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Demand Response Programs in Conventional and Smart Grid Electricity Networks: Chronological Development in Different Regions

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Abstract

Nowadays countries around the world are using more renewable energies such as solar and wind energies. The most important issue of the renewable energies is that their output is intermittent. So, there has to be a way to make a balance between demand and production in different situations. Demand response programs are the key issue to overcome this problem. In electricity distribution, demand response programs can improve the satisfaction of customers by using bidirectional communication between supply and demand. These programs provide a variety of services from installation of load limiters to Direct Load Control (DLC) or many activities designed for influencing the habits of customers and their electricity consumption. This paper overviews the history of demand response programs and the practices of demand response in the United States as well as some other countries in Europe and Asia. Literature shows that the demand response program is successful in many countries to reduce the outage and control the demand in response to generation condition. However, there still exist some key issues such as equipment cost and lack of standardization.

Keywords: *Demand response program, Renewable energy and Smart Grid*

1. Introduction

In recent times, due to the worldwide concern about emissions of greenhouse gases into the atmosphere, demand response programs in power distribution systems are getting more attention [1, 2]. Demand response programs will enable us to reduce the greenhouse gas emission and improve grid efficiency as well as stability of the power plant. In other words, we can achieve more efficiency in the electricity market by providing smart supplying the electricity, smart consumption and storage methods.

Demand response programs consist of several types of load-modifying methods that provide a various number of electric power system functions [3]. These days, by developing the technologies, the role of demand response programs have been expanded from shaving the peak loads to shift/shedding them. These programs also can provide a decrease in electricity consumption based on integrating renewable sources, more storage devices and central operation signals [4, 5].

Demand response resources can interface the wholesale market either as dispatchable resources or as none-dispatchable resources. Dispatchable resources commonly participate into contracts to reduce the demand, whether in response to an event or high market prices. In contrast, none dispatchable resources commonly participate in time sensitive programs such as time of use or critical peak pricing (CPP). The demand Side Management Categories are summarized as shown in Figure 1.

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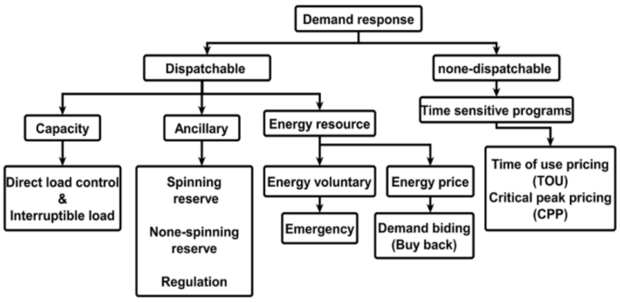

Figure 1: Demand Side Management Categories

This paper presents an overview about the demand response programs. In the following section, background of demand response programs in the United States will be discussed and thereafter current status on demand response in the United Stated, Europe and Asia will be introduced briefly.

2. Background

In 1970, increased air conditioning usage aimed hot summer hours led electricity shortage in United State. While facing this problem required new generators to handle peak loads, due to high system costs, utility companies were encouraged to look for load management programs [6]. Therefore, demand response programs appeared to reduce and control peak hours` usage. Incentive programs and Time of use pricing (TOU) were became two important demand response programs that standardized in many utility companies [7]. Incentive programs allow utility companies to reduce some part of customer`s load in exchange for lower electric rate on their bill [8]. Direct load control and interruptible programs are some incentive programs. Direct load control programs required to install control technologies on costumer appliances such as air-conditioning systems, water heaters and pool pumps. While interruptible programs are offered for commercial or large industrial consumers who have the ability to completely shut down by pre-noticed which is sent by utility companies [9]? Interruptible programs were established by utility companies during 1980 and 1990. Participant of this program received 15 percent reduction in their bill payment, however, these programs were not successful in many cases as commonly customers refused to reduce their loads at required times [10]. Until late 1990, utility companies in the United States had a vertical structure of power plants and they had their own management on generation and distribution assets. By acting the new policy on the US electric industry in 1992 that allowed the independent electric power generators to participate in wholesale markets and also by starting the Federal Energy Regulatory Commission (FERC) `s grant for wholesale power producers which allowed them for sale at "market based rates" based on the dynamics of demand and supply, many states choose to experiment the competitive market [11]. Therefore, vertically integrated utilities take their place into the individual generators such as stand-alone generators, regulated distribution and regional grid operators. There are two types of regional grid operators that are existing in the United States that are listed as independent system operators (ISOs) and regional transmission organizations (RTOs). They are responsible for supervision and operate high voltage systems, coordinating electricity generations and organizing the long term regional scheduling [6, 12].

By growing the competitions and establishing the regional wholesale market, the responsibility of utilities for maintaining reliability of the grid was shifted away to operating systems. Also, utilities started to divest their generation assets [13]. Alternatively by restructuring and more focus on the whole sale market, the opportunity of demand response to create benefits for customer`s was expanded. Previously, vertically integrated utilities had implemented the demand response programs to avoid blackouts or control costs during peak hours, although with the development of wholesale markets, the dimensions of impact were greatly expanded. In the new structure, rather than reduce load during peak hours, demand response providers were allowed to join on an ongoing basis in the market to decrease the volatility, improve the elasticity of demand, and decrease industry clearing price for electricity purchases for larger quantity of customers across entire regions [14].

Very soon it became clear that, basic implementation of the competitive wholesale market has not all the expected benefits when the policy had been written and it was needed to manage the electricity price and ensure the reliability of the system. Therefore, policy makers started to invest on demand response programs to ensure the efficiency of a wholesale market and reliability of the grid. Since 2005, some modifications have been done in energy policies by FERC. New modification on operation of the wholesale market, have set the demand response equal with generation resources. Gradually FERC has tried to remove the barriers to demand response during few past years and utility companies started finalize their market rules changes. As an example, Concerning Order No. 745, each ISO or RTO should submit consistence filings to FERC including tariff modifications to implement the requirements of the orders. In this case, Pennsylvania-New Jersey-Maryland (PJM) commenced to perform the changes in 2012, while other utility companies such as ISO-New England, Midwest are in the process of making the changes. Little by little, importance of demand response has been recognized by other countries and it was implemented in several countries to achieve reliable and efficient electricity market. As an example, China was successful to reduce the number of outages of this country by using demand response programs in 2006. Japan has started to install the smart meters and by developing of home energy management systems has expected to save 17% by 2024. I addition in Europe Union, it is agreed by all EU members to increase the electricity production through renewable energies by

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2023 [15], therefore several demand response programs are implemented in Europe union. In the following section current demand response programs in the United States and other countries will be discussed briefly.

Currently Used Demand Response Programs in Electricity Markets

Demand response programs can be active programs that means they can fully integrated into the market based programs and participate in the market clearing price, or they can be reactive programs, which are unable to participate in market clearing price, while offers common services same as the fully integrated demand response programs[16, 17]. Nowadays, fully integrated market based demand response can perform an important role in electricity market such as:

• **Energy Resource**:

Adjustment in output of resources in real time in response to demand condition is called dispatch. Demand response that participates in an electricity energy market can be dispatched for economic reasons [18].

• **Capacity Resource**:

This service involved a mechanism of payment which is designed to remunerate the members of market to commit a volume of firm capacity to produce power or decrease demand during peak times.

Demand response can play an important role in capacity markets to ensure the resource adequacy. Providers of demand response programs, should be able to reduce load on a very short notice within 30 minutes to two hours [19].

• **Ancillary Services Resource**:

This service is helping the system to work continuously with the required parameters such as voltage or frequency ratio and has the ability to make a balance between demand and supply after significant unplanned changes. Demand response that capable of reducing the loads by notice (less than 30 minutes) can play a key role as ancillary services in ancillary markets [20]. Some of ancillary services are listed below:

Frequency regulation (primary reserve):

This service is an automatic generation control which is provided by reserves and can be responded immediately to any changes in system frequency [21].

Spinning reserve:

This service is the on-line and unused reserve capacity that is synchronized to the grid and can be activated any time by decision of the operator [22].

Supplementary reserves (Replacement service):

This service is the same as spinning reserve, but it will not be responsive immediately (Commonly 30 to 60 minute delay) [23].

Non-spinning reserve:

This service is off-line generation capacity that can be synchronized to the grid by decision of system operation [24].

Regulating reserve:

This service consists of centralized, automatic control that has authorities to adjust the sources and demand to maintain the reliable system. This service commonly runs after 30 seconds with full availability [25].

Responsive reserve*:*

This service is the reserved supply generation and will be used when the abnormal condition happens [26].

Table 1: Currently Used Demand Response Programs in Electricity Markets

Demand response services	**Features**
Energy Resource	Its an electricity energy market which can be dispatched for economic reasons
Capacity Resource	Involved a mechanism of payment which is designed to remunerate the members of market to commit a volume of firm capacity to produce power or decrease demand during peak times
Ancillary Services Resources	Capable of reducing the loads by notice (less than 30 minutes) and it can play a key role as ancillary services in ancillary markets
Frequency Regulations	An automatic generation control which is provided by reserves and can be responded immediately to any changes in system frequency
Spinning reserve	An on-line and unused reserve capacity that is synchronized to the grid and can be activated any time by decision of the operator
Supplementary reserve	Same as spinning reserve, but it will not be responsive immediately (Commonly 30 to 60 minute delay)
Non-spinning reserve	An off-line generation capacity that can be synchronized to the grid by decision of system operation
Regulating reserve	Automatic control that has authorities to adjust the sources to maintain reliable system
Responsive reserve	Reserved electricity supply during abnormal condition

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3. Demand Response in United State Electricity Markets

PJM Industry:

In PJM electricity market, demand response programs are designed based on encouraging the customers to reduce the power electricity consumption during the peak hours based on locational marginal prices (LMP) [27]. Type of ancillary services that are using in PJM are categorized as, spinning reserve, supplemental reserve and regulation response services [28].

Participant in this program have two options that are listed below:

● Day a head option: this program provides the mechanism to help the customers to reduce their power consumption based on the draw map of peak times from a utility company in advanced and their payment bill is measured based on the day ahead time schedule.

● Real time option: this program provides a mechanism to help the customers to reduce the loads based on the map of peak times from a utility company in real time and their bill payment is based on real time pricing schedule.

ISO-NEW England Market:

In the New England market demand responds program is designed based on real time and day ahead options [1, 29]. This program is allowed to participate in forward capacity auction (FCA) and designed to reduce the load in demand side within 30 minutes to two hours after New England independent system operator`s request which is called “ reliability events”. Demand response is allowed Participant in this program should install special smart metering hardware to collect and record their consumption [16].

MIDWEST Marketplace:

The Midwest has robust demand response programs in its capacity resources. These programs are allowed to participate energy and ancillary services.

These programs are reliable and providing considerable contributions to system resource adequacy goals. In the Midwest there are 3 competitive ancillary programs that are categorized as primary reserve, supplemental reserve and regulation response services [30].

There are two types of loads that capable of providing demand response programs that are listed below:

● Loads with the ability to be physically interrupted. Therefore, these loads can only provide supplemental reserve.

● Loads with ability to be controlled by the Midwest ISO's dispatch instruction. Therefore, these loads can provide whole the ancillary services, are used in Midwest market place based on the instruction of dispatch centre.

Electric Reliability Council of Texas (Ercot) Market:

ERCOT has done a good work to use ancillary services in the market by using the necessary communications and control devices. Electricity rates are based on TOU pricing for different periods of time, commonly define 24 hours in advanced and it can be change day by day or season by season. Ancillary services are used in ERCOT are listed as: replacement reserve, responsive reserve, none spinning reserve and regulation reserve services [31]. Loads that are used in ERCOT market are categorized as below:

● Loads that are participating in the energy market and get the electricity bill based on actual load reduction.

● Loads that are participating in none-spinning reserve market and get the electricity bill based on capacity payment.

● Interruptible loads that are participating in other ancillary services and get electricity bill based on qualified scheduled entity.

4. Demand Response at the European Union Level

As mentioned before, if EU members has to increase the portion of renewable energies in their production [15]. Therefore, Demand response programs come to attention among the EU countries as it has many advantages when renewable energies with intermittent outputs are utilized in electricity production. EcoGrid is a project which is completed in 2014[32]. This project was designed to support the power grid in case of balancing when a large number of renewable energies are producing electricity. Eco-Grid Europe union supports priced based tariffs. In the first phase of EcoGrid-EU around 1200 price responsive equipment were installed in the house in order to control the electrical appliances. Since that time 1900 house in addition to 100 industries received this equipment [15].

5. Demand Response in Other Electricity Markets

China*:*

These days, China is very successful to reduce the number of power outages and improving the system load factor by establishing demand response programs. These programs are categorized as time of use pricing, interruptible load pricing and development of storage devices. Through these programs, dwellings are encouraged to shed or shift their consumption from peak hours to off-peak hours [33, 34].

New Zealand:

Demand response programs, mostly are used in New Zealand are incentive based programs such as dispatchable demand and interruptible load, however, deployment of smart meters at dwellings may lead to use price based programs. Recently, home energy management systems (HEMS) are developed in this

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country [35]. HEMS are able to monitor, control and analysing the energy consumption of demand by deploying smart meters and controllers [36].

Japan:

Although the Japan market place is still using the traditional analogue electricity meters and most of the customers are charged based on the flat-rate tariffs. The government has started to use digital smart metering and plans to improve the efficiency in residential energy management by deploying smart meters, possible HEMS, using dynamic pricing programs, such as real time pricing and critical peak pricing to encourage the customers to use the electricity more efficiently by 2024 [37, 38].

6. Challenges of Implementing Demand Response Programs

As discussed in the previous sections, besides United States, some other countries have started to use demand response programs to overcome the abnormal or peak hour situations. Although these programs were successful, there are still some challenges avoiding demand response programs from achieving its full potential. Demand Response is defined as the modification in normal electricity consumption when the price of electricity in the wholesale market is high or system reliability is in jeopardy, according to FERC [39]. To achieve it, a new infrastructure is required to install some costly components such as smart meters, communication devices, HEMS and smart controllers to maintain reliable and secure. Additionally, while utility companies have many methods to measure the consumption of demand, it seems that a uniform method and protocol among utility companies to measure and verify the demand response is unavoidable. These protocols can help the utility companies to provide demand response programs in multiple regions and encourage customers to participate more in DSM programs [3, 40]. Figure 2 shows the challenges that demand response programs commonly facing with in different countries.

Figure 2: Most challenges that demand response programs facing with

7. Conclusion

Electricity demand is varied in hours of the day by the changes the environmental conditions and human activities. Traditionally balancing between electricity suppliers and demand was performed by adjusting and dispatching generators in power networks, which commonly needs a large investment on expensive and rarely used components or dispatch of inefficient generators that are not Affordable. Environmental effects of using fossil fuels and growing the consumption of these sources, led to use more renewable energies rather than fossil fuel sources. Recently by developing HEMS, demand response providers have been able to have a good command on monitoring and controlling of demand. This, helps utility companies to, on one hand, reduce loads at peak hours by shifting or shedding the loads and on the other hand to increase the demand at off- peak hours or when, there is excess of power. These programs also are more compatible with renewable energies since they can immediately response to the condition of demand or generation. Literatures shows that although there was a good development of demand response programs, there are still some issues such as costly equipment and lack of standardization. A new generation of grids that compatible with demand response programs to monitor, control and communicate between utility companies and demand is called the smart grid.

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