PARIPEX - INDIAN JOURNAL OF RESEARCH | Volume - 11 | Issue - 12 | December - 2022 | PRINT ISSN No. 2250 - 1991 | DOI : 10.36106/paripex

ORIGINAL RESEARCH PAPER

Energy

DEMAND SIDE MANAGEMENT STRATEGIES IN RESIDENTIAL LOAD WITH RENEWABLE ENERGY INTEGRATION: A BRIEF OVERVIEW

KEY WORDS: Demand side management; demand response; residential sector

Ward Ul Hijaz Paul*	Research Scholar, Jamia Millia Islamia, New Delhi *Corresponding Author
Anwar Shahzad Siddiqui	Professor, Jamia Millia Islamia
Sheeraz Kirmani	Associate Professor, Aligrah Muslim University, Aligrah

ABSTRACT

In conventional power grids, the supply and demand sides of electricity are largely separate, and the operations side is the only one who has access to grid monitoring data. Power networks need to be able to meet electrical demand on a regular basis in order to remain stable, which necessitates planning and communication from both parties. Electric power generation and supply must advance if grid stability, security, and effectiveness are to be improved. The smart grid concept makes the next-generation electricity network smarter and more intelligent by enabling information flow in both ways and active engagement from all connected parties. Modern technologies must be created in order to address issues with economic growth, energy security, and energy sustainability. Demand-side management (DSM) gives consumers and utilities the power to make informed choices about how they use energy, changing the load profiles and lowering peak demands in the smarter distribution network. DSM has been employed recently as a method to maintain a balance between increasing energy needs and consumption.

INTRODUCTION

DSM is one of the strategies used by utilities to directly or indirectly control demand side resources, such as electric loads, in order to accomplish specific goals. By introducing strategies like DSM, certain significant concerns like the gap in the supply and demand in upcoming power grids could be resolved. According to the estimates cited in [1], the integration of renewable energy sources in the modern grid has become anticipatory in order to compensate growing demands of home and business usage. In order to offer a consistent and reasonably priced supply of electricity in the upcoming years [2] without adding many new generation plants, it is therefore necessary to manage household demand side resources in an efficient manner. The managing of household resources is crucial because residential users account for a large portion of peak transmission line loading [3]. Most utilities keep a reserve capacity of twenty percent for satisfying these peak demands, which only happens 5% of the times [4] & [5]. Installation of conventional thermal generation plant is a way to deal with rising consumption rates and, consequently, rising peak demand, although it is not preferred due to their environmental impact [6] and the exhaustion of fossil fuel [7]. The installation of additional power plants to fulfil the rising demand is not the best course of action because the additional demand will only last for a short period of time, during which time energy and resources will be wasted [8]. Thus, the installation of energy storage facilities, the use of renewables, and the deployment of programmes like DSM are some of the other alternatives suggested in the paper [9] & [10] for handling this rising demand and peak load. In contrast, due to their intermittency, the output power from renewables can't be consistently assured if they are integrated into the grid [12]. DSM is the process of managing the electric load existing on customer side so that their energy utilization pattern matches with the power generated in order to satisfy the load demand while taking into account all the issues stemming of renewables, thermal plant units, and energy storage facilities [13], [14] & [15]. In brief, methods like demand side management would force electric load to follow the pattern of energy generation that is available, lowering the capital expenditure for building infrastructure.

This paper is discussed as follows: The architecture of DSM along with its schematics is given section 2. Section 2 also gives an account of various DSM methods, its constituent components, motivations behind and some of its benefits. Section 3 discusses some of the issues of DSM and its solutions. Some energy efficient practices are given in the section 4 followed by conclusion in section 5.

ARCHITECTURE OF DEMAND SIDE MANAGEMENT

The DSM architecture's basic design consists of the following basic parts: i). Local distribution generators that can inject power locally or to the grid in both modes of operation. ii). Sensors to track various types of data and, as a result, control the appliances. iii). Smart automatic gadgets that can be monitored and operated remotely. iv). Energy storage schemes to increase power consumption flexibility while maintaining high reliability and security. v). Distribution, operation, and consumer domains of the smart grid are examples of smart grid domains. vi). Power management unit governed the various sectors of the system. The schematics of the architecture of demand side management is given in Figure 1.

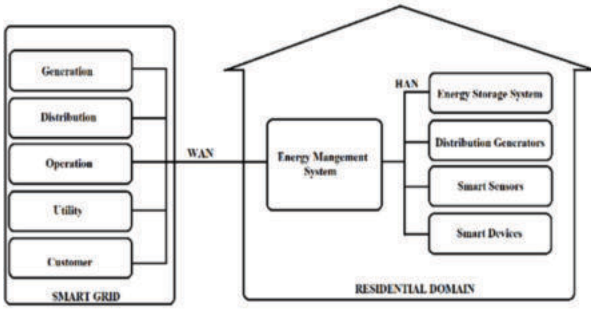

Figure 1: Architecture of Demand Side Management

Demand Side Management Methods

There are many different DSM procedures, and common DSM methods are shown in Figure 2 and Figure 3 in a hierarchy. These methods can be summed up as follows: i). Top clipping is a technique for reducing load demand at peak periods. ii). Valley filling is a method that improves the load factor of the system. iii). Load Shifting is the process of dropping load demand iv). The technique of reducing utility usage throughout the day is known as conservation. v). The process of increasing or growing the load during times of excess electricity is known as load building. vi). The practice of allowing consumers to use energy according to their needs is known as flexible load shaping. Demand side management must choose one of these methods to improve power management in order to achieve advanced efficiency, based on the purpose and possibility of usage.

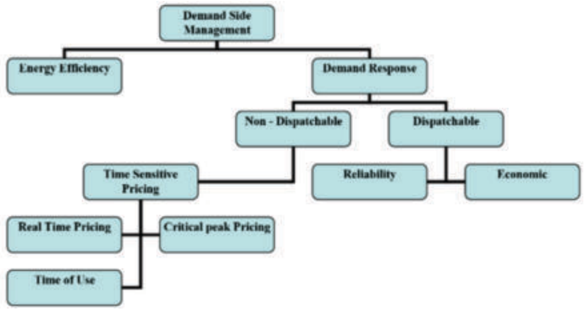

Figure 2: Different Demand Side Management Methods Hierarchy

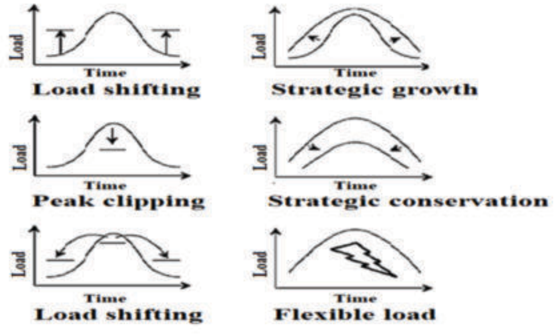

Figure 3: Demand Side Management Techniques

Motivation Behind The Increased Interest In DSM

Reliability, security, stability, and profit maximisation needs have provoked such attention in different sections of demand side management study. The following is a description of the reasons for the increasing attention in DSM approaches application:

- To raise consumers understanding of the advantages of DSM in order to stimulate adoption or a shift in power usage patterns.
- To build an interactive demand management marketplace in which each customer takes an active role in obtaining a high energy efficiency overall.
- Without adding additional resources to the current system, control overall requirements by balancing energy resources and availability.
- To allow for appropriate load balancing by reducing or shifting energy usage from peak times to less congested times.
- By incorporating demand reduction-bidding incentives DR and DSM programmes, consumers will feel less annoyance.
- Due to load shifting, enhance load factor.
- Building a system with control and economic mechanisms to achieve a dynamic balance of demand and supply across the whole electric network.
- To adapt to the modifications brought on by unpredictably high demand and a lack of knowledge about the condition of electric gadgets.
- Making the grid dependable and efficient, reduce the peak to average ratio after sinking demand during peak consumption hours.
- To attain the lowest possible price of power from an economic standpoint, the highest possible usage of energy from localized renewables from an ecological standpoint, and to prevent power quality issues.

Benefits of Demand Side Management

The notion of DSM comes into the equation to resolve such problems pertaining to the existing scenario at the customer side and to facilitate even more efficient and flexible functioning of specific appliances and devices on an individual level through smart control techniques. DSM can bring a number of advantages, including:

- It enables energy usage to be reduced at a lower cost while also assisting in the achievement of beneficial environmental objectives.
- It saves money, makes blackout avoidance easier, and instils a sense of accountability in users.
- It ensures a consistent and long-term source of energy.
- DR minimises load patterns by dynamically managing loads.
- DSM can help minimise voltage difficulties on the poor distribution feeders by offering control grid support.
- If DSM ideas are successfully implemented, they can benefit both consumers and the utility economically.

Constituent Components Of A Dsm System

The adoption of DSM concepts involves several elements of the power grid and communications network architecture, allowing for faster and effective functioning and also adaptability in their operations. The following elements and drivers are commonly found in them:

- In a current smart grid setting, growth of information & communication technologies makes it simple to implement domestic demand side management.
- Inside the household load demand sector, electrical energy storage techniques increase energy dispatching and control.
- Widespread use of IoT for improved energy regulation.
- An occasion-based architecture incorporates home area network, virtualized smart metering, advanced metering infrastructure, metre data management system for enhanced monitoring.
- By close surveillance and planning of the load embedded system applications and web of things are connected to control residential load usage.
- For the evaluation and implementation of best solution, effective advanced optimization algorithms are used.
- Bluetooth, Wi-Fi, and Konnex, ZigBee are grid-focused network protocol for implementing high-reliability, high-speed and secure communication capabilities.
- Weather prediction can keep track of changes in the climate, reducing the likelihood of the energy network failing as a consequence of it.

ISSUES, CHALLENGES, AND SOLUTIONS

The path to RDSM adoption is paved with numerous obstacles and problems that must be overcome in order to ensure a smooth execution and efficient coordination between the DSM program's involved parties. The following are some of the concerns and challenges that are addressed:

- Adopting the most efficient load scheduling approaches.
- Adaptive multi-consumption level prices are implemented smoothly.
- Household loads frequently significantly contribute to daily and seasonal peak usage, causing the power system to be under sized to meet peak power demand.
- To accomplish Direct Load Control, interruptible tariff rates, demand-bidding programmes, and emergency programmes, centralised controller for the control actions and decisions must be implemented.
- To address the contradictory objectives of improving customer satisfaction and reduced usage, reducing energy usage for customers while improving profitability for utilities with accessible power sources, and so on while formulating energy regulations.
- Customer feedback to a price signal, which modifies consumer preferences, varies unexpectedly depending on their character of widespread adoption, indifference to minor dynamic pricing, and pricing scheme understanding.
- Since the client needs the money on energy, as well as the company seeks to maximise profit from the energy available, the objective is the balancing electricity usage and the money saved.

- To tackle the effects of certain customers on some other consumers' price rates.
- Strict network privacy will be used to safeguard the critical info of participating consumers.
- Absence of proper coordination to solve the multi-vendor issue, improve the system, or expand the system.
- Solar and wind energy can have an impact on and make it hard for the grid to stay stable.
- To cut down on peak usage and total energy costs while still providing enough ease and satisfaction for the people who live in the homes.
- To give customers more authority over how much energy they use since each consumer has unique attributes, criteria, and goals that work on their own.
- In an unforeseen situation, the job of making sure there is enough energy and not enough of it at the same time.
- A disparity among demand and supply can take place at different points on a demand curve that isn't always the same length.
- When you use DR, you have to deal with four big problems, like how to make it big, how to distribute control, and how to aggregate data.
- The people who use electricity may not recognise or be able to help with the configuration of the DR.
- The lack of technology, the lack of smart metres that can communicate with each other and regulate equipment from afar, a wide range of consumer habits, and the monopoly of the investor-owned utility are all holding back the wide use of DR.
- Traditional power generations, which is linked to global warming and climate change, makes it crucial to figure out how to get energy.
- Traditional electric grid operations don't have enough central power generation capacities to meet the increasing demands, as well as the increasing prices of conventional supply choices and the need for better power quality and reliability in the digital age.
- It used to be hard to keep important information safe from cyberthreats, but now that's the main problem.

REM and DSM systems have a number of difficulties and problems when they're put into place. The following solutions are feasible to make the integration programmes run more smoothly and efficiently:

- People who use the electricity prediction model can get feedback about their RDSM, and people who pay more for the same thing can get motivation for improved RDSM from the price.
- In huge homes and businesses, the time-of-day tariff could indeed help them utilise energy more effectively.
- The right way to set prices will result to an adaptable power system which will address the needs of domestic consumers and utility companies.
- The notion of transitive electricity came up with a good way to make sure everyone gets the most out of their energy.
- Multi objective and stochastic optimization techniques that uses a model predictive control system to find the best way to schedule numerous home devices.
- The concept of a transitive electricity market being able to operate inside a building is a perfect option for new and more advanced home energy management system. This would keep the grid running efficiently and reliably.
- As a way to keep the energy market profitable, an incentive-based strategy can make old-fashioned customers into new-age prosumers by altering the way they use energy.
- Numerous intelligent methods can be used to take into account individual housing customer costs and priorities, individual consumer schedule optimization, and the positive effects of DSM.
- The governments have made a lot of changes to how electricity users and providers can participate in the electricity market and send signals through the market.
- In this case, solar photovoltaics (SPV) and energy storage systems (ESS) work together to store energy for home automation systems to use during times when energy prices are high.
- Comprehensive service oriented architectural style is required to guarantee that all of the aforementioned services can be integrated flexibly and dynamically using best practises. There are two ways in which DSM members can work together: they can act as cooperating agencies or as simulated electricity generation models to use either or generate power in a coordinated manner. This is a way of emulating the performance of a single big source that is part of the grid.
- DR principles in housing utility companies work much better when there are procedures for measuring and verifying as well as an automated process that can be used.

ENERGY EFFICIENT PRACTICES

Improved energy efficiency is a critical aspect for dealing with the concerns and challenges that develop in the energy industry, and it necessitates a significant improvement in recent trends. A reduction in the energy utilized for a particular plan without altering the user service is characterized as energy efficiency improvement. In this direction, the following points can be drawn.

i). Overall performance in reducing demand is the ratio of total intake to GDP.

ii). Rules are designed in response to local circumstances, taking into account the complexities of the political, economic, and cultural surroundings. As a result, this aspect has to be investigated further in order to improve DSM implementation.

iii). The precise valuation of a policy's achievement or letdown is difficult to determine in various circumstances due to a lack of adequate data gathering where infrastructure is lacking.

The residential customer base is an important part of a demand-side power method that aims to achieve prize-effective solution. The aforesaid impediments and challenges highlighted the need to emphasize the importance of stronger DSM implementation based on demand response, particularly in the residential sector.

DSM Policies In Housing Area

The following DSM rules are stated in a categorical manner.
Framework policy: Establishes organizations responsible for enacting necessary legislation and programs that follow realistic principles and methodologies.

Capacity building: persuade people to modify their intake habits by offering information.

Incentive-based and financial measures: To calculate optimal power prices while addressing variables, financial and incentive-based strategies are used.

Regulatory and control events: It creates laws for accurate size and equipment, as well as conducting audits and energy management.

Market-based Tools: The rule is designed to provide consumers with more options by fostering a competitive market by offering a variety of options and tariffs.

Voluntary agreements: Using strong mutual understanding and agreements, this approach aims to encourage customers to modify their performance.

Obstacles To Power Efficiency

To successfully use the DSM method in a smart grid setting, many challenges must be overcome with a better strategy and planning. A few of the major challenges can be stated as follows:

- Lack of customer understanding or inertia towards energy conservation.
- Due to a lack of competition, a traditional and inefficient tariff structure may emerge.
- There is monopoly in the energy market as a result of privatization or a lack of collaboration between the state and private utilities.
- A lack of incentives for customers to adjust their demand patterns and the usage of inefficient appliances.
- There is a significant energy supply and demand discrepancy.
- The addition of DSM to a power system increases the complexity of its operation.
- Inadequate regulatory (restructuring) and policy support.
- The initial cost of technology and its financing.
- Infrastructural shortage

The quality of service could be improved with reduced load shedding and improved reliability after the application of demand response programs because of reduction of operational stresses. The application of demand response programs could enable the transmission system operator with advantages like improved reliability of transmission system with less outages. Apart from this, its application into the distribution system operator, it helps in reducing the issues linked to the voltage constrained power transfer, improved power supply quality, less congested substations and simplified load shedding. The peaks on the load curve could be shifted and thus the requirement for the additional power plant could be avoided. The tariff structure could also be reduced by the implementation of demand response programs through the energy forecasting technique.

CONCLUSION

An outline of a few DSM strategies that can be used with residential customers is provided in this article. From the analysis that has been given, it is clear that increasing comfort levels will not lead to a decrease in energy bills, and that higher cost savings will always necessitate some degree of comfort level sacrifices. Further, it became clear during the evaluation process that telecommunication infrastructure development and deployment are required to increase the effectiveness and efficiency of DSM programs. A more thorough and in-depth analysis of the DSM procedures utilized for commercial and industrial purposes may be the future goal of this study.

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