A Smart Survey on Demand Response Potential in Global Energy Market

S. Sofana Reka* and V. Ramesh

School of Electrical Engineering, VIT University, Vellore - 632014, Tamil Nadu, India; sofana.reka@vit.ac.in, vramesh@vit.ac.in

Abstract

In the last decades, more and more stress is put on the electricity supply and infrastructure; thereby the need for reliable power supply resulted in the smart grid perception. Hitherto the increasing demand and peak loads lead to an increase of required grid capacity and preventing larger investments. Demand Response (DR) assumes a critical part in rescheduling of utilization by the consumer side in a smart grid environment as from their nominal consumption patterns reacting to hike in the price of electricity over time and when framework unwavering is under risk. In the proposed paper an complete analysis of DR study is made on the basis of the outlook evolved in various countries potential in energy market paradigm and a detailed scenario of various DR programs are portrayed. Further the elaborate comparisons of the programs initiated are cumulatively elucidated by different bar graphs and pie charts. This comparative analysis exhibits the present scenario of demand side management interpreted in different countries.

Keywords: Demand Response (DR), Electricity, Energy Market, Peak Demand, Smart Grid

1. Introduction

In electrified parts of the world, a simple switch brings lights and luxury of other gadgets and appliances to life. This seemingly simple luxury requires a complex network, technically called Power grid, among supply, service and consumption. This network comprises of generation plants, transmission lines, and transformers. Communication between these entities is quite complicated. Smart grid attempts to efficiently address this task. It actually doesn’t specify any scale and it ranges from a single chain to a power network of an entire country. The power transmission from the power plant to an individual’s house is carried via a series of transformers and adjusted, often manually, to deal with fluctuations in demand capacity. Managing this network in a more responsive and efficient way is the target of changing the present day grid more astute. The smart grid uses computer technology which improves the communication, automation, and connectivity of the various components of the power network. This improves distribution by relaying information from consumers to the generation plants. One key element to this system is the installation of smart meters in homes and commercials. Unlike the traditional analogue meters, these digital devices are capable of two-way communication. They provide relaying information about both supply and demand between producers and consumers. The data collected via smart meters is imperative to the function of the smart grid. By analysing this data, power generation plants are able to better predict and respond to periods of peak demand. This allows them to reduce production when less power is needed and quickly ramp up generation when peak periods approach. By harnessing the power of computers, communications, and data analysis technologies, the smart grid reforms the flexibility upgrading the efficiency and susceptible to different events in order for more intermittent generation methods like wind and solar and handles new stresses to the network like the electric vehicle. Moving to the expending side, consumers uses anticipated amount of energy, called the base-load. During a stipulated period, the grid develops to procure

*Author for correspondence
more requirement of energy as in the case of the utility and
the user as a handshake environment for development of
more energy in case of sudden haphazard that happens.
In particular the diverse need for power is commonly
most noteworthy toward the evening and early night, and
also amid the mid year when aeration and cooling sys-
tems run day and night. At the point when a large num-
ber of electricity users turn on their aeration and cooling
systems after work, it builds the interest on the lattice.
When the grid is not able to handle the demand, power
will be shut off in some regions to reduce the demand.

With demand response, for the fore coming years could
make a green framework with the users’ participation.
Plants that produce peak power frequently likewise creat-
ing elevated amount of pollutants. A smart grid is all more
effectively balanced for taking care of power handling
resources that may be discontinuous in power and may not
generally be available. At the point when the power shoots,
smart grid would have the capacity to move to fuel sort
it uses, adjusting fossil energizes and renewable vitality
source. Being a source to improve clean energy the de-
mand response market has wide percentage of acceptance.

Figure 1. Block diagram of challenges faced by electricity market.

Figure 1 explains the challenge faced by the present
grid system. The power grid supplies only the electricity as
per demand and therefore it is necessary for conserve the
energy produced for further use and development needed.
One way of diminishing the demand is versatile over the
need of new developments in the present day of epoch of
grid with a study of utility and the user interaction. In wide
terms, demand response programs provide - residential,
commercial and industrial consumers for the capacity to
voluntarily trim our power utilization at particular times
of the day, for example, crest hours amid high power costs,
or amid crises, (for example, keeping a power outage).
Numerous field researchers assume that if consumers are
given a decision under conservation of energy, they will
decide to ration in light of the fact that it's a vibe decent,
green commitment.

However, there are some challenges preventing DR achiev-
ing its full potential worldwide. Lack of uniform baseline
protocol among DR aggregators and large potential in-
dustrial customers provides barrier to the participation
on whole and also increases the transaction costs. Creat-
ing normal estimation and check norms would better em-
power outsiders and interest reaction aggregators to give
request reaction in numerous areas. In case of residential
customers, various DR programs with accurate, reliable,
sophisticated and user friendly environments are required
to make the customers actively participate in the DR events.

2. Demand Response

Demand response defines as the progressions in power
use by consumer side from their ordinary consumption
patterns in accordance with subsequent change in the tariff changes of electricity with user and utility interaction. Its objective is to equalise both the energy providers participating in the energy market to reduce the tariff with different programs initiated. When DR event call is given by controllers some measures are taken by industries to overcome this peak demand like turning off some unwanted loads. The example for demand response is given in Figure 2. Further, it can be also be characterised as the arrangement developed to incorporate usage of power subsequently less at the peak load paradigm. It can also be described as the intentional pattern that is modified by utility side customers. They do amend the level of time changes, with the progress of changing demand, or utilising the power usage. Demand Response is really important for the balance for grid and indeed maintain of demand with supply.

DR EVENT CALL

- Turn off some elevators
- Pre-cool buildings in early hours
- Turn on emergency generator
- Turn-off non-essential loads

DR BENEFITS

- Bill Savings
- Reduced outages
- Environmental benefits
- Customer benefits
- Efficiency improvement
- Risk management and reliability

Figure 2. Typical example for DR event call.

2.1 Benefits

DR programs can spare power bills of the utility side clients on the off chance that they lessen their use of power amid crest periods. A few consumers may have the capacity to expand their aggregate vitality utilisation without the need to pay more tariffs by working all the

off peak. The administrator in the grid side has more alternatives and assets to keep up framework accuracy, accordingly lessening constrained blackouts and it enhances power market execution. DR can possibly decrease expenses and carbon dioxide discharges over the power framework, permitting more productive utilization of existing power era and system limit. On the verge, this lessens the requirement for interest in new limit and minimizes the need of less effective new generation plants. Subsequently it is proposed that the DR programs effectively engage in natural issues as well. The demand response advantages are sorted as indicated in Figure 3. A demand perspective is very much prevalent to increase in balance process which develops the user node of each consumer to behave as perfect balancing one. The very quintessence of the smart grid is demand side management. Invaraiably the broadcast need of smart grid, has a hand in gesture of environmental distribution with the renewable energy and electric vehicles. The principle goal of thus to burden control is to lighten up the peak loads which cause real consumptions in power utilities. This can be attained to by exchanging non-crisis power demands from peak to off peak loads and take non-emergency power demands from peak load to off-peak load times.
real-time electricity prices get lowers. For the development of a DR program cost plan is sectioned in the Figure 4.

![Figure 4. DR Cost plan.](image)

2.2 Classification

Basic classification of demand response is given in the reference\(^{13}\). In incentive based programs taking an interest of the consumers to actively receive payment rates for their cooperation with the participating events. The emergency Demand programs and participating load programs are been included under MRTU, the Market redesign\(^{26}\). In market-based programs, participants are remunerated for their active execution of performance in the programs in par with the measure of usage in non-peak hours and in discriminating conditions with money for their performance, depending on the amount of load reduction during critical conditions.

2.2.1 Time of Use Tariffs

As the name suggests, TOU tariffs requires the change in pricing with respect to the tariff developed for entire day. The tariff phenomena habituate the change in the cost with that of the supply in order to avoid higher prices over the shooting up of the demand. TOU tariffs remain same with the need of fixing the same period over the demand over the need of usage\(^{10}\).

2.2.2 Critical Peak Pricing

This type of pricing develops the consumers to change in the tariff giving a short notice in accordance with the demand usage\(^{11}\).

2.2.3 Real-Time or Dynamic Pricing

In accordance with this pricing system the tariff changes variably with the usage of power in the peak time in reflection on the overall market costs\(^{12}\).

2.2.4 Direct Load Control

Dynamically more used type of pricing systems can be analysed by developing smarter devices installed in different localities and checking the power outage, forming a direct control over the loads even in a remote area\(^{14}\).

2.2.5 Interruptible/Curtail able Rates

Users develop special recruitment based on the practice of load sheds in a particular day.

2.2.6 Emergency Demand Response Programs

checks out immediate reaction with the voluntary need.

2.2.7 Dynamic Demand Control

Devices which can be utilised with whatever time adaptable electrical burden (refrigeration, ventilating, heating). They can turn devices on and off in effect of changes in the recurrence of power supply.

3. Communication Technologies

The challenges addressed in demand load control for the smart grid framework is trying to improvise the present forthcoming era with the improvement in the communication technology standard by engrossing a prospective need of development acquisition with different utility providers communicating with the users. Thereby enforcement of virtual power plant concepts and also with the complete vitality role of renewable energy resources improves the world of the grid into to next level.

Smart metering and two-way communication infrastructures\(^{15,16}\) had a futile realize real-time interconnection of IP addressable components at the consumer and operator premises over the Internet through an RF, wire-line or power-line communication infrastructure. Combining of electric energy storage entities such as batteries, backup devices (e.g., Uninterrupted Power Supply, UPS), and Plug-in Hybrid Electric Vehicles (PHEVs), these technologies provide unique opportunities to address the challenge of managing the consumer power demands in real time\(^{17}\).
4. Demand Response in Various Energy Markets

The importance of DR is likely to increase as the various countries move to a low-carbon economy. DR vulnerability for cost reduction and carbon dioxide emissions by proper approaching of programs making the users compatibility and actively inculcate in the programs worldwide. In this situation developing new power plants can be reduced and bringing in the need of increase of economy.

4.1 Power Demand

The literature shows that economic incentives are effective in changing consumer behaviour. Consumers respond to static Time of Use (ToU), Critical Peak Pricing (CPP) and Critical Peak Rebate (CPR) price signals according to their need of demand in the situation\(^1\)\(^8\),\(^1\)\(^9\).

The whole energy used by all of human civilization is energy consumption. Typically measured per year, it involves all energy utilized by every industrial and technological sector, across every country towards humanity’s welfare being the power source metric of civilization. As power consumption increases day by day demand increases simultaneously. These type of programs which had been developed across countries after the successful installation of the smart meters, making the grid much more effective. These active programs also exhibit the need of the supply with the demand by controlling the loads by scheduling them actively depending upon the devices they use in the strategy of the different consumer levels. We can see the power demand for various countries in various periods as shown in Figure 5.

4.2 Evolution of Auto-DR

Auto-DR is nothing but the automation systems which acts as event control, information and reporting centre. The auto-DR sites in various countries are shown in the following bar chart Figure 6.

![Auto-DR Penetration in various countries.](image)

4.3 Penetration of Smart Meter

The smart grid had a enhance growth and still develops its approach in the development over the next decade. This review understands the reader the paradigm of the new grid of smart meter installation creating an environment to develop programs enhancing the users. In many developing countries, the energy theft had become a strong advisory fact for the new technology and blossoming worldwide with a static ratio with the users and the utility. Electricity meters are the point of interface between the utility and consumers. The penetration of smart meters in Europe is shown in Figure 7.

![Penetration of Smart Meter](image)

4.4 United States of America

The different Demand response programs ongoing in US are of two types – one that induces the customer to alter behavior by offering certain incentives (referred to as ‘incentive-based programs’) and the other that offers price signals so as to make the customer change her usage pattern (‘time-based programs’). The FERC survey reports that so far incentive-based programs have been more popular with customers as compared to time-based programs. Currently, most demand for smart meters in the United States is for residential meters, since many U.S. commercial customers have long had smart meters to monitor facility electricity usage more accurately. The entities of DR programs are embossed in the pie-chart exhibiting the required data of the programs installed.
and their participation in Figure 8. The need of these type of programs in countries developed has the need of consumers to participate and the population enhancement of the residential consumers actively participate in accordance with the installation. Figure 9 represents clearly the penetration view of smart meters in US in different places. The diverse need of the consumers in the upper class to middle class families, installation of smart meters with the knowledge build with the demand side management programs progress the success of them to the next level.

### 4.5 Australia

Australian retail electricity prices have risen by more than 70% over the last 5 years, and are expected to continue to increase. Even though average electricity demand has fallen, due in part to energy efficiency programs, an increase in distributed generation and a response to rising prices, meeting peak demand.

By finding ways of moderating demand peaks, generators and network business operators may be able to avoid or defer the large capital expenditure needed to cater for these infrequent extremes of demand.

### Number of entities DR programs in the US

- Direct load control
- Interruptible/Curtailable
- Emergency Demand Response Program
- Capacity Market Program
- Demand Bidding/Buyback
- Ancillary Services
- Time-of-Use
- Real-time Pricing
- Critical Peak Pricing 3%

![Figure 8. Percentage of DR programs in US.](image)
This includes reducing or shifting consumption, and using standby generation to divert electricity use from the grid to on-site generation. Notice periods of about 2-4 hours was considered as enough time to safely implement a shutdown plan with minimal impact on machines and materials.

4.6 Japan

The Japanese model is government-led. The Japanese national government has made very effective and unique initiatives on improving the development of smart grids through the regulatory role of the government, the development of business models, and programs to encourage consumer engagement. The paper has examined the needs and to what extent the state played a role in transition of developed projects in Japan. It has addressed a serious note about low-carbon transition studies in the Asian context. Another unique and appreciative feature of the Japanese approach is the promising role of the business sector. Some of the corporates like Toyota, Mitsubishi, Sharp, Toshiba, Fujitsu, Panasonic, NEC and Nissan Motor are involved in these projects. They were the major sources of capital investment and innovation in those demonstration projects. Financing the massive investments has been widely identified as a key barrier for smart grid deployment which is often not present in many countries. The government’s failure in taking up a major regulatory role, the absence of active involvement of established utilities such as TEPCO. The lesson for smart grid policies is that much more attention needs to be given to three areas government role, corporate support and customer active participation.

These areas helps to overcome the critical technological puzzle, and thus to achieve more advancement in smart grid deployment.

4.7 Canada

In the reducing of the load in maximum hours, the need of dynamic pricing programs is enrolled for the price elasticity with a standby analysis of the demand and the user profile. The types of customer are classified into long range customer and short range customer. The long range has maximum benefits compared with the other. The customer substitutes off-peak electricity consumption for peak time usage in response to the demand to change the prices. This kind of elasticity is important in TOU and CPP. Elasticity is used in compensation of expected price to modify expected demand. The illustrative studies and integrated resource planning studies project provide more benefits from DR programs, program evaluation studies prove the substantial benefits of these programs. The comparison between prices, contingency, base-case were evaluated with respective to this elasticity.

4.8 Europe

The price for electricity in Europe is expected is thereby increased with the rapid change of change in fossil fuel generation and electric vehicle enhancements.

Illustrative Savings In Energy Consumption using Demand Response in Europe

Figure 10. Energy savings using DR in Europe.
Figure 10 clearly explains the rise in energy saving through DR in Europe. The DR projects as been a roller coaster profile sector depending upon the percentage need of the consumers to present a project to develop the need, with a static demand produced.

4.9 India

India's rapid increase in population and increase in per capita income of the population make the country poised towards peak demand in electricity. The Figure 11 shows the different energy consumption in accordance to the market rate.

**Table 1. Power supply position for various regions.**

| Region          | Power (MW) | Peak Demand | Peak Met |
|-----------------|------------|-------------|----------|
|                 | Feb'13     | Feb'14      | Feb'13   | Feb'14   |
| Northern        | 36923      | 37895       | 33494    | 36780    |
| Western         | 37343      | 41184       | 36382    | 40331    |
| Southern        | 35901      | 36427       | 31189    | 34544    |
| Eastern         | 14338      | 14976       | 13585    | 14499    |
| North Eastern   | 1934       | 2025        | 1845     | 1929     |
| All India       | 126439     | 132507      | 116495   | 128083   |

**Table 2. Deficit position for various regions.**

| Region         | Deficit (%) |
|----------------|-------------|
|                | Feb'13      | Feb'14      |
| Northern       | -9.3        | -2.9        |
| Western        | -2.6        | -2.1        |
| Southern       | -13.1       | -5.2        |
| Eastern        | -5.3        | -3.2        |
| North Eastern  | -4.6        | -4.7        |
| All India      | -7.9        | -3.3        |

**Figure 11. Consumption of different sectors.**

The power supply position for various regions of the country including demand and availability with the percentage is represented in Table 1 and the deficit position for same regions is tabulated in Table 2.

A few big challenges are posed in DR programs in case of industrial sectors. In a developing country like India, the smart grid epoch can develop a massive improvement in both residential and in industrial sectors. Figure 12 represents the validation of dynamic DR end use technology used in India emerging from the load shedding of different appliances. Starting from the small scale to big scale industries there can be complete change in the power us...
proper outcome of the Demand side management programs. Thereby educating the middle class profile people with need of the electricity pricing and how can be the cost been reduced by shifting and using of appliances in the right time and certain type of incentives can be enhanced for them. And also question of using the load in the non-peak hours the demand reduces. Further in the industrial domain starting from small mills to bigger concerns, power outage can create bigger problems enabling their profit concerns. So the need of these type of programs understand the bigger appliances shifting by scheduling them properly can get back a revolution in India. So cutting edge technology will invoke the programs to the betterment.

5. Conclusion

Demand response has developed its need over the successful installation of metering in the epoch of smart grid with the curtailment of the pricing and tariff balanced with the utility providers has its own challenges. This paper portrays the need of these type of programs with the aid of usage of customers without paying more for their electricity usage, but the adequate knowledge of the consumers have to be enriched with these type of programs. Also it is evident that the benefit of demand response is not just in the economic cost savings, but also in environmental costs. While there is no definitive research yet on how demand response systems will or won’t impact the environment, there are some positive effects that can be expected. It is evident that countries are keen to improve the end use load reduction through various demand response programs. This paper presents the overview of various countries energy demand and DR programs implemented the impact of those programs implemented. The impact of those programs on energy efficiency and peak power demand reduction is also analysed. Since these programs are at earlier stages in many countries including India, it invokes gives new techniques to implement these DR programs on end usage systems.

6. References

1. US Department of Energy. Benefits of demand response in electricity markets and recommendations for achieving them. Report to the United States Congress. 2006 Feb.
2. International Energy Agency. The power to choose—demand response in liberalized electricity markets. Paris: OECD; 2003.
3. US Department of Energy. Benefits of demand response in electricity markets and recommendations for achieving them. Report to the United States Congress. 2006 Feb.
4. Albadi MH, EI-Saadany EF. Demand response in electricity markets: an overview. Montreal: IEEE PES GM; 2007. p. 1–5.
5. Jazayeri P, Schellenberg A, Rosehard WD, Doudna J, Widergren S, Lawrence D, Mickey J, Jones S. A survey of load control programs for price and system stability. IEEE Trans Power Syst. 2005; 20(3):1504–9.
6. Kirschen DS. Demand-side view of electricity markets, IEEE Trans Power Syst. 2003; 18:520–7.
7. Goel L, Qiwei W, Peng W. Reliability enhancement of a deregulated power system considering demand response. IEEE PES GM; 2006. p. 1–6.
8. Spees K, Lave L. Demand response and electricity market efficiency. Electricity J. 2007: 20:69–85.
9. Palensky P, Dietrich D. Demand side management: Demand response, intelligent energy systems, and smart loads. Industrial Informatics. 2011; 7(3):381–8.
10. Gellings C, Chamberlin J. Demand side management: concepts and methods. US: The Fairmont Press Inc; 1988.
11. Charles River Associates. Primer on demand-side management with an emphasis on price-responsive programs. Report prepared for The World Bank. Washington, DC; CRA No. D06090.
12. Bloustein E. School of planning and public policy, assessment of customer response to real time pricing. Rutgers, The State University of New Jersey; 2005 Jun 30.
13. Albadi MH, EI-Saadany EF. A summary of demand response in electricity markets. 2008 Apr 8.
14. US Department of Energy. Benefits of demand response in electricity markets and recommendations for achieving them. Report to the United States Congress; 2006 Feb.
15. Granzer W, Fraus F, Kastner W. Security in building automation systems. IEEE Trans Ind Electron. 2010 Nov; 57(11):3622–30.
16. Treytl A, Palensky P, Sauter T. Security considerations for energy automation networks. 6th IFAC International Conference Fieldbus Systems and their Applications (FeT 2005); Puebla, Mexico: 2005. No. 9076019096.
17. Moslehi K, Kumar R. Smart grid: a reliability perspective. Proceedings IEEE PES Conference Innovative Smart Grid Technologies; 2010.
18. Wellinghof J, Morenoff DL. Recognizing the importance of demand response: the second half of the wholesale electric market equation. Energ Law J. 2007; 28(2):389–419.
19. Barbose G, Goldman C, Neenan B. The role of demand response in default service pricing, report no. LBNL-59737. Berkeley, CA: Lawrence Berkeley National Laboratory; 2006.
20. Ngar-yin Mah D, Wu Y-Y, Chi-man Ip J, Hills PR. The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan. 2013 Jul.
21. International Energy Agency. The power to choose-demand response in liberalized electricity markets. Paris: OECD; 2003.
22. Tan Y, Kirschen D. Classification of control for demand-side participation. University of Manchester; 2007 March 29.
23. Lijesen MG. The real-time price elasticity of electricity. Energy Econ. 2007; 29:249–58.
24. Implementation of demand response program in Tamil Nadu. Shakti Sustainable Energy Foundation; 2014.
25. Available from: http://www.iea.org/publications/freepublications/publication/SmartGrids_Foldout_A3.pdf
26. Rahimi F, Ipakchi A. Demand response as a market resource under the smart grid paradigm. IEEE Trans on Smart Grid. 2010; 1(1):82–8.
27. Community research: European Technology Platform SmartGrids. Brussels: European Commission; 2010.
28. Farhangi H. The path of the smart grid. Power and Energy Magazine. 2010; 8(1):18–28.
29. Albadi MH, El-Saadany EF. A summary of demand response in electricity markets. Elec Power Syst Res. 2008; 78(11):1989–96.
30. Koutsopoulos I, Tassiulas L. Challenges in demand load control for the smart grid. Network. 2011; 25(5):16–21.