total time interval of wind abandon (hours)	34	0

To sum up, the computation result of the model herein shows the integrated DR reduces the operating cost of the system, reduces the impact of wind power's random fluctuation on the system, improves the consumption capacity of system for wind power and verifies the consumption feasibility of DR for wind power.

4. Investigation on environment of electricity market

Electric power market refers to the process in which the electric energy and its related products are traded via negotiation, price bidding and other methods in the course of its production, transmission, distribution and distribution; where the price mechanism is determined through market competition. In view of the means of transaction of electricity market, there are future goods, share option, bilateral trade and centralized bidding and etc. [37]; in view of the operation pattern of the market, there are complete monopoly pattern, power generation side competition pattern, wholesales competition pattern and retailing competition pattern [38].

Structure and regulation of electricity market are the important connotation of electricity market pattern; where the electricity market structure is the base of realizing the functional objective of electricity market; the electricity market regulation has important significance to control the market competition degree. In this chapter, by starting to analyze the environment and the regulation of the electricity market, the characteristics of the different market environments of China and USA are analyzed.

4.1. Structure and operation of electricity market in China

4.1.1. Structure of electricity market in China

The market-oriented reform objective of the electric power industry in China is to reconstruct the monopoly-oriented electricity market structure into the competitive electricity market structure. See Fig. 4-1 as follows.

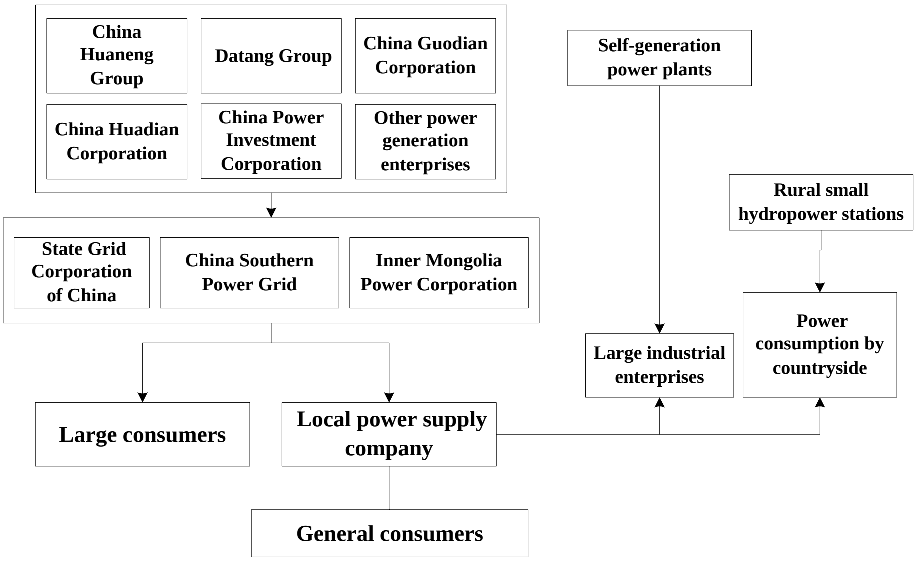

Fig. 4-1 Status quo of structure of electricity market in China

4.1.2. Operation of electricity market in China

Currently the trading of electric energy in the electricity market of China is divided into the non-competitive trading and the competitive trading.

The non-competitive trading of electric energy includes the base-number electric energy trading, the other electric energy trading arranged and planned by national and local government, electric energy trading of non-competitive power generation enterprises and etc. As for the trading of such type, the government defines the trading electricity quantity and tariff.

The competitive trading of electric energy includes the direct trading with big customers, cross-province competitive trading, power generation right trading and auxiliary service compensation trading and etc.

4.1.3. Implementation and operation of DR

China has not yet formed the fully market-oriented DR mechanism; where the detailed DR measures are closely integrated with the current electricity market structure and the electric power supply and demand of China.

(1) Orderly use of electricity

Administrative Measures of China for Orderly Power Utility specifies clearly that governmental department is the main responsible department of orderly power utility management, the electric power company is the important implementation entity of orderly power utility, and consumers support to implement the orderly use of electricity[40] in a cooperative way.

According to ***Administrative Measures of China for Orderly Power Utility***, the areas where the given conditions are available can integrate with the IL tariff and the high-reliability tariff mechanism. The orderly power utility is a transition mode of China for conducting the DR project.

(2) Energy efficiency planning

During the early planning construction period of demand side management, energy efficiency improvement is an important measure for saving electric power and electricity quantity. Nowadays the electricity efficiency power plant (EPP) construction in China has obtained great efficiency. The operation pattern, namely the contract energy management project by introducing the third party institution (energy service company) provides practical experience for the demand response project development of China.

(3) Electricity price project

There are plenty of price structure categories in China; the objects cover not only the large consumers, but also the citizen consumers. Currently China adopts the following electric price categories, namely time-of-use power price (TOU), critical peak price (CPP), step tariff (ST), reliability power price (RPP) and interruptible power price (IPP). Among which the IPP has been conducted in the pilot areas.

4.2. Structure and operation of PJM electricity market in USA

4.2.1. Structure of PJM electricity market in USA

The PJM electric market in USA takes the Regional Transmission Organization(RTO) as the centre to organize all parties engaging in power generation, transmission, and distribution to participate in market transaction.

The basic characteristics of the RTO are: having no economic relationship with market members, having the decision-making rights, having enough larger geographical coverage, having control power for the operation of equipments of power transmission network, responsible for short-term grid reliability.

The market members include power generation producer, power transmission provider, power distribution provider, other electric power suppliers and consumers; every member is independent each other and can conduct the electric energy transaction through centralized competitive tender or bilateral trade.

4.2.2. Transaction of PJM electricity market in USA

The transaction in the PJM electricity market in USA is mainly divided into two types, namely capacity market transaction and primary energy market transaction.

The capacity market is established as the electricity marketing process is opened. The capacity credit refers to the completely usable power generation capacity, and every electric power supplier needs to fulfill the capacity obligations corresponded by the load sum of its end-consumers. When the power generation capacity owned by the electric power supplier cannot meet the corresponding capacity obligations, it is needed to buy the differential capacity credit from the capacity market; vice versa, it is alternatively needed to sell the surplus capacity credit in the capacity market.

The primary energy market in PJM region in USA includes: day-ahead planned market, real-time balance market, power distribution right transaction market, and frequency modulation market.

4.2.3. Implementation and operation of DR

(1) Implementation background of demand response in USA

USA promulgated and implemented ***Energy Policy Act***, ***Energy Independency and Security Act***, and ***American Recovery and Reinvestment Act***[41] respectively in the year of 2005, 2007 and 2009 to ensure to provide policy and capital support for the implementation of DR project.

In accordance with the nation-wide demand response investigation conducted by United States Department of Energy every one year, the type of the DR project in USA is shown by Table 4-2 as follows, where 14 detailed projects are contained. However for the comparison on the peak clipping potential of every project, please refer to Fib. 4-2[42] as follows.

Table 4-2 Detailed Project Types of DR in USA

Incentive-based DR	Electric price-based DR
Direct Load Control (DLC)	Real Time Pricing (RTP)
Interruptible Load (IL)	Critical Peak Pricing (CPP)
Emergency Demand Response (EDR)	Time-of-Use Pricing (TOU)
Load as Capacity Resource (LCR)	Peak Time Rebates (PTR)
Demand Side Bidding (DSB)	System Peak Response Transmission
Spinning Reserve (SR)	Tariff(SPRTT)
Non-spinning reserve (NSR)	Critical Peak Pricing withLoad Control
Regulation Service (RS)	(CPP & LC)

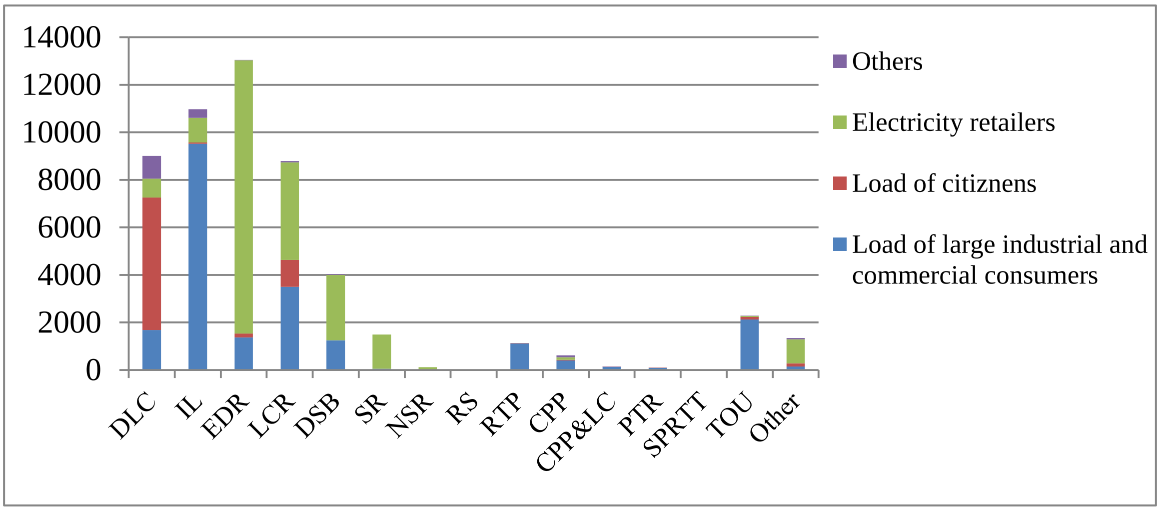

Fig. 4-2 Comparison on peak-clipping potential of various DR projects in USA

(unit: MW)

(2) Implementation of DR in USA

In the PJM area in USA, the operation plan of DR projects is divided into two types, namely economic load response and emergency load response. The two operation plans are respectively available in the primary energy market (day-ahead plan and real-time operation) and various auxiliary service markets.

①Economic load response plan

The Fig. 4-3 lists the operation status of the economic load response plan on the last day of every month from the year of 2008 to 2011; the Table 4-3 lists the settlement [43] of economic load response plan of every year from 2008 to 2011. From which, it can be seen the economic load response plan development in the PJM electricity market in USA was tended to decline year after year.

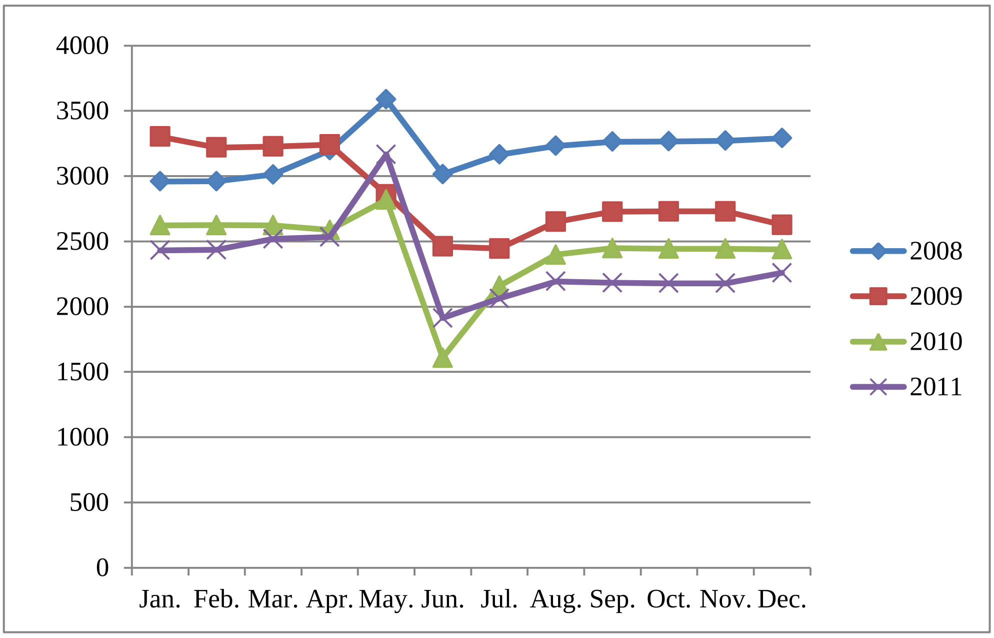

Fig. 4-23 Operation of economic load response plan in PJM area in USA (unit: MW)

Table 4-3 Settlement of economic load response plan in PJM area in USA

	Annual response electricity (MWh)	Average response price ($/MWh)	Max. daily load response capacity (MW)
2008	452222	60	197.1
2009	57157	24	23
2010	74070	42	42.9
2011	16782	120	8.2

In accordance with the annual electricity market's operation report of PJM corporation in 2001, among the DR resources participating in economic load response plan, 98.6% response electricity was settled in the real-time operation market; only 1.4% response electricity was settled in the day-ahead planned market.

②Emergency load response plan

Table 4-4 Yearly participation capacity of load management project (LMP) in the PJM electricity market in USA (MW)

	Interruptible load for assuring system reliability (ILR)	Load demand responses (DR)	Loan management projects (LMP) - total
2007/2008	560.7	1584.6	2145.3
2008/2009	1017.7	3480.5	4498.2
2009/2010	1020.5	6273.8	7294.3
2010/2011	1070.0	7982.4	9052.4
2011/2012	2792.1	8730.5	11522.7

Upon the comparison above, it can be seen that the participating percentage and the implementation effect of economic load response plan, which declined year after year, were far less than that of the emergency load response plan. From the perspective of the PJM electricity market's regulatory authority of USA, the economic load response plan, as the demand side resource bidding deeper and deeper in electricity market, is an implementation mechanism that demand side resources participate in market bidding transition phase; however the emergency load response plan requires the support of relevant technology and management system advancement (determination of load baseline, test and settlement of response load and etc.). The implementation and operation of future demand response will be closely integrated with every process of operation dispatching.

5. Design for business operation mode of demand response

5.1. Design objective of operation mode of demand response

To conduct demand response project under electricity market environment is to develop the demand side load control potential by using market competition mechanism, highlight the interaction of demand and supply, exert the role of competitive mechanism, improve the utilization efficiency of equipments and electric energy; therefore it is not only required to maintain the supply and demand balance of electric power, but also maintain the electricity market stabilization.

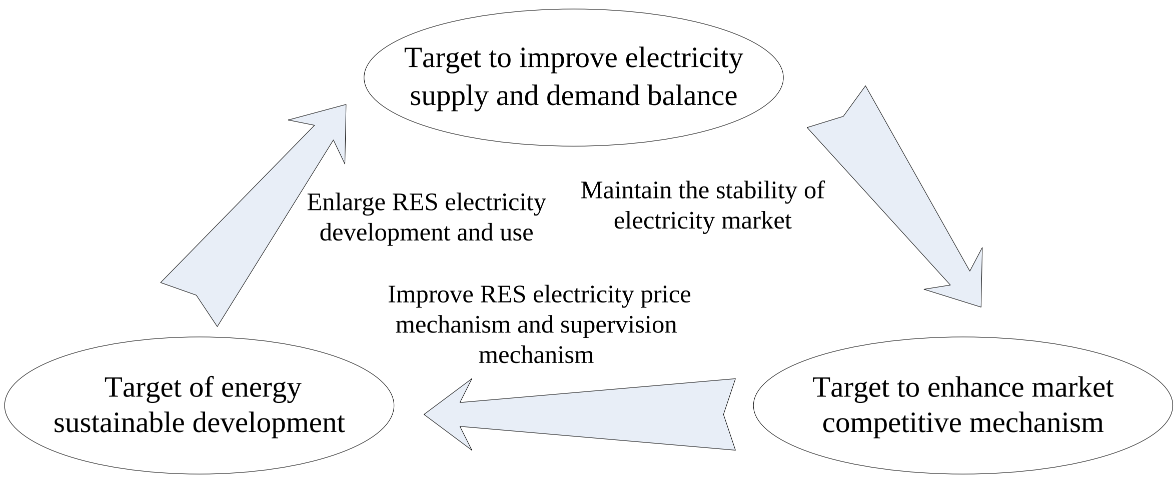

Fig. 5-1 Main objective of operation mode design of DR project and its interrelation

Under the background of environmental protection and energy structure upgrade, it is inevitable to conduct the development and utilization of RES electricity; the objective to design the operation mode of DR project should cover three aspects, namely supply and demand balance of electric power system, sustainable development of energy, competitive mechanism of electricity market.

5.2. Contents of design for DR operation mode

5.2.1. Organizational structure of project

The responsibility of the principal entity of the electricity marketin every process, such as power generation, transmission, distribution and sales, is interlinked each other. In the DR project, the organizational structure of operation will be subject to the structure of the existing electricity market and should exert the characteristics of every market principal entity. The organizational structure for DR project operation should be designed in accordance with the organizational structure of electricity market and the type of the DR project.

5.2.2. Market transaction mechanism

The design of market trading mechanism is to formulate the trading mode and the trading rules of DR resources, general power generation resources and RES electric sources; it is the guarantee for the transparent price signal and efficient competitive efficiency. The market trading mechanism will further clarify the trading hierarchy and trading modes of every trading entity on the basis of the organizational structure design; where the appropriate trading mechanisms under different environments are different each other.

5.2.3. Pricing mechanism

(1)RES electricity pricing mechanism

RES grid subsidy mechanism is the one that subsidy is added to the electricity price of the common benchmark generator units to form the grid price of the RES electricity. The grid subsidy mechanism of RES electricity allows to exert the roles of administrative means; however such pricing mechanism requires only the RES electricity generation producer to implement incentives unilaterally, but can not improve the utilization of RES electricity from the prospective of general electric power generation producer and electric power consumers and other principal entities.

RES quota system refers to the system that a certain value is granted to the RES quota (it is also known as the "Green Certificate") after the electric power utilization percentage of power generation side (or consumer side) RES specified by market rules reaches to the given limit.

(2)Pricing mechanism of DR resources

The mode to determine customer to participate in electricity market bidding is the one-part tariff and the two-part tariff; besides it is also allowed to integrate with multiple pricing mechanisms, such as reliability pricing and interruptible pricing, to form the integrated pricing mechanism.

When trading centre organizes both trading parties of DR resource to conduct trading, there are two settlement modes, namely the mode to pay off according to the system's marginal price and the mode to settle according to given quotation.

5.2.4. Risk prevention and control mechanism

Price in the competitive market environment may get intensive change; therefore it is very necessary to identify and control the risk factors, establish the reliable risk prevention and control mechanisms; the relevant measures include:

(1) To balance the share rate of every market participant, and control the impact of market force on price;
(2) Under the mode of making settlement according to given quotation, the trading centre should set the appropriate upper limit for price according to the supply and demand balance of electric power and the share rate of market participant so as to avoid overmuch supernormal profit;
(3) To set the favorable price linkage mechanism and exert the role of price elasticity;
(4) To introduce the trading modes, namely medium and long-term contract, option and future goods, to improve risk management.

5.3. Discussion on operation mode of DR project in different electricity market environments

5.3.1. Design for business operation mode of DR project in unilateral electricity market environment

(1)Organizational system

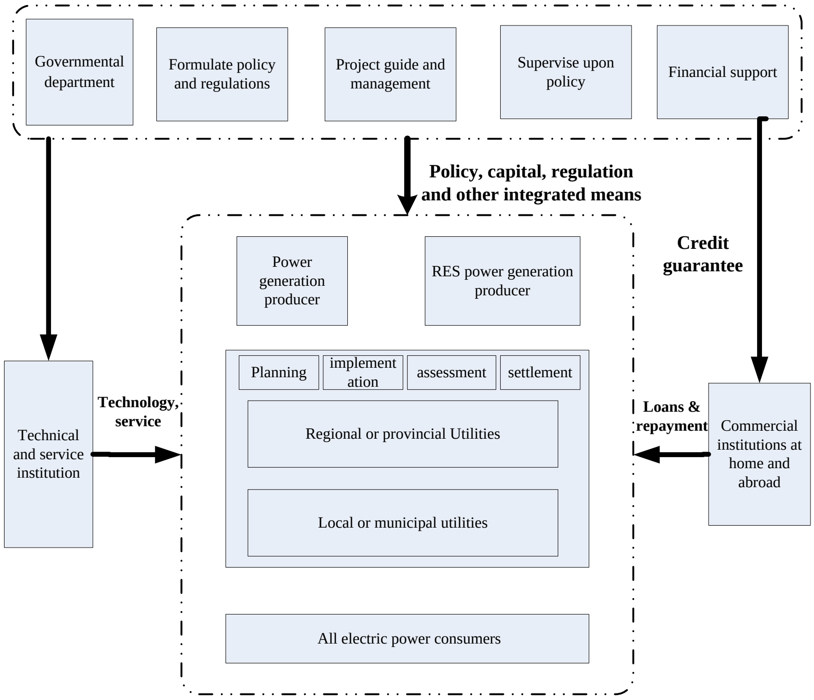

Fig. 5-2 Design for DR organizational system in unilateral electricity market environment

By integrating with the characteristics that DR project can improve the utilization of RES electricity, the social benefit and the social benefit of DR project will be exerted; this is rightly the starting point of designing organizational system for project operation. In the unilateral electricity market environment, governmental department and electric power company are the principal guiding and management departments of the organizational system; meanwhile commercial institution and technical and service institution play the auxiliary supporting role in the organizational system, and can efficiently improve the DR implementation effect for customer classification management. As for the organizational system, see Fig. 5-2 as above.

(2) Project implementation process

①Project financing

Governmental finance department provides credit guarantee to the approved RES power generation project so as to obtain the loans from commercial institutions with low interest or without interest, and provides a certain governmental fund to reduce the percentage of VAT of grid electricity sales amount.

Energy conservation equipment manufacturers and electric power consumers are the major objects to be subsidized in the DR project construction process. Electric grid company has diversified financing channels, namely governmental finance department establishes the DR initial funding, electricity surcharge source, some commercial loans, pollution discharge tax collection against high energy-consumption enterprises; all these channels can be the financing channels of electric grid company for conducing the DR project construction.

②Technical and service guarantee

In view of the whole structural system, the main providers of technical and service guarantee for DR project are the technical service organization of governmental department and third party institution; electric grid company is responsible for dispatching communication.

When energy conservation equipment manufacturers sell or release energy conservation equipments, all users shall enjoy the technical and service guarantee of these equipments. In the condition that the industry of third party institution has higher development degree, the DR service company can provide the sales and leasing services for energy conservation equipments.

At the pilot stage of the project, technical and service institution provide DR technical and service guide to electric power consumer free of charge under the guide of governmental department; when the project is made the commercialized popularization within a given range, the third party service institution obtains the capital return of consumers through "project effect guarantee" or "benefit share". The third party institution, under the guide of governmental department, is responsible for the process evaluation, effect verification of regional project; where the results will be used as the main basis for the analysis on input and benefit of DR project participants, and will provide the basis for stipulating the rational project operation rules.

③Implementation rules

Since the RES power generation cost is higher than that of the ordinary power generator units, in addition to the subsidy and loan support in sense of fixed cost input and for the purpose of shortening the payback time of RES power generation project, the mode of on-grid power tariff subsidy will be adopted so as to provide capital support to RES power generator units at the stage that the competitive electricity market has not formed. Since the ordinary power generation producers obtain the benefit (the newly establishment cost and operation cost of peak-shaving generator units can be exempted) higher than its input for DR project, the preferred subsidy method is the mutual capital contribution, namely general power generation producer, electric power company and government will mutually contribute the capital to provide the on-grid power tariff subsidy for RES power generation producer.

As the implementation entity of DR project, electric grid company is responsible for establishing the load monitoring system and communication network for the project, subsidizing electric power consumers to purchase terminal energy conservation and load control equipment to some extent, and determining the project type and subsidy percentage to be implemented in accordance with the type of consumer. Generally speaking, the industrially differentiated electricity price, TOU price and reliability price and other modes that are easy to be implemented are adopted to tap the DR potential. In order to improve the consumption of RES and soothe power distribution and transmission blockage, the incentive power consumption modes are adopted to encourage electric power consumers to change electric power consumption modes in the special areas and the time quantum.

Technical and service institution includes energy conservation equipment manufacturers and third party service institutions. As for the energy conservation equipment industry, the government adopts the energy efficiency ranking policy and specifies the classification of very kind of production equipments, corresponding tax reduction and exemption, guarantee loan and other capital subsidy limit. Energy conservation equipment manufacturer can provide the energy conservation equipments to electric power consumers, RES power generation producers and other organizations for use through leasing or marketing. The third service institution can apply the electric power company for contracting the DR project and bear the responsibility for consumer side equipment installation, energy efficiency assessment, electric power consumption optimization in the project implementation process, and sign legal contract with consumers.

(3)Price and trading mechanism

①Price mechanism

In the condition that cost is higher a bit, it is needed to grant a certain subsidy to RES electricity price. In the power generation process, the RES power generators will be classified in accordance with the capacity grade; the generator unit of the same type and the same capacity will be adopted the same and fixed on-grid power tariff.

Generally the electricity price of price-based DR project is determined by the single electric quantity price; however the electricity price of incentive-based DR project is composed of electric quantity price and capacity price. The settlement method will be the contract quotation.

②Trading mechanism

By referring to the trading status quo of the existing electricity market, it is required to clarify the principle as follows in the process when designing the trading mechanism in unilateral open market environment, namely the principle to take contractual transaction as the dominated part and spot transaction as the auxiliary service, take the one to start pilot construction for some incentive-based DR project as the opportunity, introduce the demand side resources into the auxiliary service market and financial market, and then lay the basis for promoting market competitive transaction, improving transaction mechanism and risk prevention mechanism.

5.3.2. Design for business operation mode of DR project in bilateral open market environment

(1)Organizational system

As the guiding core for the operation of DR project, the non-governmental intermediary organ is responsible for the design, construction, operation and management of DR project, and receiving the supervision of governmental organs by signing agreement. Other DR service institutions and economic entities can also participate in the construction and operation of DR project by the way of providing equipments, technologies or capitals. As for the organizational structure, see Fig. 5-3 as follows.

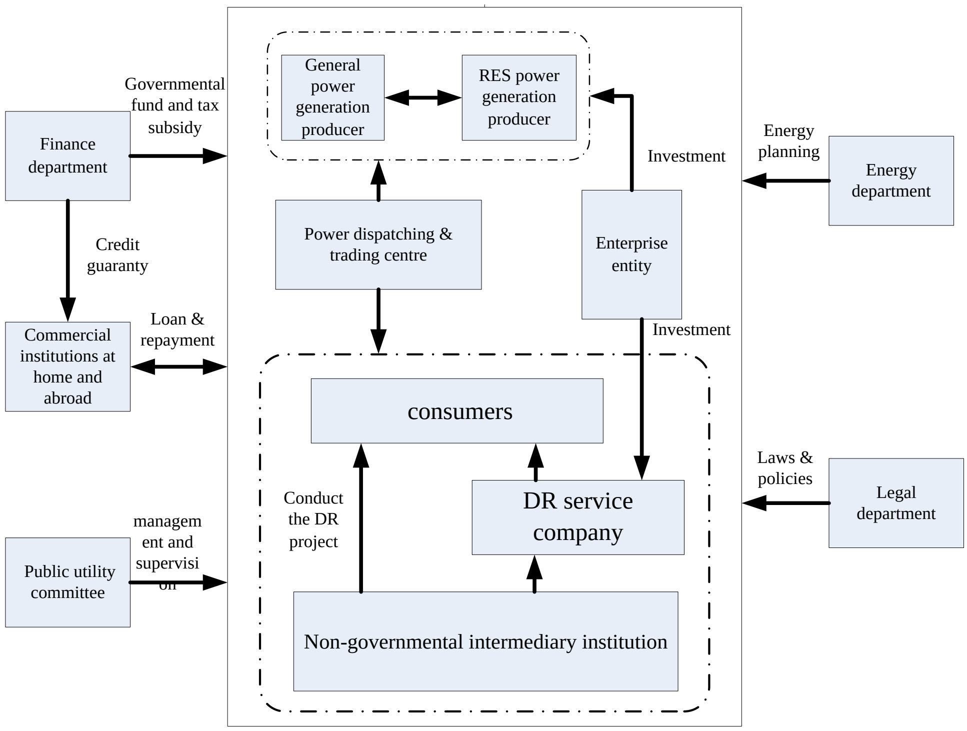

Fig. 5-3 Design for DR Organization System in Bilateral Open Market Environment

(2)Implementation process of project

①Project financing

The financing channels of DR project in bilateral open market are diversified; power generation producer, non-governmental intermediary organ, DR service company and consumer are the main investor objects of the project. The main financing ways include: DR special foundation established by government, financial award and tax reduction and exemption, consumer side electric power surcharge, loan of commercial institution at home and abroad, and other social capitals.

Governmental departments raise policy and capital support standard for RES power generation producers and corresponding capital support standards for the acquisition and construction of the different types of power generation equipments. Meanwhile the relevant industrial institutions in the energy industry are encouraged to participate in the RES power generation project development directly as to get profit therefrom, and then attract social capital to flow towards the RES power generation project development.

Financial department and other commercial organization provides the loan with low interest to energy conservation equipment provider, and reduce price to sell the energy conservation equipments to consumers through various financial means; in the course of investing the DR equipments, customers can obtain the capital subsidy offered by government, non-governmental intermediary organ and DR service company; the financial department will provide the loan with interest or without interest for the investment expenditure of consumer itself.

The non-governmental intermediary organ is the guiding department of DR project; it implements the DR project program for consumer directly, or manages the DR service company under independent operation system to conduct the DR project, and provides the capital support to DR service company (including governmental foundation, loan of commercial institution, tax collection and etc.).

②Technical and service guarantee

As for the DR project conducted in the bilateral open market environment, the non-governmental intermediary organs, DR service companies, related equipment providers, technical and service departments of social enterprises provide technical and service support for its required equipment systems, communication and dispatching, load monitoring and other aspects.

As for the RES power generation industry, the technical and service access mechanism will be adopted. The governmental department will formulate the grid connection standard for RES power generator units (including capacity, efficiency, power forecast and controllability and other requirements) so as to encourage the RES electricity developers and the relevant departments to put into technical forces.

The DR service companies, as they grow bigger and bigger, can incubate related technical and service forces; moreover their provision patterns for technical and service support for users can be extended to the development, lease and distribution process of the relevant equipments.

The electric power dispatching centre is to make uniform dispatching on power generation side resources and demand side resources; it is needed to install the load monitoring equipments, communication equipments at the power grid side and the consumer side so as to construct the integrated dispatching platform, and organize the corresponding technical service teams to participate in the management of the demand side dispatching. In line with the technical and service input of electric power company, the economic incentive means are adopted to improve the input implementation results.

③Implementation rules

Governmental departments promulgated laws and regulations for RES electricity to determine the subsidy limit enjoyed by the RES power generator units of various types. The subsidy limit reduces as the lapse of the generator unit's construction year. All electric power producers, electric power suppliers (or electric power customers) will be distributed a certain of RES power generation and consumption quota; as for the power producers and electric power suppliers who are found inadequate quota, the fine of a certain of percentage will be charged, and such money will be returned to the RES power generation producers.

Implement the incentive mechanism conducted by electric power company for cooperating with DR product: separate the electricity sales amount from the direct revenues, implementation effect award, benefit share and etc. the electric power trading centre is liable for organizing consumer and DR service company to participate in bidding transaction; the management cost, such as the dispatching input and the transaction input can be returned from the trading parties through trading surcharges and other ways.

The non-governmental intermediary organ guides and organizes all DR service companies to participate in the design, construction and operation of DR projects, and bears responsibility to formulate the institutional access rules and administrative methods of the industry. The non-governmental intermediary organ will directly participate in the design and implementation of DR projects of most of consumers; the distributed customers are organized to participate by other DR service companies.

Consumers shall be entitled to participate in demand side bidding transaction by themselves or under the organization of agency, receive electric power trading and the plan arrangement of the dispatching centre, and participate in the emergency demand response project to stipulate response capacity, early notice, duration, price, fine and other information in the form of contract.

(3) Price and trading mechanism

①Price mechanism

In order to improve the utilization of RES electricity, in addition to the grid subsidy mechanism, it is also needed to implement the RES quota system. As for the ordinary electric power producers, the governmental department should specify the percentage of the RES electricity to the total generated output; as for the electricity sales department and some consumers, the percentage of the RES electricity to the total generated output must be specified.

Consumer and DR service companyparticipate in demand side bidding; the transaction price will be determined mutually by multiple parties participating in the bid. According to the prevailing price regulations for electricity purchasing and selling bidding, the demand party and the supply party need to submit the price-quantity curve, and the electric power trading centre will determine the transaction price and quantity according to the quotation. The price will be subject to the multiple-part tariff method, namely the electricity quotation and capacity quotation. In the bilateral market environment, the settlement method is subject to the uniform pay-off method.

②Transaction mechanism

In the bilateral open market environment, RES quota transaction market, main energy market participated by demand side resources, auxiliary service market, capacity market can be incubated and multiple financial means, namely multiple contractual transactions, spot transaction, future goods and option and other financial means will be adopted by taking advantage of the advantages of open competitiveness so as to finally form steady and flexible price response chain.

5.4. Commercialized operation of DR-considered RES

5.4.1. Commercialized operation of DR-considered RES in unilateral market environment

(1)Transaction of RES electricity

Government promulgated the fixed electricity price purchase policy for RES electricity; the government will set the annual power generation benchmark electricity for the RES generator unit, provide the guide through the medium and long-term contractual trading pattern, and organize the RES power generation producer and the electric grid company to sign contract. The fixed electricity price contains the wholesale price of electricity generated by the regular power generator units and the fixed subsidy.

Collect the fixed subsidy ofwholesale price tariff of RES through electricity price, incentives and other ways, and divert the responsibility to utilize RES electricity to consumers.

(2) Subsidy and punishment mechanism of RES electricity

Refer to the factors of RES, namely the power generation conditions, cost of generator unit's capacity, operating hours and others, set the rational subsidy percentage for different generator units; as the generated energy (or annual operating hours) increases, the subsidy (aiming to RES power generation producer) contained by the fixed on-grid power tariff will decrease; or the subsidy benchmark electricity demarcation point is set; where the subsidy will be granted to the RES power generation producer for the one beneath the benchmark electricity, and the subsidy will be granted to the consumers who participate in DR for the one over the benchmark electricity. As for the schematic diagram for subsidy, see Fig. 5-4 as follows.

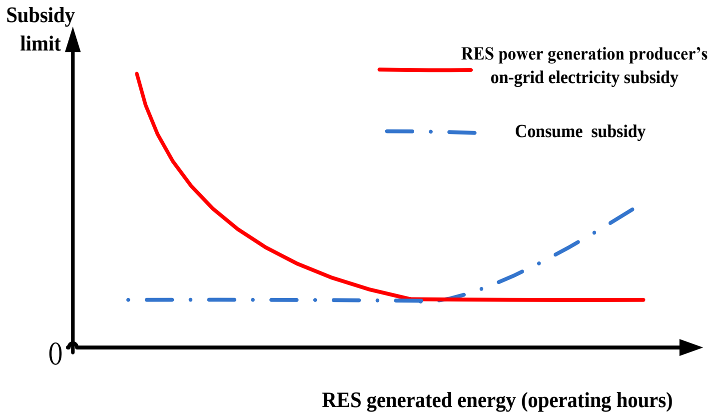

Fig. 5-4 Schematic diagram for RES subsidy mechanism

(3)Analysis on business plan

①Planning and financing

In an investigated area, the price-based DR project and the incentive-based DR project (by household and by capacity) are conducted; where consumers are classified according to the capacity classification.

Table 5-1 DR project planning

Customer type	Price-based DR planning		Incentive-based DR planning	
	Incoming capacity classification	Planning percentage	Incoming capacity classification	Planning percentage
Industrial consumer	630-2000kVA	50%	630kVA and below	0
	2000kVA and above	85%	630kVA and above	15%
Commercial consumer	——	85%	——	10%

Price-based planning capacity	1700MVA	Price-based household	1636
Incentive-based planning capacity	329.3MVA	Incentive-based household	228

By referring to the DR pilot implementation effect of China, the peak load can be reduced by 10% appropriately; considering the requirements that large-scale RES requires quick position/negative spinning reserves, it is planned to use the figure, namely 30% of the saving potential (about 60MW) as the spinning reserve capacity when the generated output of RES fluctuates.

As for the capacity quotation, annual operating hour, output fluctuation characteristics of RES under the bidding and tendering parts, it is planned to select the one to be planned to invest and construct for bidding after investigation.

Fig. 5-2 RES bidding-tendering result

No.	Capacity	Capacity cost	Output fluctuation range (<15min)
1	35MW	RMB8,300/kW	<85%
2	2MW	RMB9,000/kW	<85%
3	5MW	RMB1,000/kW	<95%

Adopt the fixed on-grid power tariff mechanism for RES electricity. Within the range of the benchmark electricity, the sum of the benchmark price and the fixed subsidy will be used as its wholesale price; for the one beyond the benchmark power output, the benchmark wholesale price will be adopted; whereas the fixed subsidy will be used as the extra reward to consumer who implements DR. as for the benchmark electricity price and the fixed subsidy of every capacity generator unit, see Table 5-3 as follows.

Table 5-3 Detailed rules for fixed subsidy mechanism of on-grid power tariff of RES electricity

No.	Capacity	Annual benchmark generated energy	Fixed on-grid power tariff subsidy
1	35MW	70 GWh	RMB0.15/kWh
2	20MW	35GWh	RMB0.15/kWh
3	5MW	10GWh	RMB0.25/kWh

The main financing method is shown by Table 5-4 as follows.

Table 5-4 Main Financing Method

	Investor	Item	Limit	Description
Financing before starting	Government	Financial budget subsidy	RMB 0.133 million	10% subsidy to control centre; 30% subsidy to consumer for equipment installation
	RES power generation producer	Power generation equipment	RMB0.1427 billion	Invest 30% one time

		input		
	Electric grid company	DR software and hardware cost	RMB 0.416 million	Including the subsidy of 30% for consumer for equipment
	Loan of commercial institution	——	RMB0.3329 billion	RES power generator producer's construction investment load (70%)
Financing in the operating process of project	High energy-consumption enterprise	Pollution discharge tax	RMB 0.222million/year	Load of high energy-consumption enterprise is 5% of the total load approximately; RMB0.03/kWh * year

②Implementation and settlement

5% of total load of the system (about 4.2%, 130MW load) mentioned in the Part 1 of the report will be used as the positive and the negative spinning reserves of the RES electricity through DR, averagely the wind-abandoned capacity will be reduced by 1.59% (averagely the wind-abandoned generated capacity of 450MW wind-power unit will be reduced by 7MW).

In accordance with the implementation project, the pilot electric power company conducts the price-oriented and the incentive-oriented DR project to realize the permanently load conservation by 10% around, namely 202.9MW. In the extreme conditions (the wind power generator unit's generated output is 0), almost 30% (60MW) DR resources will be used as the reserve capacity, and the averagely actual called resource capacity is 17,.3MW. From which the saved electricity, saved quantity, energy conservation and emission reduction amount, as well as the acceptable RES benefit will be calculated.

Table 5-5 Project Operating Benefits List

Principal part	Annual yield	Total cost	Payback period	Remarks
RES power generation producer	RMB73.455 million	RMB0.4756 billion	7 years	The cost is the new energy source's installed capacity cost.
Electric grid company	RMB4.7096 million	RMB4.1595 million	11 months	——
Participating consumer	RMB3.645 million	RMB1.359 million	5 months	The cost is the fixed equipment input of DR consumer of RES; the

transfer cost varies with the consumer.

5.4.2. RES commercialized operation of DR in bilateral market environment

(1) Trading of RES electricity

In the bilateral market environment, the RES electricity is traded under the RES quota system. Government specifies the limit of the "Green Certificate" bought by the regular power generation producers and consumers (or electricity distributor) according to the percentage of the RES generator unit's capacity to the total capacity.

In the bilateral open market environment, it is preferred to restrain the annual maximum operating hour of the RES power generation producer and buy the corresponding DR resources so as to improve the RES generated energy, reduce the unnecessary close down and wind abandon. RES power generation producer can buy the reserve capacity resource through the DR-participated auxiliary service market and capacity market to guarantee the on-grid restraint requirements of RES generated energy.

(2) Subsidy and punishment mechanism of RES electricity

Since the "Green Certificate" determines the price through the supply-demand relation in the market, the amount of RES generated electricity, RES quota object and the required quota limit are the critical factors affecting the price. In order to adjust the price fluctuation of RES rationally, government and energy department should set the rational annual benchmark generated energy for the RES power generator unit and the resource's actual conditions so as to guarantee the market turnover of the "Green Certificate". The RES quota object are certain consumers, namely the thermal power generation plants and the high energy-consumption enterprises. The RES quota limit is subject to multiple factors, namely the annual generated energy, annual electricity consumption and percentage of RES' annual generated energy to the total social electricity.

RES power generation producer, thermal power generation producer and high energy-consumption enterprise that fails to fulfill the given obligations according to the subsidy mechanism shall be given the economic punishment; the fine will be used for subsidizing and aiding the RES power generation producers.

(3) Business plan analysis

① Planning and financing

By selecting an area to conduct the project planning accommodating the utilization of RES, the regional investigation result is shown by the Table 5-6 as follows. Make statistics for the cut-off percentage of the load of various types and refer to California Fast Auto-DR RES access project report [44].

Table 5-6 Regional Investigation Result

Industry type	Load type	Statistical capacity (MW)	Cut-off proportion	Total (MW)
Industry	Illumination	29	35%	1437
	Data centre	301	15%	
	Refrigerated warehouse	568	30%	
	HVAC	377	60%	
	Agricultural production	162	100%	
Commerce	Illumination	78	33%	1141
Others	HVAC	1063	65%	

Set the annual benchmark generated energy according to the annual operating hours of the RES power generator unit; the RES power generation producer must meet the annual benchmark generated energy through DR (the energy-storing equipment has higher cost, so it is not considered this moment).

Table 5-7 RES Power Generation Planning Table

No.	Capacity of generator unit	Cost of unit capacity	Annual benchmark generated energy
1	260MW	RMB10,000	568GWh
2	180MW	RMB11,000	350GWh
3	70MW	RMB12,000	120GWh
Total	510MW	——	938 GWh

On the basis that the percentage of the RES electricity is 20% approximately of the total electricity, the ordinary generator unit will be required to buy the "Green Certificate" with the value equaling to 4.5GWh RES electricity for its unit power generation capacity; the consumer bearing the "Green Certificate", provided that it fails to meet the quota limit upon the statistical data at the end of year, will be charged the penalty; the penalty is subject to the market price of the "Green Certificate". The main financing method is shown by Table 5-8 as follows.

Table 5-8 Main Financing Method

Investor	Item	Limit	Description
Government	Financial budgetary subsidy	RMB0.56 billion	Consumer will be subsidized by 30% for the installed equipment; RES power generation producer will be subsidized by 10%.
RES power generation producer	Power generation equipment input	RMB2.71 billion	One-time input 50%
Third party institution and consumer	Consumer Side DR cost	RMB60.00 million	If every household costs RMB3,000 (by the unit AMI cost), the total number of household is 20,000.
Commercial institution	Loans	RMB2.168 billion	RES power generation producer gets loan for construction investment (40%)

② Implementation and settlement

As for the RES power generation producer, the yield from electricity marketing includes the direct wholesale bidding and the revenue by selling the "Green Certificate". The sufficient DR resource will be used as the reserve capacity of the RES electricity; where the average maximum operating hour of RES generator unit will be improved hugely; it is estimated that the average maximum operating hour will be 2,800 hr, and the wholesale price will be RMB0.4/kWh. On the basis the sales revenue of "Green Certificate), refer to the difference between the cost of RES generator unit and the common thermal power generator and the service life.

The annual income of the RES power generation producer is about RMB0.6477 billion. It is estimated that the cost the RES power generation producer buys the DR resource as the standby source is about 10% of its yield. The direct benefit of consumer and third party institution when participating in DR is about RMB60.00 million. Therefore the payback period is about 10 years for RES power generation developer and about 1 year for DR participant.

The consumption of large-size RES electricity (about 20% of the total electricity output) can bring larger energy conservation and emission reduction benefits; for example the regular power generator unit, its CO_2 emission and SO_2 per unit power generation output is 0.92×10^{-3}tons and is 4.6×10^{-6}ton respectively,so the reduced emission of CO_2 and SO_2 will be $13.14\text{x}10^6$ tons and 6.57×10^4 tons every year. From which it can be seen that as the RES access proportion increases, the cost payback period of RES power generation producer, since the governmental subsidy ability is very limited (fixed cost subsidy and wholesale price subsidy), will be longer than that of the small scale (Section 5.4.1). However the utilization level of the RES generator unit can be improved through DR resource. Moreover the commercialization operation under the quota system can reduce the cost difference between RES power generator unit and the common power generator unit, and realize more benefits from the perspective of the social benefits.

5.4.3. Comparison on DR operation modes in different market environment

Compare the DR operation modes in unilateral open market environment and bilateral open market environment in sense of three aspects, namely organizational system, project implementation process, price and trading mechanism. For details, see Table 5-9 as follows.

Table 5-9 Comparison on different points of two operation modes

		Under unilateral market	Under bilateral market
Organizational system	Project implementer	Grid company	Non-governmental intermediary organ and DR service company
	Financing system	Government subsidy, loan of commercial institution	Governmental subsidy, loan of commercial institution, business capital
	Technical service system	Government and other non-profit organization play the role of support	DR service company and business enterprise sector provide equipment, technology and service by adopting the profitable ways.
Project implementation process	Utilization of RES	Government, grid company grant the fixed grid subsidy to power generation producers	Organize the market transaction with "Green Certificate", in which the period of validity and the value of certificate are respectively stipulated.
	Demand response (DR)	Government guides, approves and regulates; grid company conducts; the third party institution proves technical support and effect verification services.	Non-governmental intermediary organ and DR service company are responsible for project planning, construction and operation; and government is responsible for supervision; social enterprises are included.
Price and trading mechanism	Pricing mechanism	As for the pricing system under control, the one-part tariff (electric power price) will be adopted; some incentive DR projects adopt the two-part tariff; the bidding projects shall be settled in accordance with quotation.	Exert the characteristics that market competition forms price, adopt two-part tariff or multiple-part tariff; bidding project will be settled in the pay-off way.
	Trading mechanism	Dominated by the medium and long-term contractual transaction planned by governmental department, and auxiliary by the spot transaction.	Dominated by the medium and long-term contract and the spot transaction, conduct the future goods and option transaction.

6. Research on the implementation program of demand response pilot

6.1. Summary of DR implementation program

DR implementation program refers to the one that the different DR programs in different power market conditions are adopted to let consumer change its regular electricity consumption behavior; the essence is the process to expand and use multiple DR programs.

6.1.1. Division of DR implementation program

Since DR programs in different market conditions have different adaptability and maturity, the DR implementation program has the staged development characteristic; therefore it is needed to improve the measures as the market conditions at different stages improve. In accordance with the difference of administrative means and market-oriented means in the implementation process, the DR implementation program l can be divided into three modes, namely the primary stage mode, development stage mode and mature development mode[45].See the Figure 6-1 as follows.

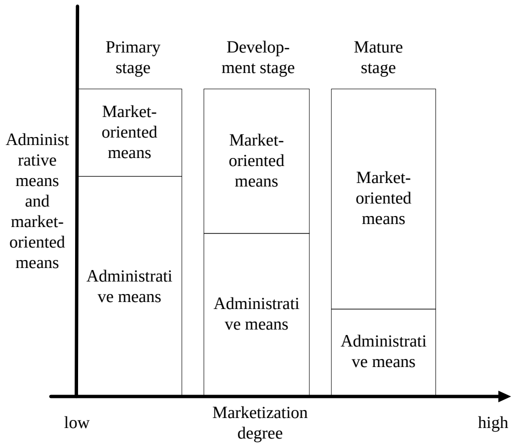

Fig. 6-1 DR implementation program at different stages

6.1.2. Development planning of DR implementation program

By integrating with the application and development of different detailed programs at the different stages, such as TOU, CPP, RTP, DLC, IL, EDR, DSB and others, the development planning of the DRimplementation program is proposed as follows:

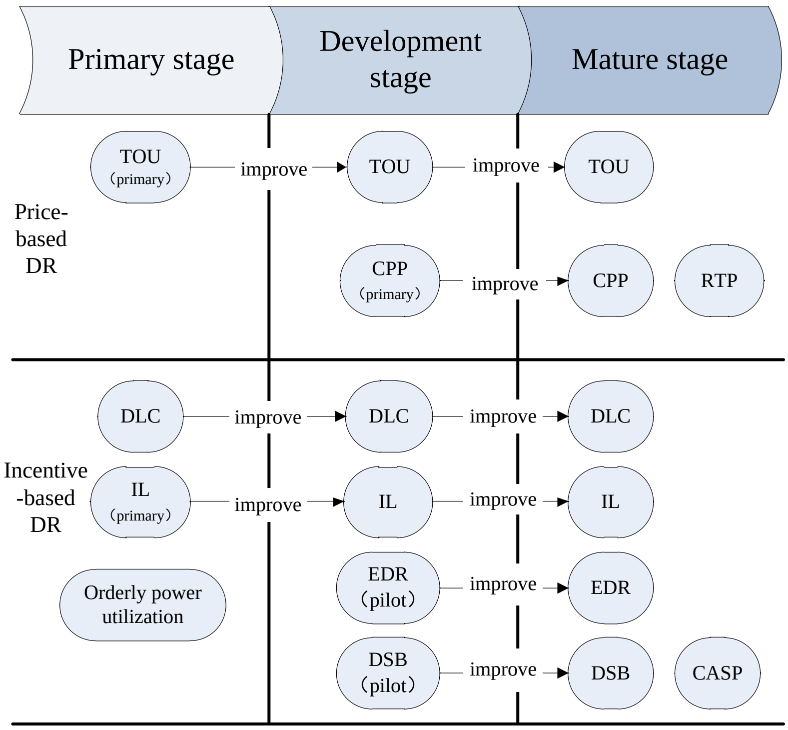

Fig. 6-2 Development planning for DR implementation program

The above mode division and development planning are done in accordance with the overall market environments and the DR characteristics. Due to the development difference of every area, the detailed project must be designed by integrating with the actual conditions of each region; the DR implementation program subjecting to the local conditions should be designed.

7. Design contents for DR pilot implementation program

In this chapter the design contents for the DR implementation program are analyzed and the key points of implementation program design and their mutual relation are determined, which provide the theoretic basis for conducting DR project in different pilot implementation environments.

7.1. Investigation on pilot environment

In view of China is geographically vast and there is unbalanced regional economic development, different power grid software and hardware and management level, and different DR implementation fundament, the job focus of DR project at different development stage is different; therefore when making the implementation program design, it is needed to firstly investigate the area in which the pilot project is located, analyze the local economic conditions, and then design the different DR implementation programs for different economic entities.

Consequently, investigating the pilot project implementation environment and analyze the regional electricity consumption characteristics is the first job of DR implementation program design.

7.2. Management mode

Management mode design is the basis to implement DR project. Generally speaking, the management mode of DR project is subject to the organizational structure of electricity market, type and contents of DR projects.

In the implementation process of DR project, the principal departments, namely government, electric power company, energy service company and electric power consumer, will be involved. The participating principal parts of the different types of projects are different, and the responsibilities are different too. In view of the different DR projects, it is preferred to clarify the detailed implementation flows and operation process and make rational labor division for the functions of every principal department.

7.3. Capital operation mode

Capital operation mode is the key to DR project. In the previous research, the innovative capital operation mode of China was mentioned, namely point evaluation system and insurance system. Such two innovative capital operation modes will be introduced hereinafter.

7.3.1. Point evaluation system

Point evaluation system applies to the price-based DR project and the incentive-based DR project. It has low participating threshold for consumers and consumers in small, medium and large-sized industrial and commercial can all participate. Consumers adjust their respective load in accordance with the electricity price or the incentive signal posted by electric power company, and electric power company accumulates the point of consumers in accordance with the point standard; consumers participating in the price-based DR project can exchange electricity price discount or offset load reduction indicator according to the given regulations (if the local conducts the incentive-based DR project at the same time), however, consumers participating in the incentive-based DR project can only offset load reduction indicator. In order to commend the consumer who participates in DR project actively and encourage other consumers, the electric power supply to consumer with higher points will be guaranteed firstly in the same circumstances.

(1)Point accumulation standard

Price-based DR project: on the basis of the monthly baseline load of consumer, the points will be accumulated in accordance with the reduction load. For instance in the point accumulation time specified by by an electric power company, consumer's (max. baseline load –max.actual load) on a day / max. baseline load = 5%; 10 points will be granted.

Incentive-based DR project: On the basis that consumer plans to reduce load (quota) on the day, the reduction load will be given the points according to the given percentage; for instance in the point accumulation time specified by an electric power company, consumer's (actual reduction –planned reduction) on a day / planned reduction = 5%; 10 points will be granted.

Within a year, when the grid load is in short supply, electric power company sends the signal to be incorporated into the point accumulation time to consumers; the original point is 0. The point in one year can be carried over to the next year; however a certain point will be reduced.

Point accumulation standard can be adjusted in accordance with project demand. In order to prevent consumer's response uncertainty from causing a higher point and the electric power company to undertake more risk , we can set the max-point of a day to be 20 points; if consumer does not complete the target to reduce peak load, the point on the day will be a negative value.

(2)Point exchange standard

Discount for exchanging point for electricity price: it is only limited to the price-based DR project. Consumer can exchange for electricity price discount towards electric power company at the end; for instance the 200 points can be exchanged for 0.1% price discount.

Offset load reduction indicator: the points arising from the price-based DR project and the incentive-based DR project will be exchangeable. Consumer can apply for exchange one week in advance; for instance the 100 points can be applied for exchanging for the daily planned reduction by 5%.

7.3.2. Insurance system

Insurance system applies to the incentive-based DR project and it is mainly aimed to large consumers. The incentive-based DR projects share a certain percentage in the local regional load and they are the important guarantees for implementing effectively the regional DR implementation effect. Electric power company needs to sign an one-to-one contract with large consumers. These large consumers will make a decision to buy insurance or not in accordance with the experience in the previous years and the yearly production plan.

In view of the different requirements of consumer on reliability, the higher the insured amount of consumer is, the higher the right to consume electric power is (in the circumstance that load is in short supply and the guarantee-oriented load is excluded); however when the load is specially in short supply, consumer needs to obey the dispatching and arrangement of the electric power company, however the compensation positively proportional to the insured amount’s multiplying power will be obtained. The insured money of consumer will be used by electric power company for publicizing, pacifying and managing other uninsured consumers when implementing the load reduction measures; which will be helpful for improving the service image of an electric power company and expanding its marketing ways.

8. Pattern design for DR pilot implementation project in typical region

Electric grid enterprise is the implementing entity of DR project. By integrating with the typical regions, the DR implementation program is specially researched and designed from the perspective of electric grid company; where the implementation scheme of DR project in different stages is studied in sense of implementation environment, implementation scheme, management mode, capital operation mode and other aspects.

8.1. DR implementation program in RES input area

Beijing-Tianjin-Tangshan region formed by the delta region among Beijing (the capital of China), Tianjin (a municipality directly under the central government) and Tangshan (an important city in East Hebei) involves in the tightened balance for electric power supply and demand; and the electric power gap may occur in the load peak period. However in sense of the Mengxi wind power consumption, Beijing-Tianjing-Tangshan electric grid plays important role. The electric power of the Inner Mongolia is transmitted to Beijing-Tianjing-Tangshan electric grid via an originally existing 500KV double-circuit line. In May 2008, the second 500KV double-circuit line was put into construction and the electric power transmitted from the Inner Mongolia was doubled to 4,000,000 KW from 2,200,000KW. In the year of 2011, Beijing-Tianjing-Tangshan electric grid and Liaoning electric grid, by sufficiently playing the role of “liaison” line, helped the regions, namely West Inner Mongolia, East Inner Mongolia, Jilin and Heilongjiang to consume the surplus wind power by 3,200,000,000 KWh.

By selecting Beijing-Tianjin-Tangshan area as the representative area of the RES input area, the DR implementation program in RES input area will be researched. Here the RES represented by the wind power will be discussed specially. Since the randomness, fluctuation and uncontrollability of wind, the wind power access to the electric grid in a large scale may cause influence to the reliability of electric grid; therefore the DR in the area and the DR related to the one receiving the wind power and other RES in a large scale should significantly focus on the system’s safety stable operation.

There are three stages for the DR implementation in the RES input are; the first stage is the primary stage; at which the implementation model integrated the Orderly use of electricity and TOU will be adopted; the second stage is the growth period and at which the TOU may be improved on the basis of the primary stage mode; the third stage is the mature period and at which the DR system featuring in using RTP and TOU as the regulation means and the DLC as the support means will gradually form.

8.1.1. DR implementation program at the primary stage in RES input area

The starting point of DR at the primary stage in such area is to guarantee system’s operating reliability maximally. In a daytime, wind power may change hugely, with the obviously anti-peak-shaving nature; however the wind power's generated output is larger in the low valley period at night and is smaller in the peak time in daytime. By integrating with the orderly use of electricity and peak-valley time-of-use tariff, the power supply shortage pressure in the peak time can be quickly soothed; which can also respond to reduce load rapidly in the high load peak time and reduce the impact caused by wind power fluctuations and insufficient power generation standby to the system reliability, and improve the operating liability of the system containing wind power.

(1)Management mode of orderly use of electricity

The business flow of the orderly use of electricity is shown as follows. Electric grid company needs to participate in proposal formulation, early-warning management and proposal implementation.

Table 7-1 Business flow of orderly use of electricity

Business name	Implementing unit	Detailed business
Scheme preparation	Provincial competent department for electric power operation Provincial electric grid enterprise	1. Determine the annual adjustment and control indicator for orderly use of electricity , issue the indicator to the competent department for electric power operation at all levels.
	Local competent department for electric power operation Local electric grid enterprise	2. Prepare the annual orderly use of electricity scheme for the local area
	Provincial competent department for electric power operation	3. Summarize the orderly use of electricity schemes of all areas, prepare the orderly use of electricity schemes of the local area, and report them to the provincial people's government and NDRC for filing.
	Competent department for electric power operation at all levels Electric grid enterprise at all levels	4. Publish the orderly use of electricity scheme and enhance publicity and drilling.
	Provincial competent department for electric power operation	5. Adjust the annual orderly use of electricity scheme of local area.
Early-warning management	Provincial electric grid enterprise	6. Follow up the electricity demand-supply change.
	Competent department for electric power operation at all levels Electric grid enterprise at	7. Publish the early-warning information timely.

	Electric grid enterprise at all levels	
Scheme implementation	Provincial competent department for electric power operation	8. Start the orderly use of electricity scheme timely.
	Provincial electric grid enterprise Non-local electric grid enterprise Power generation enterprise Electric power consumer	9. Electric grid enterprise should enhance the adjustment on the surplus and deficiency between provincial electric grids and mutual support. 10. Electric power generation enterprise enhance the equipment maintenance and fuel storage. 11. Electricity consumer enhances the electricity saving management.
	Electric grid enterprise at all levels	12. When the electricity gap is reduced, release the electricity consumption load timely. In emergency, the accident electricity ration plan, emergency plan for large area power off and the black start plan should be launched.

(2) Operation mode of capital for orderly use of electricity project

Improve the capital operation model of orderly use of electricity project by using the point evaluation system or the insurance system. ①if using the point evaluation system, consumer will refer to the orderly use of electricity scheme for implementation; where 10% will be granted if the daily peak-shaving amount surpasses 5% of the planned peak-shaving amount; if the given amount is not realized on schedule, the points will be deducted. Consumer can use the points to swap for reduction amount. For instance every 100 points can be used for swapping for the planned daily reduction amount by 5%. In order to facilitate electric power company to adjust the given plan, it is needed to make the application one week in advance. If more swap is applied in one day, electric power company and consumer can adjust the swapping date through consultation; ②If using the insurance system, consumer can sign the insurance contract with electric power company in accordance with its electricity guarantee demand. Such two systems can help consumers to improve their enthusiasm for participating in orderly use of electricity project; and more consumers are willing to participate in the orderly use of electricity project to provide more orderly use of electricity resources .for the system; thence the implementation scheme will be more flexible.

(3) Management mode of TOU project

TOU will be completely managed by the electric grid enterprise. The key to implement the TOU is the time interval division and peak-valley price determination. The researches on the peak-valley TOU are rather mature, and many provinces in China have obtained better implementation effect.

According to the actual conditions of the local area, it is proposed to determine the peak price, usual price and valley price on the basis of the electricity price directive of Beijing-Tianjin-Tangshan Electric Grid printed and issued SDPC (state development planning commission) and the ministry of electric power. After selecting the implementing object, in accordance with the historical data of load, the elastic matrix of electricity and electric price and other theories can be used for predicating the implementation result so as to find the best or optimal electricity price scheme. Since the TOU is not appropriate to adjust frequently, if it is implemented, the effect is not special ideal; therefore it is needed to use the encourage means to encourage consumers to shave peak and fill valley. On the basis of using the TOU as the basic load reshaping mean and in view of the special condition the wind power output reduces suddenly, the CPP will be introduced. When the wind power output reduces suddenly, the electric grid's operating and management institution will start the peak price to reduce the electricity consumption load level.

(4) Operation mode of capital for TOU project

As for the point evaluation system, it is needed to consider the point rolling issue; therefore it is proposed to take every three years as one cycle; during this period, the point in the first year will be reduced by half and carried over to the 2nd year; the point in the 2nd year will be reduced by half and carried over to the 3rd year. The points in the 1st year will be zeroed at the end of the third year. This description applies also to the point evaluation mechanism mentioned hereinafter.

Improve the TOU project capital operation model by using the point evaluation system. The key role of the TOU is to optimize load curve and improve load rate. When the electric power company issues the start signal of point time period, in accordance with the point (baseline max. load – actual max. load) / max. load of baseline), the daily max. point is 20. At the end of the year, consumer can use the point to swap for electricity price discount towards the electric power company; for instance every 200 points will be swapped for the electricity price discount by 0.1%.

8.1.2. DR implementation program at the development stage in RES input area

In line with the fluctuation of medium and long-term or short-term wind power output, it is allowed to improve the TOU at the primary stage in this region and implement two types of TOU price alternatively, namely the seasonal TOU and daily-peak TOU.

(1) Seasonal TOU project management mode

In this area, there is heating period in a year. During the heating period, since there is the need to guarantee the heating facilities to keep on operation, the supply side peak-shaving resource will reduce, and the wind power will be hugely abandoned. Therefore according to the division standard of "heating period – non-heating period", it is preferred to determine the seasonal TOU price. During the heating period, it is preferred to reduce the electricity's selling price level of major electricity consumer so as to improve wind power load and guarantee wind power to be consumed sufficiently.

(2) Seasonal TOU capital operation mode

The purpose to implement the seasonal TOU is to soothe the serious wind power abandon phenomenon, especially during the heating period. It is preferred to use the point evaluation system to improve the capital operation mode of seasonal TOU project. The point accumulation and exchange pattern of points are rightly similar to that of the TOU price.

8.1.3. DR implementation program at the mature stage in RES input area

At the mature stage, the DR system will be gradually formed, where the RTP and TOU will be the main adjusting means, the DLC will be the supporting means; which will guarantee the safe and reliable system operation better. In sense of the daily load re-shaping, the RTP will be of high efficiency. Therefore at the mature stage, the TOU mechanism will be improved, namely the daily peak-valley TOU will be changed into the RTP on one hand, and the seasonal TOU will be maintained still on the other hand.

(1) RTP project management mode

RTP is the advanced type of TOU. In sense of the load reshaping, RTP has higher efficiency. Therefore at the mature stage, the practice to introduce the RTP will help to improve the DR effect and soothe the bad influence caused by the fluctuation of wind power output. According to the different division methods, there are multiple types of RTP mechanisms, namely the day-ahead type, in-day type, mandatory type, and voluntary type. At the mature stage, it is preferred to firstly consider to introduce the day-ahead RTP so as to determine one day in advance to inform consumer the hourly power tariff for the next day (24 hrs). Additionally, as for the selection of RTP consumer, some large industrial and commercial consumers were selected as the “RTP customer group”, where the RTP was used as an optional electricity price mechanism. Later as the “RTP customer group” expands, the RTP will be used as the mandatory price of large industrial and commercial consumers.

(2) RTP capital operation mode

Improve the capital operation mode under the RTP mechanism by using the point evaluation system. Predicate the daily baseline load of RTP; the point = (daily baseline max. load –daily real-time max. load) / daily baseline max. load *100. The daily max. point is 20. Consumer can use points to exchange for electricity price discount towards the electric power company at the end of the year. For instance 200 points can be used for exchanging for the electricity price discount of 0.1%;

(3) Management mode of DLC project

Increase further the DLC capacity resource for wind power on-grid operation at the mature stage, enlarge the size of DLC project, guarantee the system to run reliably. The implementing institution should sign the contract with consumer in advance to determine the relevant clauses, including: quantity of event to be controlled, control cycle, load reduction amount and load reduction cycle. At the peak load time interval, electric power department can use the monitoring equipment to take different control measures for different kinds of load, and the cut off the power supply of terminal consumers through the load control devices in a circulative way or on the staged basis. In accordance with the different conditions, determine the incentive or tariff discount of consumers, set off the tariff of citizen consumers. However as for the industrial and commercial consumers, it is needed to verify the actual reduction amount firstly before payment. The DLC should be made the sequence control on the principle of power outage cost.

(4) Capital operation mode of DLC project

Improve the capital operation mode of DLC project by using the point evaluation system or the insurance system. ①If using the point evaluation system,the implementing institution will be granted 10 points if its daily reduction on consumers' load surpasses the contractual reduction amount by 5%; consumer can use the points for swapping for reduction amount; for instance every 100 points can be used for swapping for the contract reduction amount by 5%. In order to facilitate electric power company to adjust the given plan, it is needed to make the application one week in advance. If more swap is applied in one day, electric power company and consumer can adjust the swapping date through consultation; ②If using the insurance system, consumer can sign the insurance contract with electric power company in accordance with its electricity guarantee demand. Such two systems can help consumers to improve their enthusiasm for participating in DLC; and more consumers are willing to participate in the DLC project.

8.2. DR implementation program in RES output area

Gansu is one of provinces with relative rich wind power resources in China. Situated in the center of the northwest grid, Gansu undertakes the task to transmit electricity. In 2012, the construction project for the first lot of 3,000MW wind power under the Stage II project of Jiuquan Wind Power Base was launched was completely launched. It is estimated that the wind power installed capacity in Gansu will reach 17,000MW or more by the year of 2015.

Select Gansu province as the representative of the RES energy output area, and then research the DR implementation program in the RES output area. Herein the RES represented by wind power will be specially discussed. If the area has no enough standby pick-shaving resource, when there is large wind power output, certain wind will have to be abandoned; therefore the waste of wind power resource will be inevitable. The starting point of the implementation DR is to exert the advantage of the local rich wind power resource and use the wind power resources efficiently. Besides, since the transmission capacity is in short, it is hoped to stimulate the demand by implementing the DR and encourage consumers to use more electricity when the wind power output is adequate so as to improve the wind power consumption capacity finally.

Divide the DR implementation of Gansu into two stages. At the stage 1, the wind power, provide that it surpasses the wind power reception capacity of the system, will be abandoned; at the stage 2, the DR gentle wind power fluctuation will be considered to improve the wind power’s utilization efficiency. The first stage is the primary period; the second stage is the development period. It’s thought that Gansu is now transmitting from the primary period towards the development period currently.

8.2.1. DR implementation program at the primary stage in RES output area

The starting point to implement the DR at the first stage in the area is to exert the advantage of the local rich wind power resource and use the wind power resources efficiently. At this stage, the one to use the elastic load to improve the system's RES reception cannot yet realized.

Extensive mode. The thermal power generator units will be used to shave peak load without considering the coordination optimization of wind power and other resources. The efficient generated output of Jiuquan Wind Power Base is 62.9% of the installed capacity; where the generated output is high, showing the high difficulty to shave system peak. At this stage, consumers are hoped to use the wind power resources as much as possible when the wind power's generated output is high so as to reduce the standby pressure of system. For instance the wind power can be directly used for consumers for providing local heat; if the receiving capacity of the system for wind power is exceeded, the surplus wind power will be abandoned. Since China adopts the support polity, namely "electric grid enterprise acquires wind power without conditions in full" for wind power, as long as the paid peak shaving when the load is at the valley time is not enough, some wind power will be cut off so as to achieve supply-demand balance. Therefore power company can sell the wind power used for providing heating at a relatively low price. However in sum, the wind power's utilization rate is not only high, the electric power company is also hard to enjoy the benefits of consuming wind power.

8.2.2. DR implementation program at the development stage in RES output area

Since the transmission capacity is not enough, it is hoped to stimulate the demand by implementing the demand response so as to stimulate consumers to use more electricity when the wind power is enough and improve the wind power consumption ability; therefore the DR project at the development stage in such area must consider the system reliability and economy concurrently; the uncertainty of adopting DR resources to support the wind power resources makes electric grid receive more wind power in the condition of assured safety, and user can also enjoy the benefits brought by RES access.

(1) Management mode by integrating wind power with DR resources

Collaborative mode. By considering to integrate wind power with DR resources, the peak-valley TOU and the IL can efficiently improve the economy and safety of system operation. As for the system containing wind power, the peak-valley TOU, in the low valley time, may guide consumer to increase electricity consumption demand, equaling to increase the negative spinning reserves of system and corresponding to the characteristics that the higher generated output of wind power is available in the low valley at night, and thence more wind power resources can be consumed so as to efficiently reduce the wind power amount abandoned by the system. However in the peak time, IL reduces the electric power consumption demands and reduces the impact of wind power fluctuation and power generating equipment's insufficiency on system reliability; where IL can rapidly respond to reduce load and improve the operating reliability of the system containing wind power.

(2) Capital operation mode by integrating wind power and DR resources

The capital operation mode to use the point evaluation system to improve the peak-valley TOU and IL is also suitable herein. Besides a bundling operation mode is proposed additionally, where electric power company can integrate with DR resources to classify in accordance with resource load size, response speed, compensation price and others so as to be used as the paid peak-shaving output of wind power. Before wind power is connected to the electric grid, wind power enterprise needs to buy the DR resources of a certain percentage to the grid load so as to mitigate the peak shaving pressure. Such method can make wind power company use wind power resources to generate electricity more efficiently; electric power company can use the benefit from the paid peak-shaving output to pay the cost arising from consumers who participate in DR; where consumer win the ideal demand response compensation and increase their participation enthusiasm; so the DR resource may develop towards the diversified directions so as to form a virtuous circle.

8.3. DR implementation program in RES local consumption area

The load level of Jiangsu electric grid is only interior to that of Guangdong and ranks top 2 in China. From October 2006 in which the first wind power generator unit in Jiangsu province was put into operation to present, the wind power in whole province of Jiangsu has developed rapidly, and the wind power generator units have work steadily, the generated output of wind power in Jiangsu has been consumed 100% by Jiangsu electric grid, and no wind power has been abandoned since the reason of electric grid. In recent two years, the utilization hour of wind power in Jiangsu has been kept around 2,100hours, which is almost equalto the level of Europe and USA.

Select Jiangsu province as the representative of local RES consumption area, and then research the DR implementation program of local RES consumption area. The electric power consumption characteristics in the area are: more people and less land, developed economy, rapid electric power demand, available basis for implementing DR, high electric grid software, hardware and management level, local load is only inferior to that of Guangdong and ranks top 2 nationwide. Therefore the DR project related to the one consuming large size of wind power and other RES in such area should cover two issues, namely the safe and stable operation of system and bi-directional interaction of electric grid side and customer side.

The job focus at the different stage of DR project construction is different. Divide the DR project implementation in Jiangsu province into three stages. At the first stage, the peal-valley TOU, the efficiency power plant boosted by government and orderly use of electricity will be significantly implemented; at the second stage, the efficiency power plant interruptible load (IL) boosted by market will be implemented for a long time; at the third stage, it is the stage to implement CPP and DLC in the early time and introduce more flexible market-oriented means – demand side bidding in the later time so as to improve the enthusiasm of large industrial and commercial consumers to participate in RES demand response, and finally enlarge the DR project scale against RES grid.

8.3.1. DR implementation program at the primary stage in the RES local consumption area

It is required to give sufficient considerations to the impact of wind power uncertainty on reliability of electric grid, guide consumers to change their electric power consumption methods; besides the DR project must be simple to implement and it is not preferred to adjust frequently in the implementation process. At the initial stage, the governmental support and capital subsidy of governmental departments are a must. As for the orderly use of electricity project, it is required to given sufficient considerations to the load reduction capacity of consumer, namely the electric power demand of consumer will be reduced at the load peak time so as to rapidly solve the tense electric power supply pressure in the peak time, reduce the impact of insufficient power generation standby and wind power fluctuation on system reliability, realize quick response, reduce load and improve the operating reliability of wind power system. TOU project can guide consumer to increase electric power demand when the wind power has high generated output, which equals to increase the negative spinning reserves of system, consume more wind power resources, efficiently reduce system's wind power abandon quantity. Moreover since Jiangsu belongs to the high load area, in order to soothe the load peak and electricity shortage, the efficiency power plant boosted by government can be adopted; in the implementation process of such project, it is only needed to provide the support by governmental administration.

(1) Management mode of Orderly use of electricity project

Under the current management framework, it is preferred to establish the electric power balance and classification early-warning mechanism under the wind power on-grid conditions. Aiming to the different electric power balance early-warning grade, it is preferred to take actions to avoid the peak hour and peak resources rationally, and clarify the implementation measures of orderly use of electricity; when the early warning classification is low, the administrative means, namely the means to avoid peak hour, have holidays by turns and others will be adopted; when the early warning classification is high, the emergency means to ration the power supply by avoiding peak hour and apply for interruptible load (IL) will be adopted in turns.

As for the capital operation mode of orderly power utilization, it has been introduced above; therefore it is not be described herein any more.

(2) Management mode of TOU project

Based on the current management mode and within the wind power balance area, make summarization on the wind power on typical day. In line with the fluctuation law of the generated output of wind power, it is preferred to establish the daily peak time-of-use tariff. When the wind power's generated output reduces or improves, the marketing electricity price level of main electric power consumers will be correspondingly improved or reduced so as to make the load level of consumer same to the change in wind power's generated output.

As for the capital operation mode of TOU project, it has been introduced above; therefore it is not be described herein any more.

(3) Management mode of EPP project boosted by government

The management department (EPP project team) controlled by electric grid enterprise can be established as the implementing entity of the EPP project, which can conduct works by making coordination with the commission of economy and information technology. This department will control the operation of the whole EPP and will be responsible for the planning, declaration, approval, supervision and validation of EPP project, raising capital for project operation, formulating and promulgating administrative measures, specifications and incentive policies for EPP project, providing market-oriented operation guide, incubating energy service market, making publicity, training and guidance for EPP and its energy efficiency works. Electric grid enterprise is the main participating entity and plays important role in the construction process of EPP. On one hand, the electric grid enterprise co-works with the governmental competent department to conduct the energy efficiency project, participate in the planning, approval, supervision and validation of EPP; on the other hand, electric grid enterprise can provide technical guide for consumer who is willing to implement EPP project. ESCOs, through bidding or is designated to implement project, provides consumer the relevant energy services, for instance the design, consulting of energy efficiency scheme or upgrade of energy efficiency project.

(4) Capital operation mode of EPP project boosted by government

Improve the capital operation mode of EPP project boosted by government by using the point evaluation system. Herein the point evaluation system will be adjusted slightly. The EPP project team will be responsible for raising capital for the EPP project; where the capital for the EPP project will come from the self-financed fund. The capital source is the special fund of government and the supporting capital of electric power company. Currently Jiangsu grants the subsidy to the energy efficiency project by 30%~50% of the price difference between general equipment and the high-efficiency equipment. After passing the relevant review, the subsidy capital will be 50%; afterwards, if the energy efficiency project is validated, an extra 50% of the subsidy capital will be granted. In accordance with the point evaluation system, namely the point = saved peak load / declared peak load conservation x 100; if the point goes beyond 100, all subsidy capital will be granted after validation and the reward will be granted too. For instance the point 10 corresponds to the reward of 1% x subsidy capital; if the point is less than 100, some subsidy capitals will be deducted, for instance the point 10 corresponds to the punishment of 15% x subsidy capital.

8.3.2. DR implementation program at the development stage in the RES local consumption area

On the basis of the primary stage, electric power company enhances its interactions with consumer, and electric power company implements more standard project implementation flows, even the market-oriented progress is expedited further. Therefore the EPP project boosted by market will be implemented at this stage. The EPP project boosted by the market starts to use the contract energy management mechanism with the market-oriented characteristics to improve the EPP project implementation result and reduce the EPP project implementation risk. However the important measures of IL are to compensate consumer; thence this mechanism can hugely improve the enthusiasm of consumer for participating in DR, and consumer will have certain market initiative.

(1) Management mode of efficiency power plant project boosted by market

The efficiency power plant project boosted by market adopts the contract energy management mechanism to enhance its market-oriented process and reduce the burden of governmental departments and electric power companies, and is gradually turned into the diversified financing mode from the single financing mode (namely loan mode). As for the professionalized Energy Service Company ("ESCO" for short overseas and "EMCo" for short domestically), electric power company can use its professional talent and technical advantages to establish its affiliated EMCo, or is encouraged simultaneously to establish the third party's EMCo. However all EMCo have the almost same business contents, including the following service contents: ① energy source audit (energy saving diagnosis); ②energy saving project design; ③ negotiation and signing of energy-saving service contract; ④energy-saving project financing; ⑤ Raw material and purchase, construction, installation and commissioning of equipment; ⑥Operation, maintenance and upkeep; ⑦energy conservation benefit guarantee; ⑧EMCo and customer share energy saving benefit.

The contractual relationship established by EMCo and customer for the detailed implementation of energy-saving project is called as the "Energy service contract". The operation method of EMCo is called as the "contract energy management".

(2) Capital operation mode of efficiency power plant project boosted by market

As for the capital operation mode, namely the energy efficiency power plant is boosted by improving the insurance system market, in order to fit to the project, the insurance system is changed herein. When signing a contract, EMCo and consumers may pay the insurance money to electric power company; electric power company can receive the overhead cost at a low percentage. Upon the mutual monitoring or if the energy conservation effect of the energy conservation project within the term of the project contract is confirmed, provided that consumer's management and utilization is inappropriate and which causes reduction to energy conservation effect, some consumer's insurance money will be deducted so as to pay the benefit loss suffered by EMCo; provided that the energy conservation effect is reduced since the reason of EMCo, some insurance money of EMCo will be deducted so as to pay the energy conservation benefit loss of consumer. After the term of the project contract expires, electric power company can refund the balance insurance money to EMCo and consumer. Through such methods, EMCo and consumer will be supervised to use their every endeavor to do their best in the energy conservation reconstruction process, thence it can improve the project implementation effect and reduce the risk of both parties.

(3) IL project management mode

IL management is very similar to orderly use of electricity . IL is a more market-oriented form, which considers the demands of consumers and consumers can obtain interruption compensation. Power company and consumer sign the IL contract; in the peak time and when the load is in short supply, power company will compensate consumers. Such contract will specify the information clearly as follows: early notice time, minimal cut-off capacity, interruption duration, compensation and etc.

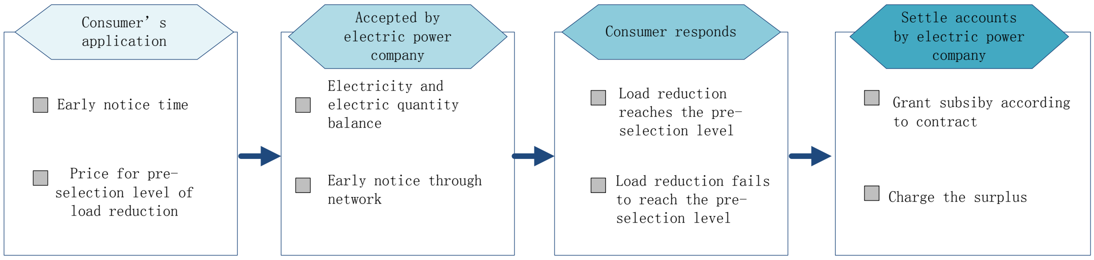

Fig. 8-1 IL management mode

(4)Capital operation mode of IL project

It is similar to the orderly use of electricity; what it is different is that IL provides consumer a certain electric charge preference or interruption compensation. The point evaluation system or the insurance system will be used for improving the capital operation mode of IL. ①If the point evaluation system is used, the function of interruption duration for point is added, namely the point = ((consumer's actual reduction capacity – contractual reduction capacity) / contractual reduction capacity x 100 + (consumer's actual interruption duration time – contractual interruption duration) / (contractual interruption duration x 100) / 2; consumer can use points to exchange for interruption compensation or apply for electricity price discount. For instance 200 points can be used for exchanging for the electricity price discount of 0.1%; ②if the insurance system is adopted, consumer and electric power company sign the insurance contract when signing the IL contract, or sign only the insurance contract; the IL contract will be used as the compensation contents in the insurance contract.

8.3.3. DR implementation program at the mature stage in the RES local consumption area

The early DR project at the mature stage in the area, based on the last stage, enhances further the peak clipping effect by starting from DR itself in sense of two aspects, namely the price-based aspect and the incentive-based aspect; therefore it is preferred to select to implement the CPP and the DLC project. The CPP project will be conducted for facing to high energy-consuming industry; where the range of the object is smaller than that of the peak-valley TOU; however the price implementation strength is strong; the DLC can guarantee the operating reliability of the system better. At the later mature stage, in order to improve the enthusiasm of large industrial and commercial consumers for participating in RES DR, it is proposed to introduce the more flexible market-oriented means, namely the demand side bidding, and then enlarge the on-grid demand response project scale of RES.

(1) CPP project management mode

CPP is the critical peak time separated from the peak time of the peak-valley time-of-use price (TOU); its management mode and business flow are very similar to the peak-valley TOU. On the basis of using the TOU price as the basic load reshaping mean, it is preferred to introduce the CPP against the special condition, namely the wind power's generated output is reduced hugely. Firstly consumer submits the application for participating in CPP project to electric power company; when the wind power's generated output is reduced hugely, the electric grid operation and management organization may trigger the CPP, where consumers will respond and the electric power load level will be reduced.

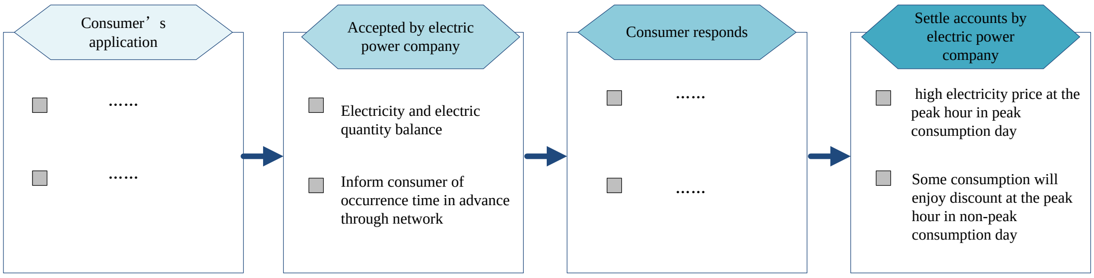

Fig. 8-2 CPP management mode

There are two types for the CPP, namely the CPP with fixed term (CPPF) and the CPP with variable term (CPPV). Under the CPPF mode, the peak load’s duration is known in advance (generally it will be noticed one day in advance); the implementation time-point and duration of CPPV are not known in advance; so the technical support from the intelligence response and both-way communication are needed. At this stage, since the relevant intelligence communication technology is not yet improved, there is difficulty to implement the CPPV, and the CPPF will be bought preferentially.

(2) Capital operation mode of CPP project

The purpose to implement the CPP is to further reduce peak load, especially to limit the peak load of high energy-consuming industry; it is planned to adopt the point evaluation system to improve the capital operation mode of CPP project. The point accumulation and exchange mode are similar to that of the TOU. Electric power company can withdraw a certain percentage from the CPP benefit and use it for supporting the development of DR project.

(3) Demand side bidding project management mode

In the circumstance that market is mature, the difference of power generation fuel cost of various generator units of power generation producers will be reflected by the purchase price of electric power company. In order to reduce the purchase cost, electric power company, after comparing with TOU price and the purchase cost, shall calculate the capacity that can be released for demand side bidding. Electric power company publishes the predicated value of reduction capacity, and consumer provides a portfolio bid containing price and reduction load quantity. The bidding principle is that consumer determines the compensation fee rate needed by itself; the one with the low price will be awarded. If the consumer is awarded the bid, it will be required to reduce the corresponding load from the next day; otherwise the punishment will be launched.

(4) Demand side bidding capital operation mode

The capital operation mode, namely use the point evaluation system or insurance system to improve demand side bidding, will be adopted. ①If the point evaluation system is used, namely point = (consumer’s actual reduction capacity – bidding reduction capacity) / bidding reduction capacity x 100. If consumer's actual reduction amount is less than the bidding value, the point will be negative; if consumer’s actual reduction amount is more than the bidding value, the point will be positive; the daily maximum point + 20. Points of consumer will be added up at the end of a year; if the points are positive, the points can be used for exchanging for electricity price discount or remuneration against electric power company; if the points are negative, the punishment will be launched; ② if the insurance system is used, the methods mentioned in the previous paragraph will apply to the mode similarly.

8.4. DR implementation program in abroad typical area

USA takes the leader status in the international RES market. Its RES exists in a distribution form and which is hugely different from the ones in China. Among which the wind power is the RES that has gotten rapidest growth. Currently USA government is very optimistic for the development prospective of wind power. According to the forecast of the United States Departmental Energy, 20% of total electric power demand of USA by the year of 2030 will come from the wind power. In USA, California, a state situating in the west coastal bank of USA, is the leader of the wind power industry of USA.

Additionally, the electric power supply crisis of California has passed for almost 10 years; there the tense electric power supply in the high electricity consumption peak time has been soothed year after year, but the problem does exist as usual. As plenty of RES electricity is connected to the electric grid, the one to further reduce energy consumption and tap RES utilization space on the basis of guaranteeing the reliability and safety of electric power system is the main problem to be faced with.

Since the electricity market environment in USA is very open, the quantity and kind of DR project to be implemented are complete in the world, and all conditions are rather mature; therefore the general development direction of DR project in USA is the Auto-demand Response. By integrating with the actual conditions of California, it is preferred to study the DR implementation program in the local area, and then integrate the Auto-Demand Response technology on the basis of the existing DR project.

(1)Project management mode of efficiency power plant

California Public Utilities Commission engages in project supervision, making overall electricity saving objective and approving project capital; electric power company engages in designing, managing and implementing energy efficiency project. The detailed role assignment is as follows:

①California Public Utility Commission and California Energy Commission are mainly responsible for making planning and policy for efficiency power plants; the planning covers a cycle of 10 years and is revised every two years. Meanwhile such two commissions are responsible for monitoring the use of special fund, evaluating and auditing energy consumption, introducing and popularizing energy conservation technology and product, establishing new standard, and making DSM project effect evaluation.

②Electric power company is the implementing entity, responsible for implementing the energy efficiency projects. The demand side management capital comes from electric surcharge; which is under the supervision of governmental department. Electric power company implements the energy efficiency project through ESCOs or by expanding market by itself.

③As the main participant, ESCOs provides energy audit (diagnosis) and design energy efficiency scheme for consumer who is found the energy conservation potential, and get benefit, namely the subsidy, with the consumer who implements the energy efficiency project. The energy efficiency scheme designed by ESCOs for consumer is implemented by the third party. The energy conservation effect of energy efficiency project is verified by California Public Utilities Commission, California Energy Commission, consumer, electric power company and other third parties.

④As the main participant, consumer can co-work with ESCOs or participate in directly through the popular energy efficiency project (for instance energy-saving lamps), and get benefits from subsidy. As for commercial projects, government usually provides rational subsidy to make the payback period of investment shorten to 2 years or less.

⑤As the other important participant, the third party is an integral part, which includes mainly consulting company, construction enterprises and others; with the main responsibly of consulting, constructing and evaluating energy efficiency project. The public utilities commission, energy commission, electric power company, ESCOs and consumer may possible establish cooperation with any third party.

(2) Project capital operation mode of efficiency power plant

The cost of energy efficiency project will be recovered through electric surcharges and other service charges. It is preferred to charge the “public benefit charge” or the “system benefits charge” to be listed separately towards the one-way consumers through the electricity bill, and then establish the energy efficiency development foundation. The system benefits charge will be collected according to the reading of electricity meter; such charge applies to all electric power consumers, and the charging standard is same and it is 1% around of the electric charge. The other expenses needed by energy conservation plan are contained in the electric charge, and the collection method is rightly as same as that of the electric power supply cost contained by the electric charge (for instance purchase financing and etc.).

(3)Management mode of Auto-Demand Response Project

PG&E is responsible for managing and constructing the infrastructure of auto-demand response project. California ISO is responsible for the system operation and issuing the dispatching signal; Lawrence Berkeley National Laboratory (LBNL) is responsible for researching Open ADR and DR control strategy and others; and Akuacom is responsible for scheduling signal automation and other relevant technical services.

By analyzing the operating status of the current system and the change in the generated output of RES, the scheduling department may decide how many DR resources will be called and the notice will be sent to consumers participating in DR; after receiving such notice, consumers will respond the instructions of scheduling department and the auto-demand response device will rapidly decrease or increase demands according to the presetting load increase or decrease control strategy so as to follow up the change in the generated output of RES and guarantee the supply and demand balance.

(4) Capital operation mode of auto-demand response

Within the range of scheduling time quantum, consumers who participate in auto-demand response will be rewarded if they respond the load increase instructions to increase the additional electric power consumption; however the participating consumer who changes the normal electric power consumption mode, if responding the load decrease instructions, will be awarded the corresponding points. Herein the point evaluation system can be used as the reference.

8.5. Analysis of examples for DR implementation program

In accordance with the design contents of the DR implementation program to which the RES is connected, an area is taken as the example to analyze the effect brought by the implementation of DR project.

8.5.1. Project scenario setting

In accordance with the main characteristics of RES input area, the main conflicts will be seized and the implementation targets will be clarified; the scenario set for implementing the DR project is rightly as follows:

Table 8-1 Scenario Setting

Time quantum / DR project set / Project type	primary stage	Development stage	Mature stage
Price-based	TOU	TOU&CPP	TOU&CPP&RTP
Incentive-based		IL	IL&DLC

8.5.2. Project planning

According to the DR project conducted by industrial customers and commercial customers, the price-based DR and the incentive-based DR planning capacity will be conducted preliminarily, see the Table 8-2 as follows:

Table 8-2 Project planning

Unit: 10MVA

Time quantum / DR project set / Project type	Initial stage	Development stage	Mature stage
Price-based planning capacity	131.93	139.85	145.12
Incentive-based planning capacity	0	29.05	52.77

The price-based DR planning capacity adopts the point evaluation mechanism;

the incentive-based DR planning capacity adopts the insurance contract mechanism. On the basis of realizing the basic TOU in the area, the point evaluation system is adopted to optimize the TOU; meanwhile the insurance contract mechanism is adopted to conduct the incentive-based DR project planning.

8.5.3. Project operation and benefit

(1)Price-based DR

Presumed that the local area adopted the uniform electricity price policy when implementing TOU, CPP and RTP project. Launch the point operation mechanism for the price-based DR for consumers within the planned range, do not change the existing settlement mode for TOU. Implement the point mechanism in the month having the maximum load; the baseline load is determined in accordance with the yearly load last year and the yearly electric power and economic forecast in the current year; herein it is temporarily fixed as the average daily load curve of the months having high load peak last year, and the load increase rate of the current year is temporarily 8%.

By referring to the DR pilot implementation effect of China and according to the conservative estimate, the load reduction potential is about 5% at the primary stage, about 8% at the development stage and 10% at the mature stage. If the peak load simultaneity factor is 0.8, so in accordance with the calculation formula:

Daily max. peak-time reduced load = peak load simultaneity factor * (1+annual load growth rate) * load capacity of participating consumer * load-reducing potential

The daily max. reduced load of the price-based DR at the peak time is about 57MW at the primary stage, 96.7MW at the development stage and 125.4MW at the mature stage.

According to the ideal condition, all participating consumers shall respond the daily load and get rational swap according to their respective potential. The point response and swapping difference of consumer (provided that it is 50%) is the actual peak-shaving value; therefore the max. peak-shaving value is 28.5MW at the primary stage, 48.3MW at the development stage and 62.7MW at the mature stage.

Cost of electric grid’s evitable capacity = peak load to be shaved * consumer’s simultaneity factor * unitary evitable capacity’s cost / (1-power distribution loss coefficient) / (1-system’s reserve capacity coefficient)

Where:

Unitary evitable capacity’s cost is RMB265/kW per year;

Consumer’s simultaneity facto is 0.8;

Power distribution loss coefficient is 0.05;

System’s reserve capacity coefficient is 0.1.

Upon the calculation, the electric grid’s evitable capacity’s cost is RMB7.0667million at the primary stage, RMB11.976 million at the development and

RMB15.547 million at the mature stage.

(2)Incentive-based DR

The incentive-based DR project is mainly conducted for large consumers. At the beginning of a year, government should forecast the annual max. load deficiency according to social economy, load and growth tendency of installed capacity, and then plan the scope of consumer for the incentive-based DR project.

Conduct the incentive-based DR project by adopting the insurance contract mechanism. Since consumer's production and living requires different electricity consumption level, the insurance limit may vary accordingly. Generally the consumer with small capacity may cover high insurance limit. As for the typical insurance limit, see the Table 8-3 as flows.

Table 8-3 Insurance Coverage for Project under Insurance Contract Mechanism

User No.	Grade of electricity reception capacity	Insurance capacity (10MVA)		Insurance multiple (K)
		Development stage	Mature stage	
1	630KVA or less	0	0	--
2	630-1600kVA	1.125	3.452	3
3	1600-3000kVA	2.2838	5.892	2.5
4	3000-5000kVA	6.27	12.072	1.8
5	5000-10000kVA	6.408	14.788	1.2
6	10000-20000kVA	8.64	16.566	1

In the actual operation process, the consumer of the same grade may cover the different insurance multiple; however the general tendency is consistent with the table above. According to the formula, namely:

Guarantee money = unitary sum insured * (type 1 insurance capacity * multiple 1 + type 2 insurance capacity * multiple + …)

Where: unitary sum insured is RMB20 /kW

So the guarantee money is RMB8.644million at the development stage and RMB16.225million at the mature stage.

Based on the incentive-based DR project under the insurance system, due to the load deficiency at the peak time, in order to guarantee the electricity consumption of highly insured customers, the measures will be taken to stagger the peak hour; thence a certain expense for publicity and placation will be needed. The worst predicated condition is that the required peak-shaving result is not realized in the given area, and the load indicator of consumer with lower insured limit is used for replacing for that of the consumer with higher insured limit; where the direct yield of electric grid company includes the difference between the insured amount and the compensation, namely the direct yield = guaranteed capacity * insured multiple – uninsured capacity * insured amount * repayment multiple.

In accordance with the consumer investigation, the IL potential is about 15%; however the uninsured consumer has low response degree; thence the response degree of insured consumer can be improved by the measures of publicity and placation so as to make it reach 50% approximately. According to the above typical value, the direct yield of the electric grid company of the incentive-based DR can be calculated.

Load capacity responded by uninsured customer at the development stage = response degree of uninsured consumer * potential of uninsured consumer = 176.1MVA. The contract capacity is 290.5MVA; in the worst condition, the electric grid company needs to repay an amount of (29.05-17.61)*20*2=RMB4.5764.576 million . Provided that the repayment multiple k=2, and the placation and publicity expense of 15% approximately are deduced, the actual yield of the electric grid company will be 864.412*(1-0.15)-457.6=RMB2.77million.

In the similar way, the load capacity responded by uninsured customer at the mature stage = response degree of uninsured consumer * potential of uninsured consumer = 158.32MVA. The contract capacity is 527.7MVA; in the worst condition, the electric grid company needs to repay an amount of (52.77-15.832)*20*2=RMB14.775million. Provided that the repayment multiple k=2, and the placation and publicity expense of 15% approximately are deduced, the actual yield of the electric grid company will be1622.544*(1-0.15)-1477.52=RMB0.9836million.

Therefore upon the price-based DR and the incentive-based DR project to be conducted, electric grid company will realize its yield as follows:

Table 8-4 Project Benefit

	Primary stage	Development stage	Mature stage	Remarks
Price-based DR project under point evaluationmechanism	RMB7.0667million	RMB11.976million	RMB15.547million	Unitary evitable capacity's cost is RMB265/kW per year; grid loss coefficient and standby amount are considered.
Incentive-based DR project under insurance mechanism		RMB2.7715million	RMB0.9836million	Unitary sum insured: RMB20/kW; the situation in which the max. compensation is required is considered.

9. Conclusion and proposal

The research achievements of the report are completed upon the sufficient investigation, exchange and cooperation; they can be regarded as the reference for other APEC economic entities.

9.1. Main conclusion

(1) Certain feasibility of DR for improving RES consumption

In this report, the wind power consumption feasibility by DR is evaluated in sense of three aspects, namely cost, reliability and impact of wind power fluctuation on system.

In sense of cost analysis: Wind power access substitutes for some thermal power generator units, and thence causes the power generation cost to reduce (comparing with the one without wind power access). The DR is integrated through the electricity price optimal load curve; the IL provides the system standby mode; and thence the impact of wind power access on system's operating cost is reduced. Since the generated output of wind power has comparatively obvious anti-peak-shaving characteristics and makes the system's peak-valley difference increase, under the condition without DR, the system’s start-up increases.

In sense of system reliability: DR’s integration makes wind power capacity’s credibility improve and makes the wind power’s WEENSB reduce, namely the DR reduces the impact of wind power intermittency and fluctuation on system reliability and improves the system reliability.

In sense of impact of wind power fluctuation on system: after DR’s integration, the average value of load loss, maximum value and the total period number of load loss will reduce accordingly. Moreover since the electric power demand increased by consumer in the low-valley period and the usual period can consume some wind power output, therefore the system’s ability to consume wind power is enhanced and

(2) DR operation mode in different market environments has huger difference in sense of organizational system, project implementation process, price and trading mechanism

In the unilateral open market environment, the organizational system dominated by government conducts project, where electric grid company is the participating entity. In the project implementation process, there are two financing modes, namely governmental subsidy and commercial loan. The technical and service institution provides all auxiliary supports; electric grid company plans, constructs and operates DR project. The price mechanism under control and the trading mode dominated by long-term contractual transaction and auxiliary by spot trading are respectively adopted.

In the bilateral open market environment, the organizational system conducts the project management and operation under the supervision of government, where the non-governmental intermediary institution is the participating entity. In addition to governmental subsidy and commercial loan, the capital of social enterprise is introduced; this is a financing method; where non-governmental intermediary institution, DR service company and social enterprise are responsible for the equipments, technologies and services of the project so as to form a DR industry chain from equipment R&D to consumer service guide. The open and competitive price formation mechanism is adopted, where the contractual transaction and the spot trading are dominated, and option and spot trading are launched to form the risk-evasive competitive market.

(3) Divide implementation program into primary stage mode, development stage mode and mature stage mode in accordance with the difference in adaptability and maturity of DR measures in different market condition backgrounds; this is the a mode fitting to the DR development in China.

Primary stage: the market mechanism and the market operation rules have not yet been improved, and the DR implementation implementation program is dominated by the administrative means and auxiliary by market-oriented means , where the mandatory policy of government is relied on to realize electricity use management and guarantee the safe and stable operation of electric power system; meanwhile the pilot works by market-oriented means are conducted gradually.

Development stage mode: electricity price and incentive mechanism are further improved, DR measures are further popularized and used, the parallel mode of market-oriented means and administrative means is adopted; meanwhile pilot implementation works by market-oriented means are conducted and the implementation scope by market-oriented means is continuously broadened.

Mature stage mode: electricity price and incentive mechanism are improved, all measures are widely used, consumers can participate in market competition and win the corresponding economic benefits in accordance with their respective electricity use pattern through various market-oriented electricity price mechanism and market incentive mechanism. At the stage, the DR implementation implementation program will be dominated by the market-oriented means and auxiliary by the administrative means; where the optimal allocation role of resources in electric market will be used for realizing the safe, stable, economic and efficient operation of electric power system.

9.2. Proposals

(1) Incorporate the RES development objective into the category of energy laws, and expedite to boost RES development

Energy planning is the important integral parts of national and regional development strategy. By formulating the energy laws and regulations, it will be helpful to realize the harmonious development among regional energy, economy and social development. In the energy laws and regulations, the clauses related to RES, electricity and electricity conservation will be highlighted. Besides the main responsibility of government at all levels, electric power company, other technical and service organization for the implementation of DR project, as well as the obligations of all concerned parties in the society for RES and electricity conservation will be clarified so as to lay a solid basis for standardizing economy, technology and service required by project operation.

(2) Establish sound DR financing and incentive mechanism

Governmental department in charge of DR project and financial department will jointly formulate the project financing policy, draw up the governmental subsidy mechanism for project type, equipment type and department type and department type, promulgate tax policy for environmental protection, production and operation, and then provide a favorable tax environment for RES electricity consumption and DR project. The governmental department in charge of DR project should formulate the incentive policy for every participant so as to improve the existing benefit distribution mode. Modify the income mechanism of electric grid company, change the situation that DR project causes the electric power company to reduce benefit through benefit share, electricity distribution separation; formulate the benefit share method for equipment manufacturer and DR service company participating in DR project; determine the on-grid power subsidy limit according to the RES electricity type and capacity standard, and provide efficient economic incentives to RES power generation producers.

(3) Research DR-related technical and service policy ASAP.

Government stipulates the policy, laws and regulations for DR technology and service industry, establish the departmental system engaging in R&D, production and application of DR equipment and technology, and specify the rights and obligations of every department. Government should put forward the capital and equipment condition support for technical service subject research through policy, draw up the technical service specification for planning, construction, implementation and evaluation of DR project., establish standard system for RES power generation device, DR load monitoring device, production, installation and maintenance of communication and scheduling equipment, establish communication and service standard for DR, and incubate the efficient, quick and diversified service mechanism, and then provide service guarantee for the implementation of DR project.

(4) Promulgate progressive electricity market-oriented reform scheme and stipulate the market-oriented operation policy

In order to boost DR to develop healthily and orderly, it is needed to clarify the competent and participating department for the market-oriented operation of DR project, the rights and obligations of every department, standardize the formation mechanism of market price, clarify the composition of price, formulate different price management and control methods in different electricity market environments, and establish efficient market regulation and implementation policy.

10. Basis of existing researches

10.1. Introduction to research unit

Southeast University is one of the pioneering universities to conduct the demand side management research in China. Early in 1999, Southeast University established "Southeast University DSM Research Institute" with State GRD Corporation DSM Instruction Centre. Southeast University DSM Research Institute is devoted to DSM theoretical research, DSM planning and economic benefit evaluation, DSM mechanism research, application in smart grid environment and the search and development of the relevant system core procedures. Southeast University DSM Research Institute, owning MAGE multi-agent simulation platform, intelligent electricity use simulation platform and DR research laboratory with complete set of equipments, was pioneered to put forward the concept and architecture of "Efficiency Power Plant (EPP)" and "Smart Demand Side Management (SDSM)" in China. In recent years, Southeast University DSM Research Institute has posted over a hundred of dissertations of high level in multiple famous periodicals at home and abroad, and has mainly researched and completed the following projects, namely NDRC "Suzhou DSM Integrated City Pilot Implementation Scheme Research" project, Jiangsu EPP Planning Project, Tianjin DSM Management "12th 5-year planning project", China Electric Power Research Institute (CEPRI) "DR Basic Theory & Business Operation model Research", USEF "Power DSM Regulation Research". Currently Southeast University DSM Research Institute, with the total fund over RMB8.00 million, undertakes over 20 research subjects, including "863" research project for key technology of flexible and interactive intelligent electricity use, "Uncertainty-considered Multiple Spatial-temporal Scale DR Model & Application Research" of Natural Science Foundation of China (NSFC). Besides, Southeast University DSM Research Institute has established close cooperative relationship with NDRC, State GRD Corporation DSM Instruction Centre, Jiangsu Provincial Electric Power Company, Shenzhen Clou Electronics Co., Ltd, USA Energy Foundation (USEF), USA Natural Resources Defense Council (NRDC) and other units.

10.2. International exchange and cooperation

With the aid of USEF, Southeast University DSM Research Institute has conducted a series of projects related to "Electric power energy conservation and emission reduction regulation and early-warning monitoring system research", "Regulation of electric power company on DSM". In the preparation process of the report, the project team has made some international exchange and cooperation, including the one to release investigation form in APEC economic entity, IEC PC 118 cooperation, ECP project cooperation and the exchange and learning of Teacher Wang Beibei in USA and etc.

1. I IEC PC118 Cooperation

On Sep. 16, 2011, IEC approved to establish "Smart Grid Consumer Interface" Project Committee (IEC PC 118), which is responsible for establishing two new standards, namely "Interactive Interface of Demand Side Smart Device and Power Grid" and "Electric Power Demand Response". The secretariat of the project committee is established in State Grid Corporation of China; the secretary-general of the project committee is Wang Like, the vice-president of China Electric Power Research Institute; and China Electric Power Research Institute and Southeast University are the major participating units of the standards. Currently the standards are under the formulation.

By relying on IEC PC 118 platform, the project team and the experts in the field of international DR field (including USA, Japan, Korea) have made multiple conference communication and cooperative research, and has obtained many precious experience in the field of demand response; which provides plenty of materials for the preparation of the report.

2. ECP project cooperation

During the period from 2011 to 2012, China Electric Power Research Institute has undertaken the energy cooperation project of China and USA, namely "Pilot and Feasibility Research of Demand Response System", which was conducted for the purpose of exerting the important role of smart grid demand response in energy conservation and emission reduction, improving the efficiency of coal power in sense of the power generation and electricity use in China, and reducing the total carbon emission.

In the project implementation process, China Electric Power Research Institute has made the complete cooperation with USA Honeywell to conduct the consumer investigation in Tianjin Economic Technology Development Zone (Taida), and has determined 2 commercial consumers and 3 industrial consumers to participate in the demand response pilot. In the summer pilot, the project has triggered the DR event by 3 times, where the reduction of commercial consumers was 15%~25%; the reduction of industrial consumers was around 10%, and the reduction under a rational production plan was 20%~45%. Currently the project has become the successful cooperation case of China and USA in the field of energy source and scientific technology.

In the implementation process of the APEC project, the project team and the experts from USA Honeywell have made adequate exchange and communication, and has put forward the duplicable and propagable DR business mode suitable for the national conditions of China based on the experience in Tianjin Taida Pilot and the implementation in USA. Such point has been embodied in the report.

3. Exchange and learning in USA

Since September 2012, the members of project team, as the 1-year visiting scholars, went to the Environment, Energy, Sustainability,& Health Institute of the Johns Hopkins University to conduct exchange and participated in USA National Science Foundation, Sustainable Energy Pathways(SEP): Integrating heterogeneous energy resources for sustainable power networks- a system approach.

In the 6th Annual Trans-Atlantic Infraday Conference on Applied Infrastructure Modeling and Policy Analysis held on November 8 and 9, 2012, the latest research achievements of experts from the electric power market in USA, UK and Germany in sense of the operation, risk management and policy design of electricity market were heard. At the end of February 2013, the members of project team attended the 4th Conference on Innovative Smart Grid Technologies held by IEEE, and held the US-China workshop: identification of challenges and opportunities for large-scale deployment of the smart grid after the conference to report their demand response research in China and introduce their practical experience, and take the opportunity to exchange experiences with relevant scholars of USA.

10.3. Introduction to paper publishing

Tab 10.1 Introduction to paper publishing

num	author	Unit	Title	Journal Title	year	note
1.	LI Yang1 ,SU Yi-qiang2 , LIU Xiao3	1.Southeast University, Nanjing 210096,China;2.Lianyungang Electric Power Supply Company, Lianyungang 222023,China;3.Nanjing Normal University, Nanjing 210046,China	A study on the measuring method of energy saving and its uncertainty	Power Demand Side Management,	2010	
2.	SU Wei-hua1,Chu Lin-lin2,ZHANG Liang3,SU Hui-ling3,Gao Ci-wei3,LI Yang3	1.Songjiang Power Supply Branch,Shanghai Municipal Electric Power Company,Shanghai 201600,China;2.Shinan Power Supply Branch,Shanghai Municipal Electric Power Company,Shanghai 200233,China;3.School of Electrical Engineering,Southeast Univ.,Nanjing 210096,China	Study on Load Forecast Method Considering Demand Side Management	East China Electric	2010	
3.	WANG Beibei,LI Yang	Research Center of Demand Side Management,Southeast University,Nanjing 210096,China	Demand side management planning and implementation mechanism for smart grid	Electric Power Automation Equipment	2010	
4.	SU Yi-qiang,LI Yang CHENG Le-xiang	Southeast University,Nanjing 210096,China	IPMVP and its application in DSM	Power Demand Side Management	2009	
5.	Wei Yan-li1, Wang Bei-bei1, Li Yang1, Xu	1.Southeast University, Nanjing 210096,China; 2. State Grid Corporation DSM Instruction Center, Nanjing 210024,China	Design and implementation of energy efficiency calculator	Power Demand Side Management	2008	

num	author	Unit	Title	Journal Title	year	note
	Jie-yan2, Fan Ming2					
6.	GAO Ciwei1,ZHANG Liang1,XUE Fei2,LIU Hongchao2	1.Southeast University;2.China Electric Power Technology and Equipment Co.,Ltd.	Grid Planning Considering Capacity and Site of Large-scale Centralized Charging Stations	Proceedings of the CSEE	2012	EI
7.	WU Chen,LI Yang,WANG Bei-bei	Southeast University, Nanjing 210000 , China	Development orientation on electricity value added services for smart grid	Power Demand Side Management,	2012	
8.	ZONG Liu1,2,LI Yang1,WANG Beibei1	1.School of Electrical Engineering,Southeast University,Nanjing 210096,China; 2.Jiangsu Electric Power Design Institute,Nanjing 211102,China	Fine-mining of Multi-dimension Electrical Characteristics Considering Demand Response	Automation of Electric Power Systems	2012	EI
9.	RUAN Wenjun1,WANG Beibei1,LI Yang1,YANG Shengchun 2	1.Jiangsu Key Lab.of Smart Grid Technology and Equipment(Southeast University),Nanjing 210096,Jiangsu Province,China; 2.China Electric Power Research Institute,Haidian District,Beijing 100192,China	Customer Response Behavior in Time-of-Use Price	Power System Technology,	2012	EI
10.	LIU Xiaocong1, WANG Beibei1,LI Yang1,YAO Jianguo2,YANG Shengchun 2	1.Key Laboratory of Smart Grid Technology and Equipment in Jiangsu Province,Southeast University,Nanjing 210096,Jiangsu Province,China;2.China Electric Power Research Institute,Nanjing 210003,Jiangsu Province,China	Day-ahead Generation Scheduling Model Considering Demand Side Interaction Under Smart Grid Paradigm	Proceedings of the CSEE,	2012	EI

num	author	Unit	Title	Journal Title	year	note
11.	GAO Ciwei1,ZHANG Liang1,XUE Fei2,LIU Hongchao2	1.Southeast University,School of Electrical Engineering,Nanjing 210096,Jiangsu Province,China;2.China Electric Power Technology and Equipment Co.,Ltd.,Haidian District,Beijing 100085,China	Study on Capacity and Site Planning of Large-scale Centralized Charging Stations	Proceedings of the CSEE,	2012	EI
12.	GAO Ciwei1,DONG Chuanyan1, XUE Fei2	1.Jiangsu Provincial Key Laboratory Of Smart Grid Technology & Equipment(Southeast University),Nanjing 210096,Jiangsu Province,China;2.China Electric Power Technology and Equipment Co.,Ltd.,Haidian District,Beijing 100085,China	Design and Implementation of Simulation Software for Electric Vehicle Charging Behavior Based on Multi-agent System	Proceedings of the CSEE,	2012	EI
13.	GAO Ciwei1,WU Tianying1, HE Ye1,HU Rong2	1.Jiangsu Provincial Key Laboratory of Smart Grid Technology & Equipment,Southeast University, Nanjing 210096,China;2.Shanghai Key Laboratory of Power Station Automation Technology, Shanghai University of Electric Power,Shanghai 200090,China	1.Jiangsu Provincial Key Laboratory of Smart Grid Technology & Equipment, Southeast University, Nanjing 210096,China;2.Shanghai Key Laboratory of Power Station Automation Technology, Shanghai University of Electric Power, Shanghai 200090,China	Automation of Electric Power Systems,	2012	EI

num	author	Unit	Title	Journal Title	year	note
14.	Ciwei Gaoa, Ettore Bompard, Roberto Napoli, Qiulan Wan, Jian Zhou	Southeast University–School of Electrical Engineering, 210096, Nanjing, Jiangsu, PR China b Politecnico di Torino–Dipartimento di Ingegneria Elettric 10129, Torino, Italy c Yangzhong Power Distribution Company, 212200, Zhenjiang, Jiangsu, PR China	Bidding strategy with forecast technology based on support vector machine in the electricity market	Physica A: Statistical Mechanics and its Applications	2008	EI
15.	Gao Ciwei Li Yang	School of Electrical Engineering, Southeast University, No. 2 Sipailou, Nanjing 210096, People's Republic of China	Evolution of China's power dispatch principle and the new energy saving power dispatch policy	Energy Policy	2010	EI
16.	Ciwei Gao, Haozhong Cheng, Haibao Zhai	School of Electrical Engineering, Southeast University, 210096, Nanjing, China; Department of Electrical Engineering, Shanghai Jiaotong University, 200030, Shanghai, China; East China Power Company, 200030, Shanghai, China	Research On Scenario Technique Based Flexible Transmission Planning	Istanbul University –Journal of Electrical & Electronics Engineering	2009	EI
17.	GAO C. W.CHENG H. Z. ; ZHAI H. B.;	Department of Electrical Engineering, Shanghai Jiaotong University, Shanghai, 200030, CHINE	Fuzzy evaluation model for uncertainties in electrical network planning	International Journal of Power and Energy Systems	2008	EI
18.	LIANG Tian-tian,WANG Lei,GAO Ci-wei	Electrical Engineering School of Southeast University,Nanjing 210096,China	Research on Critical Peak Pricing Model Based on Demand Response	East China Electric Power	2013	EI

num	author	Unit	Title	Journal Title	year	note
19.	WAN Lu-lu1,WANG Lei1,DING Hao2	1.School of Electrical Engineering,Southeast University,Nanjing 210096,China;2.Nanjing Power Supply Company,Nanjing 210019;China	Research on Charging Optimization for Distributed Plug-in Hybrid EV	East China Electric Power	2011	EI
20.	ZHANG Yan,GAO Ci-wei,WANG Lei	Southeast University,Nanjing 210096,China	Status and measures analysis of energy-saving and emission-reducing surveillance in east China power system	Power Demand Side Management	2010	
21.	LI Rui-qing1, XIE Jing-dong2, WANG Lei3	1.East China Grid Company Limited,Shanghai 200002,China;2.East China Electricity Regulatory Bureau,Shanghai 200002,China;3.School of Electrical Engineering,Southeast Univ.,Nanjing 210093,China	Influences of electricity characteristics as a product on electricity market construction	East China Electric Power	2009	EI
22.	DOU Xun1,2,LI Yang1,WANG Beibei1,XUE Chaogai3	1.Southeast University,Nanjing 210096,China;2.Nanjing University of Technology, Nanjing 210009,China;3.Zhengzhou University,Zhengzhou 450001,China	Risk distribution of electricity supply chain	Electric Power Automation Equipment,	2012	
23.	TAN Jinjing,WANG Beibei,LI Yang	School of Electrical Engineering,Southeast University,Nanjing 210096,Jiangsu Province,China	Modeling of User Response to Time-of-Use Price Based on Multi-Agent Technology	Power System Technology	2012	EI

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