Demand Side Management in Electrical Network: A Review for Theoretical Framework

Antriksh Panwar[1, a)], Dibya Bharti[2, b)] and Sukhwinder Dhillon[3, c)]

[1, 2, 3] *Department of Electrical & Electronics Engineering, Ajay Kumar Garg Engineering College, Ghaziabad, Uttar Pradesh, India*

[a)] *Corresponding author: antriksh.p1@gmail.com*

Abstract. This paper presents a detailed literature review of Demand Side Management (DSM) methods. The existing methods are analyzed on the basis of proposed techniques' merits and demerits. A summary for the application areas of each method of literature is presented in this paper. Many existing DSM methods are proposed in context of residential load management which is a part of smart home automation. Various DSM methods are proposed for optimal scheduling and energy management in electrical network. The objectives of DSM, performance parameters and challenges faced in DSM are discussed. This paper presents a study of existing DSM techniques from theoretical aspects.

Keywords: Demand Side Management, Smart Grid, Load analysis, Energy efficiency, Demand Response

INTRODUCTION

Demand Side Management (DSM) are the methods that influence consumers' choice of electricity usage pattern. [1] is a review-based study that discusses opportunities for implementation of Demand Side Management (DSM) programs by: structural changes, integration of grid and financing capabilities. In [2], Glow-worm Swarm Optimization (GSO) and Support Vector Machine (SVM) aims to minimize electricity tariff and peak hour demand for a battery-based energy storage system and a solar photovoltaic (PV) generation storage system. In [3], DSM strategy accounts for environmental impact and customer satisfaction. The objective to minimize operation cost, emission pollution, load curtailment cost and power output deviation cost is successfully achieved. In [4], an energy management program implemented by a DSM algorithm, aims to increase system stability by damping out oscillations using electrical springs, improve power quality and provide power optimization to the system, for a grid-tied photovoltaic system. In [5], a proposed price-based DSM scheme minimizes consumer cost for a residential scenario. [5] presents extensive analysis of rooftop PV system using pilot survey, with an aim to study the mindset, motivation and fears of consumers and prosumers, the whose distinction has been clearly analyzed. [6] is a review work of an extensive study of Artificial Intelligence (AI) and Machine Learning (ML) for use in Demand Response (DR) techniques. The application of Artificial Neural Network (ANN) and Reinforcement Learning (RL) has been detailed along with the best suited applications. Various types of AI methods have been studied including Game Theory, Automated Negotiations, Unsupervised Learning, Supervised Learning, Reinforcement Learning, deep ANN, hidden layer ANN, Swarm AI, Evolutionary AI, etc. The work of [7] presents optimization algorithm to reduce consumer cost and greenhouse gas (GHG) emissions for low-voltage residential load. The aim is to apply load shifting to non-critical loads. In [8], by the use of game theory approach, an algorithm is developed for a load billing scheme that makes the connected consumers to compete for minimum load bill. In [9], game theory with objective to optimize the cardinality to minimize the peak to average ratio. As in [8], [9] also utilizes the existence of Nash equilibrium and Newton method. [10] uses game theory approach with the use of blockchain technology for distributed energy management, making the system robust and efficient.

To implement game theory, a special network evolutionary game could be developed, as in [11], with custom algorithms. In [11], For some communities working as controllers, intermittent control is designed, in an open loop manner. Another networked evolutionary game, implemented in [13], uses the theory of semi-tensor product. In a networked smart grid, where all users and utilities are constantly communicating, a closed loop feedback-based system keeps system stable and oscillation-free. In [12], an initialization-free based algorithm is used to minimize unpredictability and abrupt changes in the smart grid system. In [14], a Day Ahead (DA) load shifting approach is used to modify energy demand profile. This approach uses Symbiotic Organism Search (SOS) algorithm that is tested on various consumers- residential, commercial and industrial. [15] demonstrates an approach based on stochastic linear programming game with focus on user interaction and energy trading decision. In [16], an automation-based particle hopping algorithm is used for load shifting. The concepts of load particle velocity and particle density help to establish the model in an energy storage system and then to test it by simulation over multiple scenarios. [17] presents Policy Driven Demand Response (PDDR) scheme based on Deviation maximization algorithm. The analysis and simulation are performed over energy usage data of Nanjing City, China. The system aims to integrate multiple methods into one with the objective of maximizing efficiency and minimizing cost. In [18], demand response is tested for two electricity market, which are, day-ahead market and real-time markets. The system performs simulation in form of Markov Decision Process (MDP) problem solved by row generation algorithm. In [19], five schemes have been presented that aim to minimize- cost function and total energy function of the system. An optimization algorithm is proposed through which each subscriber's DSM module is used to schedule its schedulable load. The consideration for rebound peak in the system makes it stable and Applicable to centralized as well as distributed demands.

In [20], evaluation of generating capacity is performed based on Reliability Test System of IEEE-RTS. Based on the inferences, the analysis and application of load shifting algorithm is performed for multiple sectors: agriculture, large user, residential, industrial, commercial and finally for a combined total system load. [21], demonstrates a DSM system that aims to minimize demand and cost, and tests it over residential, commercial and industrial loads by simulation. [22] has uses a thermal energy management system (TEMS) for peak load shifting of electricity demand, especially for ground source heat pump (GSHP). In [23], a two-level optimization algorithm is proposed that works over: edge cloud and core cloud, to reduce cost and improve performance respectively for an autonomous DSM system. In [24], the reduction in peak to average ratio and in cost have been achieved by genetic algorithm. Current trends in smart grid and DSM have been analyzed. [25] proposes a system in which peak shaving helps optimize demand response while Fixed Series Compensation (FSC) ensures efficient utilization of transmission capacity. The strategies of- demand shifting, curtailing the peak, and onsite generation are used to minimize cost function. In [26], particle swarm optimization algorithm (PSO) and grasshopper optimization algorithm (GOA) are used to reduce peak hour demand and consumer cost. In [27], the proposed day ahead voltage profile improvement is works by shifting flexible loads using demand and generation forecast information. [28] proposed a demand response strategy that uses Reinforcement Learning (RL) and Fuzzy Reasoning (FR) for residential consumers. The RL is used for learning by feedback and FR for reward functions. In [29], the proposed DSM scheme based on hybrid bacterial foraging and particle swarm optimization (HBFPSO) algorithm has been used to minimize electricity cost, Peak to Average Ratio, user discomfort, and carbon emissions due to electricity generation. [30] has proposed a DSM based smart energy management system (SEMS) that works with Internet of Things (IoT) to control tariffs and encourage users for participation. In [31], a peak scheduling problem is solved by a proposed algorithm which is a combination of ant colony optimization (ACO) and teaching learning-based optimization (TLBO). In [32], a flexible scheduling framework has been proposed using which a study of social and technical factors that influence smart grid optimization has been done. In [33], a load scheduling algorithm has been proposed for residential load to maximize efficiency of power consumption. This objective is achieved as a combination of reduction in electricity consumption cost and cost due to user discomfort. In [34], pricing and consumer preferences are accounted for using a proposed forecasted day-ahead DR technique based on home energy management controller (HEMC) and day-ahead grey wolf modified enhanced differential evolution algorithm (DA-GmEDE) for residential buildings. [35] provides and extensive study of review on Demand Response Management (DRM) based programs, strategies and models for application of 5G technology in Smart Grids. In [36], a hybrid heuristic-based algorithm has been proposed for DR program to implement DSM strategy in residential sector, especially in smart homes. The objective has been to minimize electricity bill costs, carbon emissions, PAR, delay time, and maximize user comfort. In [37], a contract-theoretic DRM strategy has been proposed for residential consumers. Labor economics principles have been used to maximize market profit and consumer profit. [38] has proposed a DSM program based on blockchain strategy in which integration of smart meters, IoT devices and use of renewable sources of energy generation takes place within a microgrid.

In [39], the proposed strategy of AI-empowered Recommender System for Renewable Energy Harvesting (AI-RSREH) works in a Solar PhotoVoltaic (SPV) system and a wind energy system that could be used in residential houses. In [40], a Demand Response algorithm is used to integrate renewable sources of energy into smart grid system. The proposed strategy aims to minimize stability by converging system solution to optimal values at a much faster rate than conventional methods. In [41], an unbalanced distributed smart grid was addressed using a Pareto efficient model. The model worked using real time pricing based on user incentives. Energy consumption scheduling (ECS) based on a Stackelberg game algorithm helped by maximizing profit to the utility and minimizing cost to users. In [42], a tariff-based Demand Response strategy has been proposed that could integrate Renewable Energy Sources (RES) with utility, battery storage systems and Diesel energy systems especially in rural regions. [43] has proposed a heuristic-based programmable energy management controller (HPEMC) for energy storage systems when connected with Renewable Energy Sources (RES) in residential buildings. [44] has proposed an internal market-based cloud computing strategy minimize revenue for virtual power plants (VPPs) and for users. In [45], peak load shifting and load scheduling have been addressed using real time pricing scheme based on heuristic algorithms for a smart building infrastructure for residential loads. In [46], the proposed Demand Response model based on deep learning works by load scheduling in residential sector. In [47], the proposed demand response strategy based on genetic algorithm aims to minimize electricity cost, operating power of equipment, and dynamic pricing for household management. In [48], load billing and load monitoring have been addressed to detect fraudulent customers. In [49], power management is addressed in a Virtual Power Plant (VPP) using artificial neural-network and federated learning strategy for Electric Vehicle (EV) platforms. In [50], the proposed fast and accurate hybrid electrical energy forecasting (FA-HELF) framework is used for forecasting of energy demand in a smart grid. [51] aims to fulfil multiple objectives of improving electricity bill, waiting time of appliances and peak to average ratio using nature inspired techniques of: binary multi-objective bird swarm optimization, and a hybrid of bird swarm and cuckoo search algorithms. In [52], a Time of Use (ToU) based energy pricing mechanism has been proposed to reduce cost of generation and cost to the consumers for low energy consumers. In [53], a smart controller for demand side management in smart grid has been proposed that optimizes reactive power of the grid. An elephant herd optimization–firefly (EHO–FF) evolutionary algorithm is used to provide demanded electrical power while minimizing the flow of power by increasing the number of distributed generation (DGs) units at the best suited locations. In [54], a reinforcement learning framework and a two-stage Demand Response Management (DRM) optimization strategy are used to establish a power company selection and the DRM processes in a competitive market scenario. In [55], demand response management has been addressed by the use of a proposed competitive algorithm that takes into account user choices and flexibility of operation. [56] presents a Smart Residential Electricity Distribution System (SREDS) that uses Flat Rate tariff, Time of Use tariff or Real Time Pricing to implement DR strategy in Smart Residences (SR). In [57], the proposed hybrid GA–PSO algorithm aims to reduce PAR load demand ratio and save electricity bill of day ahead market. In [58], the proposed hybrid power system (HPS) automates and integrates the use of multiple renewable energy sources: PV system, solid oxide fuel cell (SOFC) with Ni-MH battery with a variable load. [59] has proposed use of fuzzy logic controllers for the coordination of charging and discharging of Electric Vehicles (EVs) in smart grid. In [60], the proposed energy management system aims to reduce electricity cost and increase user satisfaction in residential homes. The use of Power Limit Management (PLM) and Smart Electrical Task Scheduling (SETS) algorithms automatically switches the loads on and off depending on available electricity by load scheduling method. In [61], the pricing schemes of Critical-Peak-Price and Real-Time-Price have been used to reduce electricity cost, energy consumption and peak demand while improving user comfort. [62] has proposed a meta-heuristic based home energy management (HEM) that aims to optimize energy consumption, electricity cost and PAR for residential complex of multiple homes. In [63], the proposed Fuzzy Long Sort Term Memory based Crow Search Optimization Algorithm (FLSTM–CSOA) is used to provide best communication technology in terms of spectrum available with minimum delay. In [64], a calibration-based energy distribution has been proposed that uses Horizontal Block Shifting and Vertical Column by Column Shifting to balance load on a daily basis in a tree network. These methods and techniques applicable to any of the system, but it is not so. Thus, some system may support renewable energy system and others not. Some are suitable for cost analysis and some for power system analysis. This requires thorough experimentation and analysis. Therefore, this paper presents the systematic study of the techniques, schemes and strategies of Demand Side Management in electrical network.

REVIEW SUMMARY

The various works of literature involve different methods and have different merits and demerits. This has been summarized in Table 1 for each corresponding literature.

TABLE 1. Review summary

S.No.	Ref. No.	Method	Merits	Demerits
1	[1]	Review of Demand Response Management opportunities	It points solutions to emerging challenges	Does not discuss cost of implementation of DR strategies
2	[2]	Glow-worm Swarm Optimization (GSO) and Support Vector Machine (SVM)	High efficiency and cost-effectiveness	Based on assumption that all users have battery storage system
3	[3]	General Algebraic Modeling System (GAMS) optimization	Customer choices accounted for	Costly implementation
4	[4]	Mamdani fuzzy decision making algorithm	High stability, potential for scalability	Limited application
5	[5]	Price-based DSM scheme	High scalability	Statistical analysis lacks simulation results
6	[6]	Review of Artificial Intelligence (AI) and Machine Learning (ML)	Consumer motivation considered	Execution time and cost analysis not accounted for
7	[7]	Multiobjective optimization algorithm, including customers' comfort among the priorities	Customer satisfaction and environmental considered	Limited range of testing done
8	[8]	Game theory approach	Reduces consumer bill	High computation time and cost
9	[9]	Game theory approach	Fast and efficient response	Renewable energy sources not considered
10	[10]	Game theory approach	Low-cost implementation	Based on assumption that all customers and willing to participate and share their data
11	[11]	Network evolutionary game	High scalability	Renewable energy sources not utilized
12	[12]	Initialization-free based algorithm	Economic use of active power	Renewable energy not considered
13	[13]	Network evolutionary game	Model uncertainties and fake users are detected	Multiple energy sectors not studied
14	[14]	Symbiotic Organism Search (SOS) algorithm	High efficiency	No distinction made between schedulable load and non-schedulable
15	[15]	Stochastic linear programming game	Robust system	Power consumption not studied
16	[16]	Automation-based particle hopping algorithm	Efficient and robust system	Not considering unpredictability
17	[17]	Deviation maximization algorithm	Security and stability of system considered	Instantaneous changes not considered
18	[18]	Markov decision process (MDP)	Increase in profit	Imbalances are not accounted for
19	[19]	Row-generation-based solution algorithm	Stabilizes the system	Based on assumption of only single energy source
20	[20]	Load shifting algorithm	High efficiency	Unpredictability not accounted for

21	[21]	Price modification algorithm	Decrease in cost	Oscillation damping is not performed
22	[22]	Thermal energy management system (TEMS)	Considers user comfort	No distinction made between schedulable load and non-schedulable
23	[23]	Two-level cloud based optimization algorithm	High scalability	Requires costly high communication infrastructure
24	[24]	Genetic algorithm	High efficiency	No distinction made between schedulable load and non-schedulable
25	[25]	Generation and transmission expansion planning (G&TEP)	Fast response and robust nature	Applicable only for large grids
26	[26]	Particle swarm optimization algorithm (PSO) and grasshopper optimization algorithm (GOA)	High efficiency and scalability	High computation time and cost
27	[27]	Voltage controlled strategy	Voltage level improvement	Unpredictability is not accounted for
28	[28]	Reinforcement Learning (RL) and Fuzzy Reasoning (FR)	Low cost and high efficiency	Based on the assumption that all users have battery storage system
29	[29]	Hybrid bacterial foraging and particle swarm optimization (HBFPSO) algorithm	Accounts for environmental consideration and user comfort	No consideration to renewable energy and energy storage systems
30	[30]	Smart energy management system (SEMS), iot devices	Detailed cost analysis	Narrow scope for implementation
31	[31]	Ant colony optimization (ACO) and teaching learning-based optimization (TLBO)	Accounts for environmental consideration and user comfort	Multiple energy sectors not considered. Cost analysis not performed
32	[32]	Socio-technical Smart Grid optimization	High efficiency	Renewable energy and tariff system not considered
33	[33]	Residential power scheduling algorithm based on cost efficiency	User satisfaction considered	Not included battery storage systems and distributed generation
34	[34]	Day-ahead grey wolf modified enhanced differential evolution algorithm (DA-gMEDE)	Stability in system	Commercial and industrial sectors not analyzed
35	[35]	Review on Demand Response Management	Consideration provided to environmental factors and user satisfaction	Does not account for integration of Artificial Intelligence
36	[36]	Hybrid heuristic-based algorithm	User comfort and renewable energy sources considered	Application limited to small scale level
37	[37]	Contract-theoretic Demand Response Management (DRM) strategy	High potential of scalability	Only statistical evaluation and no simulation
38	[38]	Blockchain strategy, IoT devices	High efficiency and transparency in system	Load sharing not considered
39	[39]	AI-empowered Recommender System for Renewable Energy Harvesting (AI-RSREH)	High efficiency	Renewable energy supply not accounted for

40	[40]	Demand Response algorithm	Fast response	Application for practical appliances not considered
41	[41]	Stackelberg game algorithm	Increase in profit	User choice not considered
42	[42]	Particle swarm optimization (PSO), bat algorithm (BA), and social mimic optimization (SMO)	High efficiency	Testing of industrial and commercial sectors not conducted
43	[43]	Heuristic-based programmable energy management controller (HPEMC)	High efficiency and robustness	Renewable sources and multiple energy sectors not analyzed
44	[44]	Cloud computing strategy	High savings and reduction in cost	Data privacy and safety not considered
45	[45]	Heuristic algorithms	Environmental consideration with high efficiency	Commercial and industrial not analyzed
46	[46]	Robust Adversarial Reinforcement learning	Highly efficient and learnable model	Various energy sectors not considered
47	[47]	Genetic algorithm	Reduces power surge and users receive choice of comfort level	Electricity tariff not studied
48	[48]	Ensemble-based deep-learning	Trainable system	Multiple sectors not considered
49	[49]	Artificial neural-network and federated learning	Increases safe and accountable communication	Limited communication technology
50	[50]	Fast and accurate hybrid electrical energy forecasting (FA-HELF), modified enhanced differential evolution (mEDE)	High efficiency	Only short duration analysis performed
51	[51]	Binary multi-objective bird swarm optimization, and a hybrid of bird swarm and cuckoo search algorithms	Reduced electricity bill	Scalability of the system has not been discussed
52	[52]	Fair pricing scheme (FPS) and machine learning	Reduce cost to utility and users	Unpredictability and system instability not considered
53	[53]	Elephant herd optimization–firefly (EHO–FF) evolutionary algorithm	Minimizes power loss	Cost analysis not performed
54	[54]	Reinforcement learning framework and two-stage Demand Response Management (DRM) optimization	Satisfaction of customers and companies considered	User choices not accounted for
55	[55]	Competitive algorithm	High efficiency and applicability	Cost analysis and dynamic pricing not performed
56	[56]	Smart residential electricity distribution system (SREDS)	Multiple communication technology considered	Various energy sectors not considered
57	[57]	Genetic Algorithm–particle swarm optimization	Reduction in operational costs	Limited study of energy sectors conducted
58	[58]	Proportional-integral (PI) and adaptive neuro fuzzy inference system (ANFIS)	Efficient control even with unstable supply	Limited energy scenarios considered
59	[59]	Fuzzy logic controllers	Smooth control and robustness	Incentive-based system not utilized

60	[60]	Power Limit Management (PLM) and Smart Electrical Task Scheduling (SETS) algorithms	High user comfort and reduction in electricity cost	Integration of renewable energy sources not considered
61	[61]	Harris-hawks optimization algorithm	Increase in user comfort	Battery storage system not studied
62	[62]	Meta-heuristic based home energy management (HEM)	Cost reduced	Storage systems not integrated into the system
63	[63]	Fuzzy Long Sort Term Memory based Crow Search Optimization Algorithm (FLSTM–CSOA)	Allocates communication spectrum with minimum delay time	Cyber attacks not considered
64	[64]	Horizontal Block Shifting and Vertical Column by Column Shifting	High fairness and calibration	Integration of renewable energy not applied

From Table 1, it is clear that many literatures are based on the method of swarm optimization. In many cases the method of genetic algorithm has been put to use. Many of these techniques are hybrid of multiple methods while others involve a single method. Next to it, algorithms based on Fuzzy Logic have been put to use. Other than that, the use of network evolutionary game has been utilized in many literatures.

OBJECTIVES OF DSM

Implementation of DSM involves the use of following six main objectives.

- **Peak Clipping:** By the use of peak clipping, the flexible loads of consumers are switched off by direct load control during the peak hours of electricity consumption. The limit to which the load could be switched off is decided by prior cooperation between utility and consumers. It is used in [25, 26, 32].
- **Valley Filling:** Valley filling is used for increment in electricity consumption during off-peak hours, as in night hours for industrial load. The surplus generating capacity is better utilized. This process improves load factor and economy of utility. It is used in [28, 29].
- **Load Shifting:** Load Shifting is used to schedule the operation of some electrical appliances to off-peak hours, there were previously supposed to operate during peak hours. It is mainly used in residential load. Load shifting improves the peak to average ratio of system. It is used in [7, 9, 14, 16, 17, 20, 22, 25, 26, 27, 28, 29, 45, 59].
- **Strategic Conservation:** The utility achieves this objective directly or indirectly by motivating the consumers to use as many high efficiency equipments as possible. This may include using photosensitive switches for conventional lighting systems. The technique results in reduction in load and cost. It is also beneficial for the environment.
- **Strategic Load Growth**: This technique is used with support of valley filling. During strategic load growth, the load is increased in a manner that is suitable for the utility to maintain a smooth demand curve. It consequently increases the total load and electricity sale. It is used in [3, 7, 31, 35].
- **Flexible Load Shape:** In this technique, the utility directly changes the load shape. The consumers are encouraged by the use of incentive-based schemes. The loads are interruptible and require devices that could limit or increase power and energy when required. This technique helps utility meet reliability constraints of the system.

The above objectives and their characteristics, elaborated in [65], are shown in Figure 1.

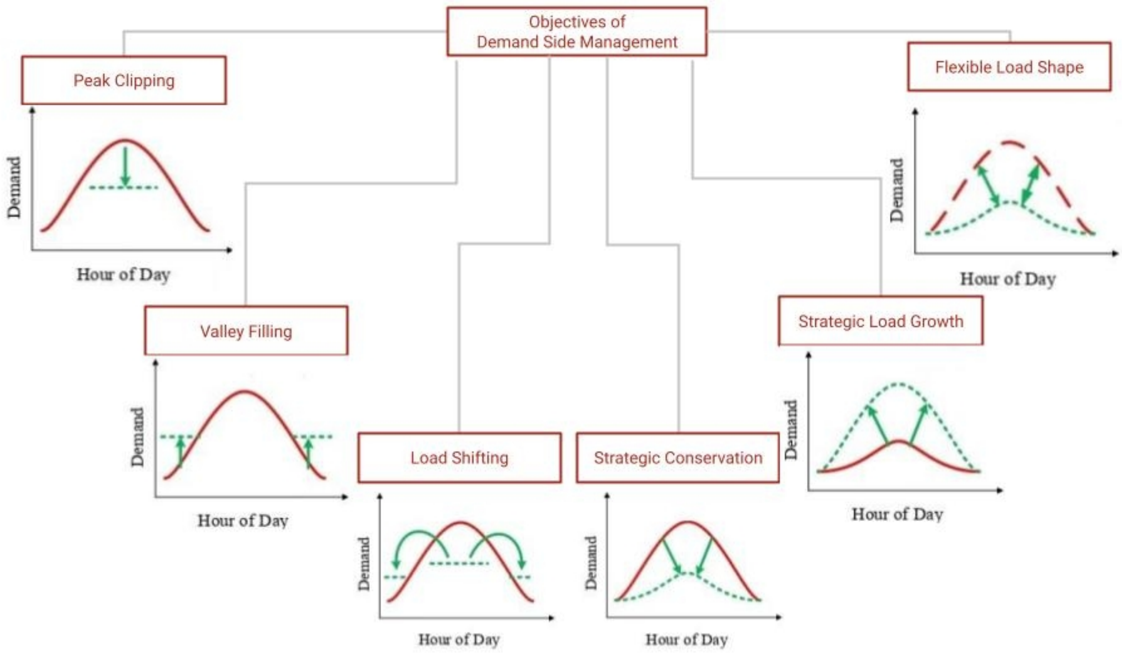

FIGURE 1. Various objectives of DSM

PERFORMANCE PARAMETERS OF DSM TECHNIQUES

The DSM techniques are implemented by aiming to optimize one or more of certain parameters. These parameters also help to analysis the performance of the technique applied. These parameters help to check and compare one technique to another. The knowledge and analysis of these performance parameters help to identify the best suited application of each technique.

- **Peak to average ratio:** It refers to the ratio of power consumption during peak hours to the average power consumption and is measured in decibels (dB). The DSM system aims to minimize it. It is used in [9, 10, 23, 24, 29, 31, 34, 41, 43, 45, 47, 51].
- **Peak demand:** It is the highest magnitude of load demand that occurs in a given time interval. The higher the peak demand, higher is the operating cost of generating stations. DSM strategies aim to minimize the peak demand so as to smoothen the demand curve. It is used in [32, 61].
- **Unpredictability:** Unanticipated changes to the system or unavailability of data at any time could alter the response of DSM system which relies on consumer data. The feature that is preferable in the network is the one that compensates for such changes and still get the algorithms to optimize the required parameters. It is used in [12, 15, 16, 21, 27, 52].
- **Stability and damping of oscillations:** Oscillations, transient disturbances, etc. could keep the system away from producing fast and efficient response. It is desired that the system is self-balancing and stabilizing such that it gives regard to power imbalances in the network. It is used in [13, 19, 58].
- **Security:** When bidirectional communication between utility and consumer takes place, the user data of electricity consumption pattern is at risk of loss of privacy. A good system keeps the data safe and secured. It is used in [17, 49].
- **User comfort:** While minimizing electricity bill in DSM, often the user suffers by lack of choices. By considering user comfort, the system accounts for various actions that lead to better user satisfaction and choices. These may include thermal comfort by heating elements, visual comfort by lighting elements, air quality by air filters, etc. A better system is one that tends to enhance user comfort. It is used in [22, 29, 31, 33, 34, 36, 43, 45, 47, 60, 61].
- **Efficiency:** The main aim of all the DSM systems is to increase the overall efficiency of the network over a large time interval. Efficiency of the network is ensured by cooperation of the users with needs of utility and also by choice of efficient user appliances. It is used in [2, 7, 14, 17, 18, 20, 22, 26, 28, 29, 32, 33, 38, 43, 45, 51, 52, 53, 54, 55, 57, 58, 62, 64].

- **Robustness:** A robust system is one that could be applied to various scenarios of load type and still provide fast and efficient response. A robust system precisely accounts for the stability and reliability aspect of a network. A better DSM method is one that provides highest robust system. It is used in [9, 10, 15, 16, 25, 43, 46, 55, 59].
- **Scalability:** A system has potential of high scalability if it could be applied to a large network of users and supply stations. The higher the number of users and supply stations that could be included while maintaining reliable response, the higher the scalability. This applies to large scale residential and industrial loads. DSM techniques must aim to provide potential of scalability of the system. It is used in [4, 5, 7, 11, 12, 22, 23, 26, 51].
- **Electricity bill to user and cost to utility:** When DSM strategies are implemented, they tend to reduce consumer bill by the use of incentive schemes and methods to encourage users to participate in DSM programs. Also, the operating cost of base generation power plants and peaking load power plants would be minimized when the user demand is correctly timed with a smooth demand curve. The overall cost to the utility as well as to the whole network would reduce. Higher the reduction in electricity bill, better is the system. It is used in [3, 5, 7, 8, 14, 15, 17, 19, 21, 22, 23, 24, 25, 26, 28, 29, 31, 33, 34, 36, 38, 41, 43, 45, 47, 48, 49, 51, 52, 57, 59, 60, 61, 62].
- **Speed of response:** The demand changes in fraction of second, thus it is important to get a timely response from the system. A fast response ensures reliability and increases efficiency of the DSM system. It is used in [25, 40, 42, 49, 50, 58].
- **Number of iterations required:** When an algorithm requires to use regression to reach an optimum result, it is better to choose the system that achieves the same in least number of iterations. The number of iterations save time and computational capacity. It is used in [42].

APPLICATION AREAS OF DSM METHODS IN EXISTING WORK

Various methods are suitable for different scenarios. For example, low voltage load is suitable for residential scenarios and high voltage load for industrial scenarios. According to the choice of the scenario only the method applied and the optimization technique to be utilized is decided. Table 2 presents the application area of DSM methods in existing work.

TABLE 2. Application area of DSM methods in existing work

S. No.	Ref. No.	Classification of loads
1.	[2]	Residential and non-residential cases
2.	[5]	Residential load
3.	[7]	Low-voltage residential load
4.	[8]	Distributed network of competitive consumers
5.	[9]	Residential smart appliances
6.	[10]	Distributed residential energy network
7.	[11]	Class of networked smart grids
8.	[12]	Integration of the renewable generation and the distributed load
9.	[13]	A general networked system
10.	[14]	Residential, commercial and industrial loads
11.	[15]	Distributed energy storage system
12.	[16]	Homogeneous density incompressible loads
13.	[17]	Data of Nanjing City, China
14.	[18]	Agriculture, large user, residential, industrial, commercial and for a combined total system load
15.	[19]	Residential, commercial and industrial loads
16.	[20]	Agriculture, large user, residential, industrial, commercial and finally for a combined total system load

17.	[21]	Residential, commercial, and industrial loads
18.	[22]	Ground source heat pump (GSHP)
19.	[23]	Residential load
20.	[24]	Residential load
21.	[25]	IEEE-RTS 24-bus systems
22.	[26]	Residential, commercial and industrial loads
23.	[28]	Residential consumers
24.	[30]	Residential, commercial and industrial loads
25.	[31]	Heating, ventilation and air conditioning (HVAC) system
26.	[32]	Residential load
27.	[33]	Residential buildings
28.	[35]	Residential load
29.	[36]	Residential load
30.	[37]	Residential load
31.	[38]	Residential house
32.	[39]	Residential house
33.	[41]	A general distributed smart grid
34.	[43]	Residential buildings
35.	[45]	Smart building infrastructure for residential loads
36.	[46]	Residential load
37.	[47]	Residential household
38.	[50]	Home appliances
39.	[51]	Low energy consumers
40.	[53]	Competitive market of smart grid networks
41.	[54]	Competitive market scenario
42.	[55]	Work job where identical machines work for a fixed processing time
43.	[56]	Residential load
44.	[57]	Hybrid load system
45.	[59]	Electric vehicle Systems (EVS)
46.	[60]	Residential homes
47.	[61]	Residential complex of multiple homes
48.	[62]	Residential complex of multiple homes
49.	[64]	Distributed tree network

From the analysis of Table 2, it is clear that most of the load used is based on residential load. In some cases, it is in the form of residential buildings, residential houses, residential household appliances, etc. In many other cases the load is a combination of multiple scenarios. Next to this application, a distributed network is in use. The most considered multiple scenarios include the combination of residential, commercial and industrial load.

CHALLENGES TO THE IMPLEMENTATION OF DSM PROGRAMS

From the analysis of the existing, it is found that the following challenges hinder the implementation of DSM techniques.

- **Lack of efficient machinery and appliances in the network:** Efficient machinery, equipment and appliances cost much higher with respect to their less efficient alternatives. Most consumers tend to invest on short term and purchase low cost and less efficient equipments. This increases the operating cost, maintenance cost and replacement cost of the appliances. The DSM programs encourages the consumers to use the high efficiency equipments. The government policies also tend to favor the idea.

- **Lack of reliability and high quality of power supply:** When an electrical network possesses large number of users and generating stations, then a change in the load or supply at any node of network affects the whole network. In absence of proper oscillation damping devices and compensators, the power quality could deteriorate due to such changes. Some appliances that are highly sensitive to voltage and current changes tend to alter efficiency and reliability of the system.
- **Small scale sector appliances:** The personnel in small scale sector industries lack funds and long term vision to enhance the electricity costs. Many inefficient devices are manufactured and used in small scale including ballasts, pumps, small motors, lighting fixtures, coolers, etc. The lack of check and surveys enables them to not follow norms of Bureau of Indian Standards (BIS).
- **Replacement of inefficient equipments:** For a highly efficient system of electrical network, the equipments used must also be highly efficient. But all appliances tend to deteriorate in terms of efficiency with respect to time. Their replacement is a necessity at regular intervals. But due to lack of planning and energy efficiency engineers, even substandard, inefficient and old equipments tend to be used for duration much greater than the proposed time interval. This decreases overall efficiency of the system and should be checked by making rules for energy efficiency in every system of network.
- **Lack of specialized personnel:** The implementation of DSM techniques requires the assistance of highly skilled personnel who specialize in energy efficiency and DSM strategies. Such staff is either unavailable or the industries tend to avoid hiring them to save expenditure. If any of the step in the procedure to implement DSM: identification, installation and maintenance is interrupted, then the whole system is rendered inefficient.
- **Lack of informed consumers:** The community of consumers who know and realize the significance of DSM implementation is very less. The constraint of information gap about DSM techniques and their implementation leads the consumers to lose the opportunities to improve electrical efficiency in their systems. Education through workshops and government policies help inform the consumers and motivate them to participate in DSM programs.

CONCLUSION

In this paper, the existing DSM methods have been analyzed with their merits, demerits and applications of DSM methods. Several literatures have been proposed with respect to residential loads. Evolutionary algorithms like particle swarm optimization and genetic algorithm are widely used for implementation of DSM. Some authors have applied game theory also for DSM. The literatures reveal that there are multiple techniques of DSM implementation, but still various challenges exist in full scale installation of DSM in a large network. From study presented in this paper, it can be concluded that DSM can be efficiently used for cost optimization in electrical network.

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