VOL. 10, NO. 16, SEPTEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

SMART GRID: A SURVEY ON DEMAND SIDE MANAGEMENT AND DEMAND RESPONSE ITS SCOPE IN INDIAN POWER SECTOR

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ABSTRACT

The paper presents a complete survey on developments in Smart Grid Sector in Indian paradigm, mainly on Demand Response and the possible attempts to realize Demand Response by the power grid authorities, both government and private. The paper describes every terms related to smart grid like Automated Metering Infrastructure, Home Area Networks, Demand Side management. The reader educe a concise introduction and details regarding the Demand Response, its benefits, recent activities like Building to Grid collaboration conducted in India with an elaborate study portraying in necessary charts

Keywords: smart grid, automated metering infrastructure, demand side management, demand response.

INTRODUCTION

Smart Grid is the rejuvenated form of traditional electrical power sector, by the convergence of information technology and communication. By the interdependence of these sectors, the power system performs with increased efficiency and robustness. Information and communications technology (ICT), and in particular, wireless communications will be integrated into the power grid for active operation, and efficient demand response in the smart grid. The promise and goal of a smart grid is to enable a more intelligent, efficient, and reliable power grid with increasing user visibility and participation [1]. The recent researches and advancements in the power sector progressed globally to the extent that, it is possible for anyone to monitor the power grid efficiently and cheaply.

The Smart Grid supports the customers/ consumers to facilitate real time metering by bi-directional communication. In future, the traditional power grid will change as smart grid and the consumer will change as prosumer [2], that is the consumer will then not only consume energy, but also will produce energy. So, a proper communication must be established between both the sides for achieving higher efficiency in the transmission and utilisation of electric power. The bi-directional communication between the power providers and the consumer units gives the consumer authority to control individual consumer loads so as to keep the power system parameters in safer limits. The additional visibility would promote new insights and improved understanding toward a more reliable efficient power grid.

As the main function of smart grid(SG) is to provide and control the electric power, it is of no doubt that, the failure of smart grid can cause a catastrophe, which will take more damages than the current traditional system like the blackouts happened in India during 2012 in India. It was due to the over consumption of electric power by the big industrial groups over a day which resulted in total grid collapse of half of the country. The best way to control the grid problems is either by controlling the over consumption of power by the power providers known as Load Shedding, or by controlling the same power from the consumer side, known as Demand Response(DR)[3],[4]. The author briefs some information regarding DR.

SMART GRID

SG can be defined as an interconnected system of information communication technologies and control systems used to interact with automation and business processes across the entire power sector encompassing electricity generation, transmission, distribution and the consumer [5]. SG is therefore in contrast to the traditional electricity system, outshining with a bi-directional (two way flow of power and data) leading to establish an automated transmission and distribution network. The latest topics in Smart Grid research arena are Demand Side Management and Demand Response.

There are many sub categories/ operations under SG, which are briefed below.

Advanced metering infrastructure

Advanced Metering Infrastructure (AMI) is the foundation of SG. AMI refers to a system that measures, analyze and read the energy consumed by a consumer. AMI is an approach to integrate each consumer based upon the development of open standards. The consumer is given provision to use electricity more efficiently and gives utilities an ability to detect problems on their systems, and operate them more efficiently. AMI provides utility companies the opportunity to enhance customer service and improve operational efficiency [6]. The opportunity brings with it a set of inherent security risks too, that need to be mitigated for ensuring the success of an Automated Metering Infrastructure. The Driving forces for an AMI program for utilities as follows:

- Empower utilities to get real time information of power consuming patterns and by using this data to plan for demand which increases the efficiency.
- Automate the aggregation of meter data.
- Remote management of meters to detect power outages and also prevents power theft.
- Provision for consumers for time based pricing options and therefore manages power demand effectively.

AMI enables consumer friendly efficiency concepts and plans like

Home area networks

Home Area Networks (HAN) comprise smart appliances which can communicate with one another or an HEC to enable residents to automatically monitor and control home energy usage. The widespread availability of low-cost wireless technologies such as Zigbee has accelerated the deployment of HAN's by facilitating the addition of communication capabilities to household appliances. Smart appliances are home appliances that combine embedded computing, sensing, and communication capabilities to enable intelligent decision making. Sensing capabilities enable these devices to measure their usage, communication capabilities enable the reporting of their energy consumption to the HEC, while their actuation abilities enable them to respond to commands from the HEC. These commands can be simple on/off signals, or a DR command to operate in energy saving mode.

Smart appliances support DR signals in one of two ways. They can operate in energy saving modes when electricity prices are high, or they can delay their operation till prices drop below a specified threshold. Examples include smart dishwashers, which can receive DR signals and delay wash cycles till off-peak periods, or refrigerators, which can delay their defrost cycle till off-peak periods. Legacy devices such as water heaters, pool pumps, or lighting fixtures that do not contain embedded controllers or communication abilities of their own can be controlled via smart plugs. These are intelligent power outlets with measurement and communication capabilities that enable device energy monitoring and remote device shutoff.

DEMAND SIDE MANAGEMENT

Demand Side Management (DSM), is one of the strategies capable of offering a supplementary mode of action for the power supplying authorities that enable them to effectively manage increasing demand for electricity and the quality of power supplied. The main objective or a utility's, DSM program are to improve financial performance and customer relations. Usually, the goal of demand side management is to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times. Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks for meeting peak demands. An example is the use of energy storage units to store energy during off-peak hours and discharge them during peak hours. The DSM controls the matching between the supply and demand of electricity. One objective of DSM is to maintain the power quality, in order to level the load curves of general electric demands.

DSM offers a wide variety of programs to either increase or decrease the electric load. The DSM program is classified under the following categories mainly:

Energy conservation program

It promotes the applications which increase the energy efficiency for loads such as lighting, air-conditioning, motors etc in different consumer segments. The programs are especially designed to reduce the consumption of electricity and indirectly to reduce the peak demand.

Load management program

It control, curtail or shift the load demand periodically on a daily/seasonal basis according to the peak demand requirement or constraints. These programs normally result in a decrease in peak demand and may/may not result in a decrease in consumption of electric power.

Increased electricity demand program

It may be used periodically on daily /seasonal basis in order to rectify the load curves when the network is fed by run-of-river power stations. They are generally referred to as strategic power increase or surplus consumption measures.

Benefits of DSM

Utility economic benefits

- Reduction in excess cost for meeting peak load requirement
- Reduction in Line Losses
- Increase in effective system capacity

Customer economic benefits

- Reduction in Energy Consumption
- Low Operating Cost
- Better equipment performance
- Longer equipment life

DSM: SCOPE AND POTENTIAL IN INDIA

The scenario of distribution of loads in Indian Industrial Sector is shown in Figure-1. The researchers choose industrial sector as it comprises of one of the biggest loads in the network.

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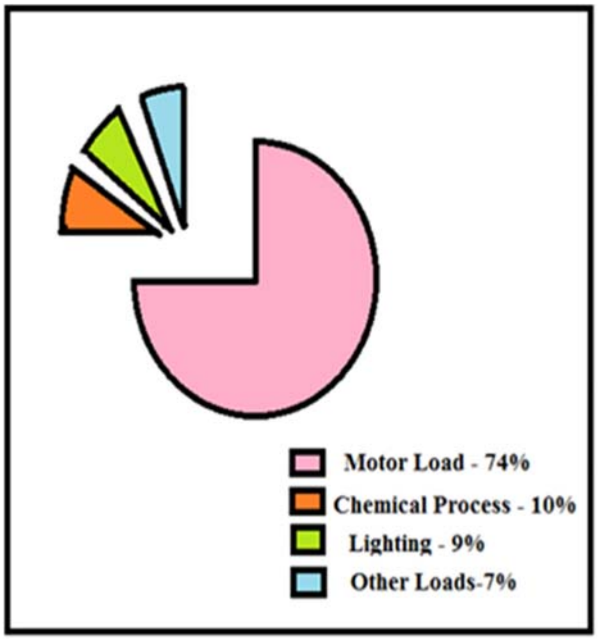

Figure-1. Distribution of loads in India- Industrial Sector.

The load curves will be evaluated and closely checked by the utility side for managing both the load and the generated power. The term "power quality" is given importance more along with fixing tariffs for the load consumed so that the load can be managed to check closely with the electricity produced.

DSM also plays to reduce power outages in agricultural sector. As the agricultural sector needs sufficient irrigation, it is the responsible of the concerned authority to supply them electricity for definite hours each day. The authority also has to check and monitor whether the agriculture related consumers are consuming the sanctioned power in the period allotted for them. So, the load forecasting can be charted with higher precision. Regarding the system reliability comprising of both commercial and urban centres in India, through DSM the reliability is improved much. This is attained by improving the power quality and the system frequency regulations across the country. The overall tariff also is being adjusted for the different sections of con summers for effective demand management.

The DSM in India also checks the scope of Energy Conservation in Energy Intensive Industries. Figure-2 shows the scope of industries in India. Table-1 shows the potential savings in the commercial sector in India.

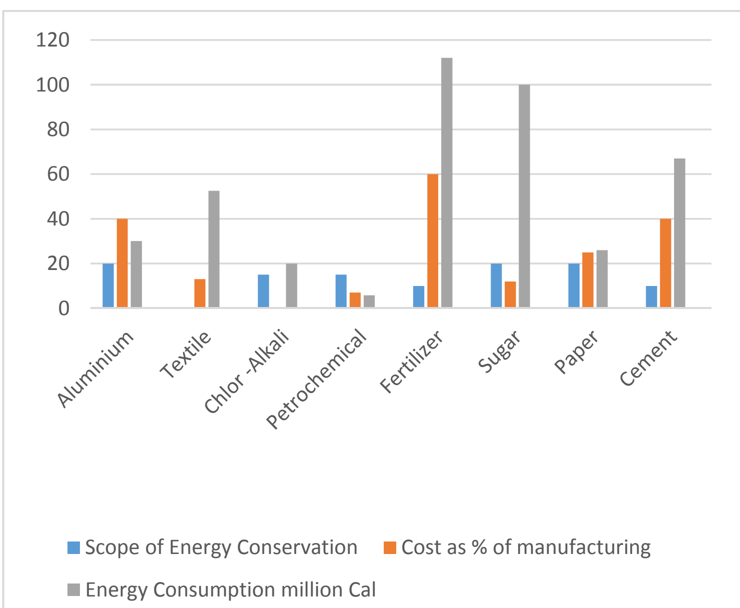

Figure-2. Scope of industries in India.

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Table-1. Potential savings in the commercial sector in India.

End use	Energy-efficiency measures	Technical potential savings estimate (%)
Lighting	De lamping; low- wattage fluorescent lamps; compact fluorescent lamps; high-pressure sodium lamps; electronic ballasts; aluminium and silver film reflectors; daylight dimming; occupancy sensors; day lighting	20-50
Cooling	Heat pumps; high-efficiency chillers; chillers capacity modulation and downsizing; window treatments; radiant barriers; economizers; proper equipment operation and maintenance	>15 without efficient lighting,80 with efficient lighting, average is 30
Ventilation	Variable air volume systems; low-friction air distribution designs; energy-efficient motors; variable speed drives; heating; cooling, and lighting improvements; proper equipment operation and maintenance	50
Heating	Building shell improvements, heat recovery, proper operation and maintenance, heat pumps integrated with water heating system	15-40
Others	High-efficiency equipment; motors , adjustable speed drives	10-30

DEMAND RESPONSE

Demand Response (DR) is the act of consumers to change the demand pattern in response to Price of electricity or whenever there is emergency in the Grid [7]. It also helps the power supply authorities to have a better control on the grid as it primarily deals with the control on loads and the tariffs which is needed for the matching between the electric power generated and the load consuming the electric power. In other words, Demand Response is a strategy used by electric utility companies to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is the greatest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be connected or disconnected by the customers themselves or by the utility, at peak times. In general, DR refers to those groups of programs in power systems which seek to ameliorate electric energy network's operating conditions by exploiting demand side control and demand side management techniques.

Since power plants and transmission systems are designed to respond to the highest potential demand, lowering the peak demand during demand intensive times of the day helps utilities reduce overall installation costs, operating costs and mitigate potential grid failures. The DR is further classified into three types namely economic demand response, emergency demand response and ancillary services demand response.

Economic demand response

The economic DR is used by the power supplying authorities to avoid the significantly higher costs of generating electricity during hours which records peak demand of electric energy of a day which is associated with ramping up "peaking" power plants to meet higher than expected demand.

Emergency demand response

This type of DR is used to mitigate the potential for blackouts or brownouts during times when demand threatens to exceed supply resources. This typically occurs on days of extreme hot or cold temperatures when heating and cooling systems are causing greater demand on the grid. The author finds this DR as the important one which protects the entire grid from collapsing, due to the sudden rise of power demand due to climatic changes, which has huge impact on the population.

Ancillary service demand response

This DR is used to support the transmission of electricity to the consumer loads in a manner consistent with reliability requirements that are imposed on utility companies by industry regulators.

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DEMAND RESPONSE-BUILDING BLOCKS

Demand response strategies

There are two ways in which DR events are executed by the power providing companies/utility companies including:

- Direct Load Control DR events involve the remote interruption of customers energy usage, in which power distributors cycle loads like heating, cooling, elevators, washing etc. on and off at varying time intervals during peak hours of the day. This Demand Response has an immediate effect on the system, as it controls direction on the consumer loads.

- Dynamic Pricing uses variable electricity rates to encourage customers' voluntary curtailment during demand response events. Utilities use a variety of pricing schemes including peak time rebates, critical peak pricing, and time of use rates to curtail usage.

Demand response technologies

Technologies to implement a demand response vary depending on the type of strategy being employed - direct load control or dynamic pricing. Generally speaking, demand response technologies facilitate communications with customers and/or control heating and cooling systems

- **End-user interfaces** - Utilities send signals to the participants of the Demand Response program using a variety of channels, including email, phone, and web portals. In-home or business display devices are another way that utilities can communicate with consumers about an event, including information about energy usage and pricing with smart grid. Consumers need to acknowledge their participation in the program. HAN can be used to connect displays, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system.

- **Load control devices** - Utilities use a number of different tools to actually cycle systems like heating and cooling on and off during demand response events. Load control switches enable direct remote control over AC units or heating systems. Smart thermostats allow utilities to adjust temperature settings remotely.

- **Advanced metering infrastructure**- As AMI enables both utilities and end-users to have more robust data about loads, energy usage and electricity pricing. By accessing the Smart meter in AMI, different consumer loads connected to the power grid can be disconnected, thereby lowering the demanded power required by the consumers. This in turn prevents not only the mismatch between generated energy and consumed energy, but also protects the grid from system frequency fluctuation and further protecting from grid collapsing due to tripping off of substations.

Demand response in Indian context

At present, India is seeing fragmented and independent Smart Grid endeavours by the national (Central), public-private collaborations, and private organizations, at different levels of maturity. Nationally, the Indian Ministry of Power (MOP) is working toward major power sector reform, which includes revolutionizing the grid with bi-directional information exchange. For the systemic growth of the Smart Grid in the country, the India Smart Grid Forum (ISGF) and India Smart Grid Task Force (ISGTF) are set up under the aegis of the Ministry of Power (MOP 2010) [1].

The ISGF is a non-profit voluntary consortium of public and private stakeholders with the prime objective of accelerating development of Smart Grid technologies in the Indian power sector. The MOP with sub- and nodal-agencies; Ministry of New and Renewable Energy (MNRE), Ministry of Communication and Information Technology (MCIT) and Department of Science and Technology (DST); governs the ISGTF. Under the auspices of the seven working groups of the ISGTF, several activities encompassing market-based mechanisms for rapid Smart Grid adoption will be evaluated. These include demand-side financing, feed-in tariffs for individual renewable generators, and a differential tariff for reliable supply and transmission pricing models, including Locational Marginal Pricing (LMP) (ISGF 2013) [2]. These financial activities will be supported by simultaneous technical feasibility assessment of connectivity, network planning, and reliability of system operation.

Demand response is in its nascent stages in India. Its benefits will mirror those seen in Western countries, such as reduced electricity blackouts, reduced electricity costs, offsetting the need to build supply resource and the ability to integrate electric vehicles and renewable energy sources. Regulatory framework also needs to be in place for implementation of Demand Response strategies. However, considering the large diversity in the consumers to be served in India, it is necessary to identify the appropriate consumers to be roped in for Demand Response to ensure the success of the program. Consumer awareness and maintaining transparency with them must be a priority to win their confidence and ensure acceptance of the Demand Response program. The electrical distribution network must be strengthened to ensure reliability in operations. Also, to cater to the diverse needs of the consumers, a variety of DR modules need to be prepared.

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DR is not an alternative to On-Going Investment Plan for New Power Generation/Additional Transmission Capability but DR is a supplemental mechanism to utilize all power related facilities (both Public and Private Own) in the most efficient manner at the least cost. For sustainable economic growth of India, Energy Conservation/Energy Efficiency should be of the essence and DR can provide both "Energy Saving at End User" and "Energy Efficiency at Grid Operator "at the same time. DR can also be introduced by private Investment if competitive commercial markets are established by new regulatory frame works.

DR helps to make the existing power system a smart system in India. Before the introduction of SG and associated bi-directional smart meters, the cost of diesel for emergency operation of Diesel Generator was very high. By DR and SG under the same situation now in India, fuel cost can be saved by using solar PV system. The traditional building, housing and Factories were converted to high energy efficient buildings by employing smart gadgets and controlling devices. Thus energy is being conserved. The Wind Farm Curtailment is provided with additional power source and Demand Response.

In Mumbai, India, the Demand Response is effectively in practice from 2011. At 2011, during day time peak, Mumbai City needs to purchase power or about 600MW to 800MW. This need to be rectified while checking the load duration curve, it was noticed that it showed large distortion in peak and off peak power requirement. The load management was done by employing DR, which acted as an emergency tool. The daily deficits in power were met through exchange, whereas normal power requirement was met by long term contracted power. The DR process was simple. During time of high demand, the grid stress/ overloading condition was rectified by the DR team. They gave instruction to the different consumers to cut off their electric loads, like say an elevator out of four in a shopping mall was instructed to stop. Similarly, many loads were cut off by the client's response to the DR team there by lowering the required demand. The Demand Response used to meet resource adequacy requirements over the period 2008-2013 is given Figure-3.

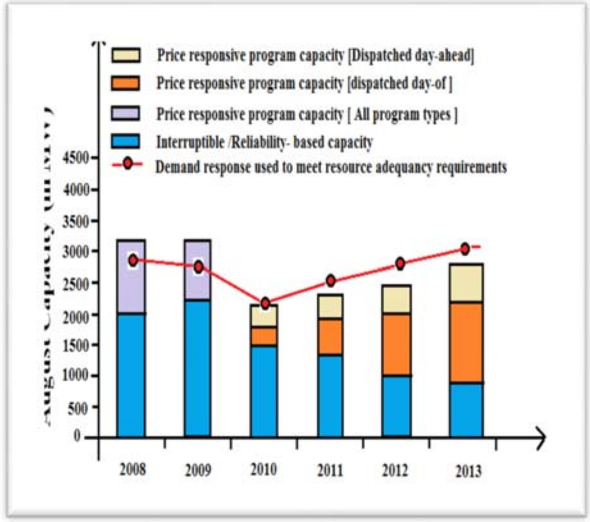

Figure-3. Demand response used to meet resource adequacy requirements over the period 2008-2013.

CONCLUSIONS

The paper detailed the various regarding smart grid, its features and gave an overall idea regarding the two emerging fields in smart grid - DSM and DR. The main aim of the paper was to brief the development if smart grid, particularly Demand Response in India. The various classifications, advantages of both DSM and DR were surveyed in this paper. The success of DR operation at peak demand time at Mumbai was also mentioned for providing the reader a better understanding of practical impact of Demand Response.

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