Novelty Journals

ISSN 2394-7314

International Journal of Novel Research in Computer Science and Software Engineering
Vol. 4, Issue 1, pp: (19-34), Month: January - April 2017, Available at: www.noveltyjournals.com

Overview of Leading Methodologies for Demand Response in Smart Grid and Demand Response case overview in China and abroad

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Abstract: **In this paper, I have deeply analyzed and outlined the development of demand response (DR) in the smart grid. By now, smart grid has turned into a common and generic development trend of the traditional grid, as it can meet the development requirements of the society. In the first phase, an investigation of the current situation of local (china) and overseas demand responses had been made. Secondly, I tried to summarize DR (Demand Response) related research status from several aspects, such as simple interpretation of demand response, incentive mechanism design, scientific support platform technologies, benefit analysis, integration of wind power and so on. With merged analysis of some typical application situations, this paper identified the current issues in the implementation of DR and related comparative measures. Hope in future, this paper will provide reference for the development of smart power application and demand response (DR).**

Keywords: **demand side management; smart grid; smart power utilization; demand response (DR).**

1. INTRODUCTION

Demand response (DR) and distributed clean energy grid, not only can effectively alleviate the rapid expansion of transmission and generation capacity of the pace, but also the inevitable requirement for sustainable development of society. The key goal of the smart grid is to generate new technologies and new business models, to attain a new industrial revolution [1]. Intelligent power is an important part of smart grid, and its function is to supply the power to the consumer side of the important appliances and apparatus, through a flexible power network and information network. These networks are connected to each other to form an adequate and complete information service system and platform [2]. The construction of power grid and the consumer power flow, information flow, real-time interaction are the new business-to-power relationship [3]. Through the interactive strategy, mobilize the consumer to participate in demand response or direct remote optimization control, to achieve flexibility in power load, to guide the user or directly to optimize the use of electricity, support the power supply side of the reliable and economical operation. The construction of intelligent power system is directly related to the energy efficiency, economic operation and orderly power consumption [4]. The power grid construction, energy saving, environmental protection and power quality management will have a profound impact [5].

With the development and improvement of the smart grid and electricity market, the roles of demand side resources in the competitive market are being re-recognized. The demand response is introduced into electric power market competition, and the role of demand side in the market is increased through price signals and incentive mechanisms [6]. The supply side and the demand side of the resources to carry out integrated resource planning; the demand for flexible interactive intelligent power supply has become the trend of development [7].

Flexible, interactive smart power is an important feature. Flexible to include 2 meaning: One for the rapid response to market changes and customer needs, including to meet customer diversification, individual needs, make full use of grid resources to provide value-added services [7]; the other to support new energy and new equipment and appliances access, a variety of distributed power for different capacity electric vehicles, energy storage devices and other new energy equipment's plug and play access [8]. The randomness and volatility of large-scale wind power bring great difficulties to wind power dispatching. How to restrain the fluctuation of wind power and make it smoothly connected to the grid is of great practical significance. It is shown from the research that, the matching of wind energy and, its equivalent grid connected power is stable in the vicinity of its expected value, and the load peak-valley difference will be significantly reduced [9].

Smart grid has a crucial and beneficial role in ensuring network security in clean energy generation and improving power utilization efficiency. A large number of smart grid technology research and engineering construction work has been carried out at home and abroad, which provides a technical basis for conducting DR research. In the first part, on the basis of consulting a large number of domestic (China) and foreign literature and typical cases, this paper summarizes the current situation of domestic and foreign demand response in the smart grid; the second part will summarize the domestic and foreign scholars research results in the fields related to the demand response, incentive mechanism, benefit evaluation, support technology and so on, and these theoretical results will be helpful for china or any other country in the development of their smart power and demand response; the third part is the introduction of the market economy oriented America's California, the PJM (Pennsylvania-New Jersey-Maryland Interconnection) demand response project and the demand response project of the regulated electricity market of the French power company, at the same time, this paper introduces the demand side management pilot project in China, and points out the problems existing in the demand response work in china and puts forward the corresponding countermeasures.

Development status at Domestic/local (china) and abroad:

1.1 Domestic (china) status Quo: In recent years, China has formulated a series of plans to promote the construction of smart grid, from the policy, reserve research support level to ensure a flexible and interactive development of smart power technology. In 2009, the State Grid Corporation china, for the first time announced the development plan of the smart grid to the public [5]. In 2011, the Ministry of science and Technology launched the national high technology research and development program of China (863 Program), which has a large proportion of smart grid research. In 2012, the Ministry of science and Technology issued a "smart grid of major science and technology industrialization project" 12th Five-Year "special plan", in this "12th Five-Year plan" china will build 5~10 smart grid demonstration city, 50 smart grid demonstration parks. In response to the needs of the relevant engineering construction, Up to now, 27 provincial power companies in the State Power Grid Corp. system have completed the construction of the provincial electric power information collection system, and cumulative installed smart meters are about 200 million. In the field of intelligent electricity, the construction of intelligent community, intelligent building and intelligent park has become the most typical intelligent power consumption practice in China. In 2010, the State Grid for the first time in Hebei, Beijing, Shanghai and Chongqing, 4 provinces and cities carried out intelligent building and residential pilot projects, and built a total of 2 intelligent buildings and 6 intelligent communities. In 2011, Gansu Baiyin, Shandong, Dongying, Jiangsu and other regions began to build the country's first intelligent park, and carried out large user energy efficiency monitoring, management practices [3].

At present, the national Power Grid Corp has 18 provincial companies in 28 provinces for the construction of the intelligent community in Shanghai, Chongqing, Zhejiang, and for the construction of 3 intelligent buildings in Zhejiang. In 2012, Honeywell and Tianjin TEDA jointly developed and completed the first smart grid demand response project [10]. In terms of demand response standards, the National Smart Grid User Interface Standardization Technical Committee corresponding to IEC PC118 was approved by the National Standardization Management Committee in June 2013. Content of the plan of National Standardization Program in 2014 include: **1)** Smart grid user interface terminology; **2)** Power demand response technology; **3)** Power demand response system interface.

1.2 Foreign Status Quo: The developed countries of the world have carried out the research and practice of smart

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electricity service related to demand response, based on the development of new energy, energy saving and emission reduction, and have improved the efficiency of power grid operation and the quality of power supply service.

1) In order to promote the development of intelligent power, firstly national legislation requires, to issue the relevant policies and regulations to support intelligent power. In Europe, the development of intelligent power mainly from the EU to promote clean, sustainable and efficient energy strategy. In 2006, EU released "The European sustainable, ambitious and secure energy strategy," proposed the goal of smart electrical power services; in 2009, the Obama administration promoted smart grid construction into a national strategy. 4.5$ billion allocated to the US Department of Energy in order to promote the modernization of power grids, integrate DR apparatus and implement smart grid technology [11]. In addition, the U.S. government asked the DOE (Department of Energy) to start power grid digital information technology R&D projects, to support smart meters, demand response and other related technical evaluation and research work, moreover start regional demonstration project of smart grid, to validate the key technology [12-13].

2) In the field of technology development, a series of technologies and standards have been developed under the stimulation of relevant policies. November 11, 2011, IEC set up IEC PC118, the Secretariat is located in China State Grid Corporation. PC118 consists of 2 working groups, in which the WG2 is responsible for the development of electricity demand response criteria, established three DR standard task groups, the tasks are CIM-DR expansion, Open ADR adapter development and compliance with the CIM rules IEC DR standards.

The EU attaches great importance to the development and construction of key platforms, such as energy efficiency and demand side management control platform, but also pay attention to the development and revision of intelligent power standards [14]; the United States are more concerned about the upgrading of power network infrastructure in the field of intelligent power. Goals are to promote energy-saving, emission reduction, improve the quality of power supply services. The United States Itron company and Comverge company's home energy management system [13], IBM, Cisco and other companies to support the intelligent power platform, the US West Pacific National Energy Laboratory "grid-friendly" technology [15], as well as Intel's "2030 energy technology, information technology and power systems and end-user interaction of smart grid information interoperability guidelines" are the examples. In Asia, Japan in 2009 did set up a smart grid technology standardization strategy-working group to carry out research work related to smart grid standards, focusing on the development of technical standards for the international development strategy [16].

3) In the application of technology, countries actively develop DR development and implementation plan. At present, the United States Pacific Gas and electric power company, Southern California Edison and other power companies have applied interactive business system, and this system encourage consumers to take the initiative to participate in demand response, which has effectively reduced the peak load [11]; From 2006 to 2007, Canada Energy Bureau, carried out an empirical study of intelligent electricity users, and effectively reducing the residential electricity consumption [17]; From 2008~2012, the European countries participated in a project related to demand side response, the goal was to make the local residents and small business users to better participate in the electricity market, and to provide more beneficial services to the consumers [14,16]. In recent years, Japan has begun to build intelligent community demonstration projects in the 4 cities of TOYOTA, Yokohama, Kitakyushu, Kansai [18].

1.3 Comparative Analysis: 1) The United States, the European Union, Japan and other developed countries have accumulated a wide range of experience in policy formulation, technology development and application, China can learn from its technological achievements and operational mechanisms.

2) China has carried out large-scale advance measurement system, power service platform and smart power demonstration research and construction, and have achieved good results. However, the practice of intelligent power consumption in China focuses on the interaction of information between the power supply companies and power users and the interactive marketing business, However, the use of energy, energy interaction and other interactive businesses have not been carried out effectively, it cannot meet the demand of flexible and interactive intelligent power consumption, the future research and practical work should pay more attention to these aspects [3].

3) IEC is carrying out the international standardization of demand response work; and china has started to carry out the national standard compilation work.

2. RESEARCH ON DEMAND RESPONSE MECHANISM AND LEADING TECHNOLOGIES

2.1 Basic concepts and implementation of DR: Demand response refers to the power consumer's respond to price signals or incentives to change the behavior of the inherent habit of electricity [6, 19-20]. An important part of the implementation of the demand response project is the response behavior of the power users to the incentive measures of the power companies and the change of the load characteristics caused by the electricity users to adjust their own electricity consumption, the way and intensity of this response behavior depend on the user's own response characteristics [21]. Demand response measures can be divided into two types: price-based demand response (PBDR) and incentive-based demand response (PBDR), and these two types are according to different response modes of users [22]. In price-based demand response project, the price has the greatest influence on the consumer's electricity consumption behavior. Generally, the price elasticity of demand is used to quantitatively characterize the effect of electricity price change on the user's response behavior. The price elasticity of load is often used to reflect the sensitivity of electricity demand to electricity price changes [23-24]. It is also used to measure the change in the proportion of electricity consumption in the peak period of electricity price with the elasticity of substitution [25].

When the data volume is small, the arc elasticity [26] can be used to describe the demand price elasticity. There are also literatures on multi-agent methods [27] and power consumer psychology models [28] to simulate the response characteristics of the consumer to the price. In the incentive- based demand response project, response time, response speed, response duration, response frequency, response interval [30], and direct load Control [31] are the main features for the modeling of the response characteristics. The idea of regression is also used to simulate the response of power users to different price and incentive signals under specific demand response [21]. In the analysis of the consumer's response characteristics, the clustering of the response characteristics of the users according to the demand can simplify the complexity of the problem analysis, and classify the user needs to grasp the response characteristics [21,32]. With the rapid development of smart grid, advanced communication, control and other demand response support technology, the user's response capability is being enhanced [33]. Demand response automation increases the flexibility and efficiency of demand response, making grid and user participation easier [34]. Lawrence Berkeley National Laboratory of America developed the OpenADR communication specification for demand response automation [35].

2.2 Demand Response target Multi-level Optimization: In the demand response project, depending on the participants and the demand response, the decision-making variables, the decision-making targets, and the constraints all are different. Power companies will participate in power generation scheduling optimization decision based on Incentive-based demand response [36], and the strategy of direct load control. Decision variables are load reduction and cut time of each demand response to user or load aggregation operator, or control strategy of direct load control [37]. The objective function is generally, generation of lowest cost [38], minimize network loss [36], the response of the project needs to minimize the incentive compensation [39], Maximize revenue [41], and minimize carbon emission [42]. When the price-based demand response is involved in the optimization decision, the decision variable is the electricity price policy [40], which can meet the peak load and valley filling requirements. The optimization goal is to minimize the peak load of the daily load curve, and maximize the user satisfaction [43].

When the consumer receives the demand of the electric power company to respond to the requirements of the project, the production life is rearranged by the intelligent interactive terminal [44] or the energy management system. User costs are generally divided into three parts, power purchase costs, service costs and power outages [45]. User interrupt cost function can be expressed as a single, two, three exponential type [46]. Industrial users of electricity and its production process, electrical apparatus and other factors are closely related. In response to system-side signals, internal economic decisions need to be taken into account in order to optimize the energy management scheme, taking into account information such as production shifts, equipment continuity, and predecessor succession relationships [47]. According to the user side system energy, Commercial consumers consume more electricity in electricity based commercial building, and power grid side provide consumers with the best energy management program with various incentive policies and operational information [48]. The household energy management system is used to optimize the use time of home appliances according to the electricity price and excitation signal [49].

2.3 Demand Response Benefit evaluation: Demand response is involved in the operation of the power market through load adjustment, improve the efficiency of the system and resources, and has an important strategic role in the power industry and economic development and environmental protection [20, 50]. The benefit of the demand response project includes the direct benefits such as, the electricity saving, economic compensation, cost reduction, benefits of the grid side such as reduced reliability costs, and the external benefit such as natural resource benefits [51]. However, it is necessary to quantitatively evaluate the benefits of the demand response for the different subjects in the power system. The benefits of quantitative analysis of demand response are important for grasping the development potential of demand response and promoting the implementation of demand response projects [52]. A multidimensional analysis of the overall benefits of demand response can be made from the subject, time, and project [53]. Decoupling is used to quantify the benefit assessment [54].

2.4 Demand Response incentive mechanism: The design of incentive mechanism is the key in the demand response project. In incentive-based demand response projects, user participation in demand response can be compensated in two ways: a method similar to the independent system operator ISO, Power exchange center PX (power exchange) and other institutions to assess the price of the user's power failure; Another method is to declare the interruptible load capacity and the corresponding power outage cost by the user [55]. In the latter case, the user has a tendency to report the cost of power shortage strategically. The incentive mechanism can be designed so that the user can get the maximum profit when reporting the real type, and encourage the users to report the real power cost [56-57]. There are also literature available based on the theory of credit incentive, calculation of consumption, reward and punishment points, and the use of extra points for electricity or electricity can be avoided [58].

2.5 Demand response is applied to the wholesale electricity market: Because of the characteristics of electric power industry and electric power commodity, the electricity market is not the perfect competition market for a long time, but the natural monopoly industry. Do not treat the demand side and the supply side equally because it cannot form a truly healthy operation of the electricity market [6]. Demand response is one of the effective measures to ensure the stability of the single market and reduce the market power of the power plant [59]. In a single generation market, the ability of an oligopoly to manipulate the market price is the market power. According to the Cournot model in microeconomics [60], increasing the price elasticity of demand and increasing demand responsiveness are effective ways to reduce market power, which is easier to achieve than reducing the market share of power producers [22].

Now, introducing demand response into competitive market, to increase the role of the demand side in the market, make the market competition more effective, more reasonable price, and promote the sound development of the electricity market, so the demand response project can be called the 'The Power wholesale market shock absorber' [61].

2.6 Demand response is applied to large-scale clean energy consumption: The randomness and volatility of large-scale wind power bring great difficulties to power grid dispatching, and it is technically and economically excellent solution to reduce the fluctuation of the renewable energy power generation by using the demand response to cooperate with the renewable energy generation process [62], and majority of countries require the use of demand response to protect new energy access [63]. The demand response and renewable energy consumption to promote the relationship between the unilateral and bilateral open power market organizational structure, the formation of trading and price mechanism [64], the use of potential dynamic game theory to analyze the the coordination and interaction [65]. The real-time electricity price mechanism guides users to use more electricity during the peak wind power output, and use less electricity in the low trough [66]. Combined with a certain amount of controllable load and dynamic demand response, [67] the load curve of the user is complementary to wind power output, so as to smooth the fluctuation of new energy sources, reduce the burden of system operation and improve the acceptance of new energy sources [68]. Demand-response and renewable energy power generation models also created a new mode of operation for demand-response projects [62], Pedro S built demand-based response to long-term, medium, and short-term market equilibrium models that take into account renewable energy and user uncertainty [69]. Direct load control and conventional power generation can be used in the micro grid, and gives the Joint control of energy storage to restrain the power fluctuation caused by distributed new energy [70]. In order to select more accurate and appropriate user demand response to alleviate the fluctuation of new energy power generation, need to use the cross spectral analysis method in frequency domain, the frequency fluctuation characteristics of wind power curve and the user demand curve for comparison, identify the target user group to match the demand for wind power generation [71], and analyze the influence of wind power infiltration on demand response strategy [72]. In addition, the use of automatic demand response can effectively alleviate the intermittent renewable energy access due to the power supply and demand contradiction, but its cost is only 10% of the energy storage device [73].

The author has done an in-depth study on demand response for wind power consumption, considering the complementarity between price and incentive based 2 DR projects [74], comprehensive time-of-use (TOU) tariff (using pricing, time head) and interruptible load (IL) to absorb wind power positive and negative fluctuations in the utility, Monte Carlo simulation is used to evaluate the DR system before and after the abandoned wind, lack of electricity and wind power equivalent capacity, verified the positive effect of DR on the wind power. [75] A stochastic optimization model with the objective of maximizing social welfare is established and the real-time price demand response resources involved in wind power accommodation system climbing ability. In addition, due to the decentralized demand response resources, response time characteristics of different response to uncertainty, how to combine the new energy power output characteristics of effective multi time scale scheduling policies and how to carry out the business model design (such as the introduction of cut aggregation quotient)? To make it play is a problem worthy of study.

2.7 Demand Response support technology: Demand response support technologies include advanced measurement systems, power public service platform [76], Demand response systems, smart power equipment and other technologies, the former 2 are already large-scale applications, to provide a large-scale application response to the needs of the support. The advanced measurement system is mainly used to collect the electric energy information of the consumer's intelligent electric energy meter.

1) Leading measurement system:

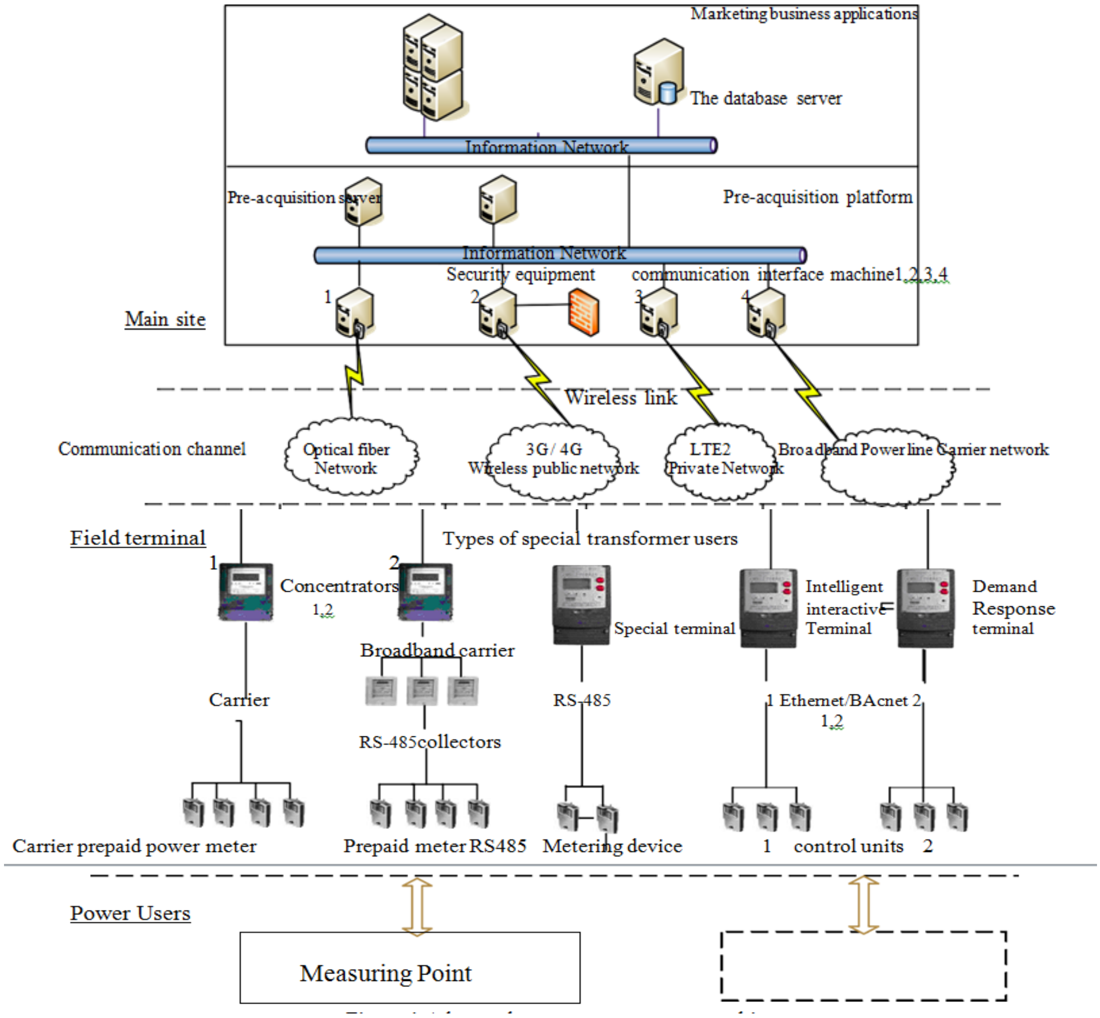

Figure 1 Advanced measurement system architecture

Logical diagram of advanced metering infrastructure:

Leading or Advanced measurement system to achieve a unified collection of data within the scope of Power Grid Corp, storage, processing and application, achieve a control system monitoring and business analysis. Advanced measurement system architecture shown in Figure 1, It can be divided into intelligent terminal layer, communication channel layer and main station layer.

International Journal of Novel Research in Computer Science and Software Engineering
Vol. 4, Issue 1, pp: (19-34), Month: January - April 2017, Available at: www.noveltyjournals.com

① Intelligent terminal layer. At present, the main coverage of the acquisition terminal contains special variable terminal, distribution transformer Terminal, low voltage collection terminal, demand response terminal and substation terminal. The local acquisition device can be networked or directly connected to the pre-communication layer as required.

② Communication channel layer. General use of 3G / 4G wireless public network transmission, LTE 230 MHz Wireless private network, optical fiber communication, broadband power line carrier and other communication methods.

③ Main station layer. According to the system size, generally can be divided into front-end communication, data storage Storage, business applications and other sub-layer.

The pre communication sub layer main realizes the access and communication of the large-scale collection terminal, which is used to complete the data acquisition task of the acquisition terminal and the task of the power information collection system. It can automatically set up the adaptation of the acquisition terminal, the channel and the protocol to meet the communication needs of large scale and different types of terminals. On the basis of reliable access to mass terminals, there are 2 provincial and municipal access modes. The provincial authority mainly completes all wireless public network mode of the field terminal and meter access, municipal distribution of the main access to private network mode of field terminal and meter.

The data storage sub-layer is a data buffering layer constructed between the database of the pre-communication platform and the production database to meet the hardware requirement of storage performance under the condition of geometric growth of data, which makes the system to have the capability of mass source data storage and data caching. On the basis of the data warehouse technology, the data communication, operation class, data such as negative control class and so on, which are very high in real time, are separated from the statistical analysis data, and the complex application of the statistical analysis of the original production base is migrated to the management database, and reduce the pressure of the production library, and for statistical analysis, data query and other high-level operation of a separate deployment of resources, so that the item has a huge amount of data storage and analysis and query capabilities.

Introducing the Hadoop distributed computing framework for parallel processing computing tasks, and the computing tasks assigned to work to improve the computational efficiency of nodes. Support calculation services including line loss calculation, power calculation, load calculation, acquisition success rate calculation, terminal equipment operation state statistics, etc. By increasing terminal size, system can Support flexible deployment and assembly of corresponding physical devices to meet the mass data real-time Processing requirements.

POWER PUBLIC SERVICE PLATFORM:

Power public service platform can be divided into five main functions, Including energy-saving service management, energy-saving monitoring and analysis, orderly electricity and load management, demand response, demand-side assessment, energy efficiency knowledge, as shown in Figure 2. Limited to space, focusing on its energy-saving service management, energy efficiency monitoring, analysis, and demand response capabilities.

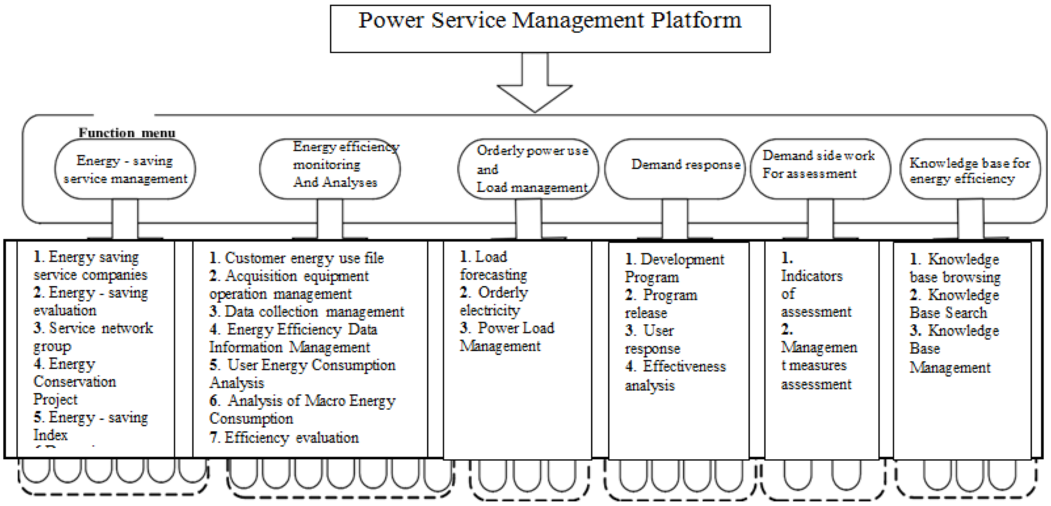

Figure 2 functional diagram of public utilities platform

Function diagram of energy management and public service platform

① Energy-saving service management. Power service management platform for specific business is through the energy saving Service companies, energy-saving evaluation agencies and other information to fill in the report, statistics, to achieve the level of energy-saving service management. And according to the national energy-saving indicators of energy conservation units at all levels by layer decomposition. Energy-saving service companies to implement the contract to carry out the entire process of energy projects tracking, statistics and evaluation, in order to achieve energy-saving statistics.

② Energy efficiency monitoring and analysis. Energy-saving monitoring and analysis are mainly include customer energy use file management, Collection and management of apparatus operation, data collection and management, site inspection, warehouse management, energy efficiency data management, user energy consumption analysis, macro energy consumption analysis, energy efficiency benchmarking and evaluation analysis.

③ Demand response. Develop a different response plan to allow power customers to respond according to demand. The program should have reasonable control of peak load, respond to changes in the price of electricity or electricity policy, and temporarily change the behavior of the fixed power mode, to achieve the purpose of reducing or transfer the power load in a certain period of time. Its functions include four aspects: program development, program release, user response and effect analysis.

3. TYPICAL CASES OF DOMESTIC AND FOREIGN DEMAND RESPONSE

3.1 California automated demand response program:

3.1.1 Project Overview: Between 2000 and 2001, California experienced an energy crisis, which was caused by the introduction of the competitive electricity market. By 2002, this pressing short-term problem was resolved, but long-term power generation and transmission network capacity shortages still existed. After the California energy crisis, the California Public Utilities Commission approved several pilot projects to strengthen the state's electricity demand response. One of the pilot projects is the Automated Demand Response System (ADRS) for residents [77-78].

To assess the demand response capabilities of a fully automated system, Pacific Electric (PG & E), Southern California (SCE), and San Diego Gas and Electric (SDG & E) With the support of the California Public Utilities Commission, the California Automated Demand Response System (PSS) pilot program was launched in 2004 and Continued until the end of 2005. This pilot project focused on the role of load control technology implemented with tariff measures, and targeting residents in California [76].

ADRS runs at a peak tariff, and is supported by automated demand-response technology at the residential user level. Compared to other projects, the ADRS pilot project is a small-scale exploratory project with only 175 California families involved. The pilot project participants installed the GoodWatts system, an advanced home climate control system that allows users to set their preferences for controlling home appliances via a network program. In the critical peak price (CPP), the peak price (working day 2 pm to 7 pm) high and all other hours, weekends, and holidays are based on benchmark rate. When a "super-peak event" occurs, the peak-hour tariff is three times higher than the normal peak-hour price.

3.1.2 Project Description: ADRS pilot users are equipped with GoodWatts system. GoodWatts is an automatic home automation control system with 1 two-way communication, users can use the web to follow their own preferences for the use of home appliances programming. Through the Internet, homeowners can set climate control parameters and pump operating parameters, and they can view these settings anywhere, anytime. Participants can also view real-time trends in the load level and historical consumption of the entire residential or terminal equipment. GoodWatts allows the user to view current electricity prices online or through a thermostat at any time, and allows the thermostat and pool load control and monitoring equipment to automatically respond to changes in electricity prices. These devices are set to work in such a way that when the price rises to a certain limit, the load is automatically reduced.

3.1.3 Project Performance: From 2004 to 2005, the participating users have completed a substantial load reduction, with the control group to form a larger contrast. In addition, peak load reductions are always twice as large as non-event days.

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From the data point of view, enabling technology seems to be the main driver of load reduction, and peak load reductions are always twice as large as non-event days. In addition, ADRS participants have greater load reductions than other demand response projects that do not use these methodologies.

In July-September 2005, there were 7 peak spikes in ADRS, with an average of 1.4 kW during high peak hours, a decrease of 43% compared to the control group. On non-event days, the average ADRS high-power user decreased by 0.7 kW vs. 27% for the control group. The results of each utility company are also different, as shown in Table 1.

Table 1 ADRS high-power users peak load reduction in July-September 2005

	Average cut	5 h Internal cut		Average cut	5 h Internal cut	
company name			Cut down			Cut down
	Reduction	Reduction	ratio/%	Reduction	Reduction	ratio/%
	kW	/(kW□h)		kW	/(kW□h)	
PG&E	0.83	4.15	29%	0.47	2.36	18
SCE	1.85	9.24	49%	0.89	4.47	30
SDG&E	1.17	5.84	38%	0.69	3.46	27
State-wide average	1.42	7.10	43%	0.73	3.67	27

3.2 American PJM independent system operation project:

3.2.1 Project Overview: As of the end of 2012, the Pennsylvania-New Jersey-Maryland interconnection (PJM) electricity market had an installed capacity of 185.6 GW and an annual electricity consumption of 832.33 billion kWh. Annual market transactions amounting to 29.18 billion US dollars, serving more than 60 million populations [11]. With the advancement of the electricity market reform process, the content of the electricity market in the PJM area of the United States has been promoted by the main energy market, the capacity market and Auxiliary service market transactions are promoted to respond to market transactions with the demand for load response as the main target.

3.2.2 Project Content: PJM market in the implementation of the DR project is divided into two categories, economic load response and emergency load response, as shown in Table 2.

Table 2 Main types of DR projects in the PJM market

	Emergency load response		Economic load response
Based only on capacity	Based on capacity and power	Based on electricity	Based on electricity
-----	RPM is cleared	-----	------
Register with ILR only		Not included in RPM	Not included in RPM
	ILR register		
Compulsoryreduction/cuts	Compulsory reduction	voluntary reduction	Scheduling reduction
RPM events have been tested	-------	-------	------
-----	RPM events tested	-------	------
Correctional Services has insufficient response	-------	-------	------
-----	With a lack of response to punishment	-------	------
Penalty/Punish		------	
Based on RMP clearing price	Based on RMP clearing price support	------	
Payment capacity price	Pay capacity price		

Note: The interruptible load response (ILR) terminates in the 2012/2013 trading year; the reliability price model (RPM) is a reliability-based auction transaction in the capacity market.

3.2.3 Project Performance:

1) Economic load response to the implementation of the project results. April 1, 2012 The Federal Energy Regulatory Commission (FERC) issued 745 regulations. In this, the criteria for economic load response are defined as the difference between the marginal price and the cost of generating electricity, in accordance with the marginal price (locational marginal price, LMP) full subsidy, which improves the economic load response, has played a greater effect. The total electricity value of the economic load response increased from 17398 MWh in 2011 to 141568 MWh in 2012, and the total settlement of economic load response increased from $2052996 in 2011 to $9159381 in 2012. The annual registered capacity of the economic load response at the highest load day is shown in Table 3 [75].

Table 3 Annual Maximum Peak Load Daily Economic Load Response Project Registered Capacity

Time	Number of registered users	Registered Capacity of Maximum Peak/MW
2007.08.08	2 897	2 498.0
2008.06.09	956	2 294.7
2009.08.10	1 321	2 486.6
2010.07.06	899	1 725.7
2011.07.21	1 237	2 041.8
2012.07.17	885	2 302.4

2) The implementation of emergency load response project.

Since June 1, 2007 began to implement the reliability of the price model RPM bidding method, the capacity of the market has become the PJM market demand side resources to participate in the market's main trading level. Total settlement of load management projects decreased from $ 487 million in 2011 to $ 331 million in 2012 and revolving reserve capacity credit value from $ 94 million in 2011 to $ 4.5 million in 2012. The annual emergency load response registration capacity is shown in Table 4 [77].

Table 4 Yearly Emergency Load Response Registered Capacity

Trading year	DR Total Capacity / MW	I LR capacity / MW	LM capacity / MW
2007—2008	560.7	1584.6	2 145.3
2008—2009	1 017.7	3 480.5	4 498.2
2009—2010	1 020.5	6 273.8	7 294.3
2010—2011	1 070.0 7	982.4	9 052.4
2011—2012	2 792.1	8 730.5	11 522.7
2012—2013	7 449.3	0	7 449.3

Note: Stop interruptible ILR from 2012/2013.

It can be seen from the PJM market, the total amount of DR response reductions and the amount of settlement is increasing year-by-year trend, and with the incentive policy, the annual economic load response and emergency load response project situation proportion has changed. With the deepening of the openness of power market to demand-side resource bidding, the economic load response plan is an implementation mechanism of the demand-side resources that are participating in the transition phase of market bidding. The emergency response plan requires the support of the relevant technology and management system, including the determination of the load baseline, the response load test and settlement, etc. The implementation and operation of future demand response will be more closely integrated with the operation of the power market.

3.3 The TEMPO project of France Electric Power Company:

3.3.1 Project Overview: In 1993, EDF, the French electric power company, proposed the TEMPO tariff based on the floating price management approach. With 4 choices, including the standard TEMPO (customers only installed electronic interval meter); dual energy TEMPO (the customer's heating boiler can switch between the two energy sources); constant TEMPO (customer installed load control equipment, according to price adjustment heating and water heater load) and comfortable TEMPO (the customer has a complex energy controller). Since 1995, the TEMPO project has been launched for all EDF customers in the mass market, with 300,000 inhabitants and more than 100,000 small business customers choosing TEMPO to reduce electricity bills. In addition to continuous red price days, customers were very satisfied with the price of TEMPO.

3.3.2 Project Description: The TEMPO price is similar to the peak price and dynamic electricity price. In France, the electricity price in the peak price is calculated according to the specific electricity consumption time, daily price of 6-22 hours 35% higher than other time. TEMPO price is in 1 day, according to the peak and the difference between the power supply and power supply time, the price according to the color is divided into three categories, namely, red day, day, blue day. Of which: red day 22 days, the highest price (5 times the price); day 43 days, the price of the second (about the usual price); blue day 300 days, the lowest price (about half of the usual price). In contrast, the highest electricity price (red) and the lowest price period (blue) price ratio of up to 9 times. In addition, the date of the three colors is determined by system operation and load conditions. The red and white days of the specific date of the latest in the evening of 5:30 announced that demand is beginning to rise or supply began to fall time. The color of the electricity price is sent to each user's meter via e-mail, SMS, TEMPO website, etc. and displayed on the corresponding indication equipment.

3.3.3 Project Outcomes: Customers in power market and ancillary service market play an important role. The French regulated electricity market 220 thousand users (i.e., total of 1.2% of the total number of users) participated in the project. In the case of France between September 2009 and August 2010, the electricity peak was reduced from 450 MW to 300 MW on a red day, and 150 MW on a white day. This saves TEMPO electricity customers 45% of their electricity bill. Compared to the blue-day tariff, the customer's electricity consumption fell 15% during the day and 45% on the red day. TEMPO customers' average electricity costs decreased by 10%.

3.4 China's electric power demand side management city, comprehensive pilot project:

In July 2012, the Ministry of Finance and the National Development and Reform Commission jointly issued the Guiding Opinions on the Integrated Pilot Project for Demand Side Management of Urban Areas (here in after referred to as the Guiding Opinions), it marks the official start of the comprehensive pilot project of electric power demand side management. "Guiding Opinions" put forward the basic principles and overall objectives of the pilot work, defined five key tasks: power management information, energy-efficient power plant scale, intelligent load management, energy service industrialization, capacity-building normalization. This work embodies the systematic engineering of the comprehensive pilot work of the power demand side management city, and the multiple roles of promoting energy saving and emission reduction and transformation of economic development mode. The peak power load of 440-550 Yuan / kW will be rewarded for the permanent power saving / transfer peak load realized by energy efficiency power plant project and peak shifting valley filling project. And by reducing the demand response measures such as a temporary reduction in peak load, reward 100 yuan /kW. Jiangsu, Suzhou is the national development and Reform Commission demand side management of the city's first batch of 4 pilot cities, following is a brief description of relevant work of the pilot cities as an example.

The construction of the demand-side management pilot cities in Suzhou will focus on the following aspects: the government will take the lead in establishing a smooth and efficient demand-side management system; exploring market-oriented mechanisms to build a sustainable development mechanism in the demand side management; strengthening financial support, guidance and incentives at all levels in Suzhou City, in-depth promotion of the demand side management; policy incentives and performance linked to strengthen the implementation of performance appraisal, enhance the power supply and demand balance of Suzhou and emergency support capabilities. The main objective of Suzhou demonstration project: **(1)** Effectively reduce the maximum load of the city, to achieve orderly use of electricity, scientific use of electricity, saving electricity; **(2)** Create demand side management application demonstration park; **(3)** to build Suzhou public service platform for electric energy; **(4)** to establish scientific electricity standards for important industries ; **(5)** to cultivate and expand the modern electric energy service industry.

International Journal of Novel Research in Computer Science and Software Engineering
Vol. 4, Issue 1, pp: (19-34), Month: January - April 2017, Available at: www.noveltyjournals.com

China's demand side management pilot effect remains to be seen.

4. EXISTING PROBLEMS AND COUNTERMEASURES

1) Need to further clarify the important position of demand response in Smart Grid.

Under the support of the advanced measurement system, the demand response can provide the electric power consumers with the ability to adjust the load, to achieve self-control power load, adaptive response, make them to control traditional electric power load. The power load becomes part of the controllable and self regulating, which is a major change in the power system brought about by the smart grid technology; Demand response in power system load peak, has a role in promoting technology between electric vehicle and power grid, accommodating large scale clean energy, improve energy efficiency, and distributed power, and has driven smart appliances, and helping in smart appliances industry development. The relevant departments of the state and the Power Grid companies should organize the production, research and development, and carry out the demand response to the construction of multi-disciplinary innovation system.

2) Demand response market allocation of resources means need to be further improved. Although a number of pilot cities in China have introduced the peak and valley electricity price policy, but the implementation of the limited range of peak and valley price and peak valley price is too small, the role of price leverage to be further developed. "Demand Side Management Measures (DSM)" clearly the power of special sources of funding channels, but not only in the documents to implement the proportion of funds allocated to the project and the amount to be further improved. The introduction of a reasonable incentive mechanism to reduce investment risk, from the financial, taxation, loans and other aspects of the development of smart electricity and demand response to give full policy and funding support, and give full play to the price and so on to optimize the demand side resource capacity to create a win-win situation of various stakeholders.

3) The construction of public service platform for electric power should be further improved. With the change of power supply and demand and the development of the concept of low carbon economy, the focus of power demand side management has shifted to improve the efficiency of electricity consumption and energy efficiency. The construction of demand-side function and the effect evaluation of power demand-side management platform at all levels need to be further improved to improve the effectiveness.

4) Need to establish a demand response standard. From the point of view of the policy, the technical service specification for the project planning, construction, implementation and evaluation of the demand response is proposed; development of demand response information model, exchange model, interface, demand response equipment, communication equipment production, installation and maintenance standard system; Service standards, fostering effective, fast and diversified service mechanisms, eliminating the barriers to automatic demand response interoperability, and providing service assurance for the implementation of demand response projects.

5. CONCLUSION

In this paper, the operation mechanism and key scientific methodologies of demand response under the condition of smart grid are introduced in detail. The typical cases are analyzed and the following conclusions are obtained:

1) The application of demand response makes the uncontrollable power load become partially flexible and controllable, so that the power load has a certain adaptive capacity, which is a major change in the power system;

2) Demand response can be used for power system peak shift, and the intelligent electrical equipment has the ability to automatically track changes in the system, which helps to protect the safety of the grid, but also conducive to the development of large-scale clean energy consumption, to expand the response to demand awareness;

3) At present, China's demand side management of urban integrated pilot project will respond to a greater demand response, through the price mechanism and market means to optimize the allocation of power demand side resources still need to focus on;

4) The design and application of demand response pilot scheme should also concern the analysis and mining of power consumers peak and energy saving potential; Consideration should be taken to stimulate the development of intelligent home appliances, intelligent electrical appliances industry and mode innovation.

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