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# OPTIMIZATION OF DSM IN MULTI-RESIDENTIAL BUILDINGS INVESTIGATE DSM APPROACHES IN MULTI-RESIDENTIAL SETTINGS, FOCUSING ON COMMUNAL ENERGY MANAGEMENT AND LOAD BALANCING.

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***ABSTRACT***

*Since it has an effect on the overall stability, balance, and effective management of power, the home load sector is an extremely important sector. This is because of the impact it has. This is due to the significance of the residential load sector in the current market. With regard to the administration and control of the power grid, the load dynamics of energy demand from residential users are inherently nonlinear, uncontrolled, and inelastic. This is because of the nature of the load dynamics. Residential users are not effectively regulated, which is the reason for this situation. As a result of the features of the load dynamics, it is challenging to do this work. Although developments in information and communication technology (ICT) and the incorporation of distributed generation (DGs) do help with some of the associated problems, the residential sector still requires additional planning, energy management, and scheduling flexibility in order to achieve greater grid stability and efficiency. This is an area that needs to be addressed. This is due to the fact that the residential sector is the largest consumer of electricity in the United States. When it comes to tackling these challenges, it is of the utmost importance to investigate demand-side management (DSM) in the complex residential sector from a variety of different perspectives. The projection of approach aspects and potential future research directions ought to be incorporated into these points of view. Furthermore, it is necessary to incorporate operational constraints, objectives, and aspects that have an effect on the enhancement of planning, scheduling, and management. We examine modeling, optimization strategies, important objectives, restrictions on system operation, components that dominate overall system performance, and feasible methods to increase the operation of residential DSM systems. This research is being conducted within the scope of this project. This is something that we are able to accomplish by drawing from the relevant body of literature. Due to the fact that the gaps in future research and predicted prospects have been briefly discussed, the necessary knowledge into the method that is currently being utilized to apply DSM has been supplied. Because it will enable them to enhance their energy management and minimize the influence of system uncertainties, fluctuations, and constraints, this comprehensive investigation of residential DSM will be valuable to researchers working in this area. This is because it will let them improve their energy management.*

***Key words:*** *dimand side management, energy management.*

## INTRODUCTION

Households that make use of electricity are responsible for approximately forty percent of the world's total energy production as well as a sizeable amount of the world's greenhouse gas emissions. Residential customers' patterns of energy consumption have been moving from being primarily passive to being more actively involved in the process as we have progressed toward smart and micro-grid environments. This development has occurred as we have advanced toward these environments. Despite this, there has been a recent uptick in the level of seriousness surrounding a project that aims to build ecologically friendly household energy consumers that are compatible with smart grids. On the end user's end, it would appear that residential energy management (REM) that incorporates DSM principles is more feasible with the help of these cutting-edge technologies. It is necessary to have a deeper comprehension of how energy is utilized in residential settings in order to address the ongoing transition of the power system from its traditional structure to a smart infrastructure. In the following, we have provided an overview of the current state of the grid system, including descriptions of its future vision, benefits, challenges, and drawbacks, as well as proposed solutions to these concerns. Intelligent management solutions such as DSM can help reduce some of the pressure that is caused by these challenges, much like many other programs that are designed to increase efficiency and decrease expenses.

In light of the existing load profile of the electrical grid system, the issue of controlling energy consumption has become a significant and pressing concern. A standardized energy management strategy is required at both the consumer and supplier levels, with a focus on load profile management at the consumption side, in order to accommodate the growing number of intelligent and energy-efficient devices that are utilized by various types of customers at both the residential and commercial levels. It is possible to achieve this control by including a number of strategies into the smart grid system and into the load appliances that are designed to reduce losses as much as possible. Through the implementation of this load profile modification, both consumers and companies that produce energy stand to earn a significant amount. Standards for efficiency and consumption management have the potential to address some of the most important environmental and social problems in the world. These problems include our reliance on fossil fuels, pollution, high energy prices, and other concerns related to sustainability. Two-way data exchange has been made possible as a result of the introduction of a large number of communication and internet of things (IoT) protocols into the growth of the traditional grid system into smart grids (Sarker et al., 2021). There are several different techniques to energy management that can make use of this information. By utilizing this data, appliances on the demand side are able to optimize their operations and efficiency characteristics. This is accomplished through the utilization of intelligent appliance control, communication with utility and grid organizations, and various other digital sensory and communication devices.

## OBJECTIVES

1. To study demand side management.
2. To study energy management

## Related Work

**Mulham B. Soudan (2018)** New possibilities for the development of a wide range of smart grid applications and services have become available as a result of developments in the Internet of Things (IoT) and cloud computing capabilities. It has become possible to design applications and solutions that are able to effectively regulate energy usage as a result of the rapidly growing deployment of Internet of Things devices. The purpose of this work is to show the design and implementation of a home energy management system (HEMS), which is capable of collecting and storing data regarding energy consumption from appliances and the primary load of the home. Two scenarios are developed and implemented: a local HEMS that is separated from the Internet and depends on its processing and storage chores utilizing an edge device, and a Cloud HEMS that uses AWS IoT Core to manage incoming data messages and deliver data-driven services and applications. Both of these scenarios are designed and realized. A testbed was conducted in a real house in the city of Valparaiso, Chile, over the course of a year. During this time, four appliances were used to gather energy consumption through the use of smart plugs. Additionally, the primary energy load of the house was collected through the use of a data logger that acted as a smart meter. To the best of our knowledge, this is the first dataset of electrical energy that has been collected from a genuine household in Valparaiso, Chile, and this dataset has a sample rate of ten seconds. According to the findings, both implementations are capable of performing the fundamental functions for a HEMS, which include collecting, storing, and controlling. In order to provide a contribution, this work offers a comprehensive technical implementation of HEMS. This implementation makes it possible for academics and engineers to build and implement HEMS solutions in order to support a variety of smart home applications.

**Shahwaiz Ahmed Hashmi (2020)** In the realm of electricity, a smart grid is a network that is concerned with electronic power conditioning and the control of production, transmission, and distribution of electrical power. This is accomplished through the utilization of digital communication technologies, which are employed to monitor and manage changes in the utilization of electricity at the local level. In the conventional power system, consumers of energy continue to be unaware of the patterns of their power usage, which leads to the loss of both energy and money. This problem is especially acute in developing countries, where there is a significant disparity between the demand for electricity and the supply of electricity. As a consequence, there are frequent power outages and load-shedding. Demand side management (DSM) is a term that describes the process of adapting to changes in customer demand for energy through a variety of methods, including financial incentives and awareness. The smart grid uses DSM to minimize the amount of energy that is consumed by the electrical grid. It is necessary for the Distributed Storage Management (DSM) in the future smart grid to utilize automated energy management systems (EMS) that are constructed using cutting-edge technologies like the internet of things (IoT) and cloud and/or fog computing. We show the architecture framework, design, and implementation of an electricity management system (EMS) that is based on the Internet of Things (IoT) and cloud computing. This system creates a load profile of the customer, which can be accessed remotely by the utility company or by the user themselves. Utility providers are able to regulate and broadcast their incentives to consumers, as well as encourage consumers to adjust their energy consumption, thanks to the load profiles of the consumers. The electronic management system that we have built is implemented on a project circuit board (PCB) so that it can be simply placed at the consumer's premises. It is responsible for the following tasks: (a) monitors the energy consumption of electrical appliances by utilizing our designed current and voltage sensors, and (b) uploads the sensed data to the Google Firebase cloud using the Internet of Things communication protocol Message Queuing Telemetry Transport (MQTT). This protocol is responsible for generating the load profile of the consumer, which can be accessed through a web portal. The implementation of the various DSM techniques is facilitated by these load profiles, which serve as input. Our findings illustrate the generation of load profiles of consumer load in terms of current, voltage, energy, and power, which can be accessed through a web site. When it comes to developing Internet of Things (IoT) and cloud computing-based Energy Management Systems (EMSs) for smart grid at all levels, such as room, home, building, area, and so on, a generic and comprehensive architecture framework is offered. This framework can serve as a guideline for the development of these systems. A home emergency management system (EMS) that is cost-effective, easy, accurate, and efficient is built and implemented using state-of-the-art Internet of Things (IoT) technologies and protocols such as MQTT, as well as cloud platforms such as Google Firebase and flow-based NodeRED visual programming tool developed by IBM according to the framework that has been provided.

**Felipe Condon (2022)** New possibilities for the development of a wide range of smart grid applications and services have become available as a result of developments in the Internet of Things (IoT) and cloud computing capabilities. It has become possible to design applications and solutions that are able to effectively regulate energy usage as a result of the rapidly growing deployment of Internet of Things devices. The purpose of this work is to show the design and implementation of a home energy management system (HEMS), which is capable of collecting and storing data regarding energy consumption from appliances and the primary load of the home. Two scenarios are developed and implemented: a local HEMS that is separated from the Internet and depends on its processing and storage chores utilizing an edge device, and a Cloud HEMS that uses AWS IoT Core to manage incoming data messages and deliver data-driven services and applications. Both of these scenarios are designed and realized. A testbed was conducted in a real house in the city of Valparaiso, Chile, over the course of a year. During this time, four appliances were used to gather energy consumption through the use of smart plugs. Additionally, the primary energy load of the house was collected through the use of a data logger that acted as a smart meter. To the best of our knowledge, this is the first dataset of electrical energy that has been collected from a genuine household in Valparaiso, Chile, and this dataset has a sample rate of ten seconds. According to the findings, both implementations are capable of performing the fundamental functions for a HEMS, which include collecting, storing, and controlling. In order to provide a contribution, this work offers a comprehensive technical implementation of HEMS. This implementation makes it possible for academics and engineers to build and implement HEMS solutions in order to support a variety of smart home applications.

## Demand side management

The demand-side management system is an essential component of any energy management system in power delivery networks. This system gives customers the ability to regulate the patterns of load consumption that they experience, and as a result, it is a vital component of smart grid architecture. According to the Electric Power Research Institute (EPRI), directed energy supply management (DSM) is defined as "the planning, implementation, and monitoring of those daily activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e., time pattern and magnitude of a utility's load." DSM is also referred to as "direct energy management." DR-based programs, power-saving methods, and variable or dynamic unit pricing are the primary elements of distributed solar management (DSM), which seeks to reduce peak load rather than relying on increased generation capacity facilities or sources to satisfy demand. The DSM design is presented in its entirety in Figure 1, which shows it from the perspective of both the ordinary customer and the fundamental operator.

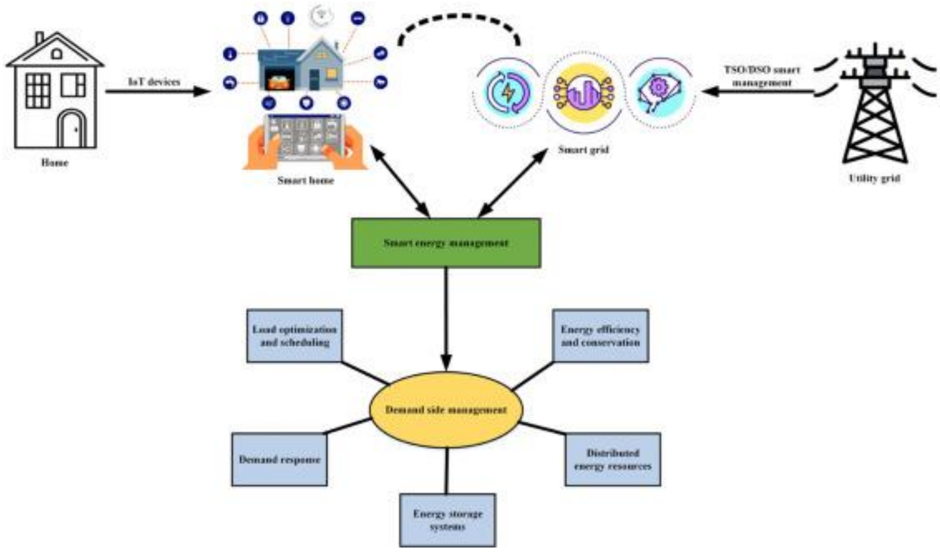


**Fig. 1. Demand-side management principle in a smart grid ecosystem.**

***Energy efficiency (EE):*** It is the primary objective of these adjustments to permanently improve load consumption. This is accomplished by reducing the load profile at the device level through the use of energy efficiency enhancement measures. In this sense, energy efficiency refers to the process of extracting more power from each watt of electricity that is fed into the appliance. This is in contrast to the practice of depending on an event-driven strategy to reduce loads. This indicates that consumption is continuously decreasing over time. Both Chowdhury et al. (2018) and Tronchin et al. (2018) present additional research on the improvement profiles, measures, and issues that are associated with energy efficiency.

***Time of use (TOU):*** Under the time of use pricing approach, which is based on dividing the fixed pricing from the utility on a 24-hour time-period basis that encompasses multiple time intervals, different pricing tariffs are applied to each load profile at each period. This method encompasses numerous time intervals. The differential tariffs of power units, which are based on peak load rates and are prone to seasonal price changes, can be regulated with the help of this method, which can be advantageous.

***Spinning reserve:*** The spinning reserve is a backup power source for the electric grid system that can be activated by the distribution network operator (DNO) in the event that there is an unexpected dip in generation levels. This is done in order to make up the difference between the amount of power that is consumed and the amount that is generated. Disruptions in power distribution can be caused by a number of factors, including improper load forecasting and scheduling, as well as unanticipated damage to the generating units. Primary and secondary spinning reserves are the two primary categories of their respective types. Primary spinning reserves are responsible for managing the active power output through the use of frequency regulation, whilst secondary spinning reserves are responsible for injecting additional active power.

***Demand response:*** During periods of high wholesale energy tariffs or unpredictable grid stability, demand response occurs when end-users depart from their typical patterns of load consumption in response to changes in unit tariffs or incentive programs aimed to reduce load consumption. This occurs when end-users are attempting to minimize their load consumption. When demand is low or spinning reserve capacity is restricted, DR mostly focuses on short-term changes. This is because the day's crucial peak price and consumption periods are during these times. In order to increase energy efficiency and customer-centric usage behavior on the demand side, Demand Side Management (DSM) places a key emphasis on the long-term load consumption profile during its implementation.

**Residential Demand Side Management (RDSM)**

Both residential and commercial settings are able to benefit from the DSM in a manner that is quite comparable. Residential loads, which typically account for forty percent of the total load profile, are responsible for the great majority of the power consumption that occurs at utility levels. When applied to residential loads, which are significantly more pliable than commercial loads, DSM approaches have the potential to yield the greatest benefits for both the utility and its customers. Utility plans make it possible to implement DSM by incorporating a variety of measures, including strategy-based conservation, load profile management, and adjustments to customer and market share. These measures are all incorporated into the program. In the DSM activity, there is a procedure that is divided into two levels:

- Level I:- Load shape modification
- Level II:- End-user side modifications, alternative technological implementation, and market implementation techniques

A number of different approaches can be taken in order to achieve the major objectives of load shape adjustment, which are the reduction of peak curves and the pricing of power units. Generally speaking, there are six different approaches to pick from when it comes to the adjustment of the shape of the residential load. DSM is responsible for the dispatch and operation of the power system, and it does so by utilizing the Load Duration Curve (LDC). LDC models are considered to be among the most significant analytical methods which are utilized in power system analysis. A graph that illustrates the relationship between loads in relation to time is called a load curve by definition. For the purpose of modifying the ratio of off-peak to on-peak load shifting, the following figure, Fig. 2, depicts six distinct techniques to load curve shaping that can be utilized.

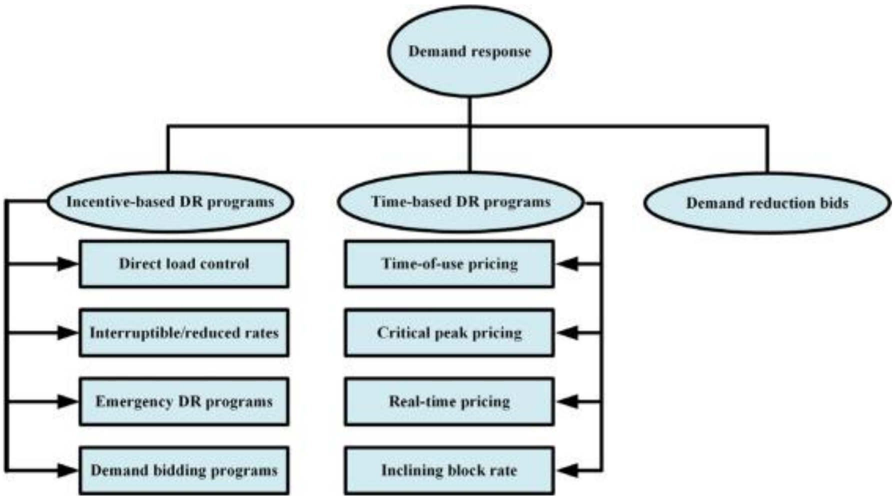


**Fig. 2. Demand response programs based on initiating party.**

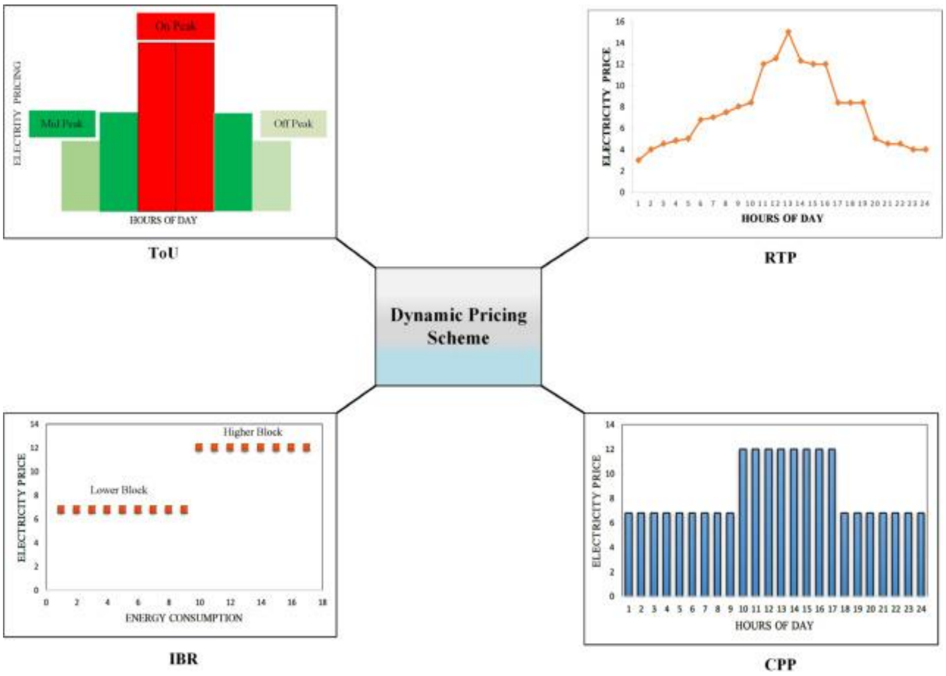


**Fig. 3. Time-based dynamic pricing schemes.**

***Peak Clipping*:** This is a reference to a DLC strategy that is intended to reduce the amount of load demand that occurs during peak hours. It is helpful to have this technology available in situations where the initial costs of building new power producing units are significant.

***Valley Filling*:** Using this strategy, clients are largely encouraged to use their appliances during off-peak hours so that they can take advantage of cheaper tariffs.

***Load Shifting*:** Through the process of shifting load from times of peak use to times of off-peak consumption, the approach achieves its objective. To further encourage customers to relocate their large loads to off-peak hours, when tariffs are lower, this method also provides an incentive for customers to do so. This presents a number of benefits, particularly with regard to its usability.

***Load Reduction***: This method is also known as strategic energy conservation, which is another term for it. In this approach, load reduction is always given the highest priority, whether it is through cyclic operation or the utilization of equipment that is more efficient.

***Load Growth***: This technique is also known as load build-up from time to time. In this situation, consumers are encouraged to use electricity up to a particular amount, and their load utilization is increased appropriately. This is done in order to maintain the smooth operation of the power utility and the stability of the grid.

***Flexible Load Shaping***: Through the employment of this strategy, load utilization can be dispersed throughout a number of different time intervals. Our company seeks out customers that are prepared to be flexible with their load usage pattern and then provides them with a variety of incentives to assist them in meeting their needs.

**Residential Energy Management System (REMS)**

In recent times, there has been a rise in the amount of active attention in the field of REM. With the assistance of REMS, a number of home appliances can be controlled and operated in an intelligent manner simultaneously. The reduction of energy consumption, overhead costs, and waste are the key objectives of energy efficiency improvements that are centered on REMS programs. The ecosystem for energy management as a whole has been undergoing development, and the incorporation of sophisticated communication technologies and the Internet of Things has made it possible to implement intelligent energy management inside REMS. They are primarily concerned with encouraging people to participate in home settings in order to enhance aspects such as dependability, security, comfort, and the execution of safety protocols. The use of DSM through REMS makes it possible to implement sensor control and advanced metering infrastructure (AMI), which in turn makes it possible to remotely exchange information, monitor, and actuate the activity of each appliance. These are vital elements for a grid that is becoming increasingly smart.

The setup includes a number of drivers, which makes it simpler to incorporate REMS into the home management system. Control and management of smart devices and control mechanisms can be accomplished through the utilization of metering infrastructure, communication protocols, and monitoring activities. This permits the reduction of the overall energy consumption of all devices in a home as well as the improvement of the energy efficiency of each individual device. As far as DSM is concerned, REMS is in agreement with the objectives that have been set by smart grid programs. In accordance with Beaudin and Zareipour (2015), the residential energy management system (REMS) enables communication between the electrical infrastructure of the home and the utility operator. This communication enables the adjustment of appliance schedules, operation within constraints, and management based on external data such as weather forecasts or revisions to unit tariffs. Typically, it is controlled by turning off appliances while they are running in order to reduce overall energy consumption and account for periods of low unit tariffs and high generating capacity. This is done in order to account for these periods.

In order to make effective use of DSM procedures, it is necessary for each and every residence to have an advanced metering infrastructure (AMI) installed. AMI keeps a record of the load characteristics of various appliances throughout the course of a variety of time periods. The Residential Energy

Management System (REMS) gives homeowners the ability to automate the scheduling and load consumption in their homes. In addition, smart Internet of Things devices that have smart controller installations are able to change the manner in which they use their appliances in order to prevent power outages during periods of high demand. By taking a customer-centric approach, REMS may provide numerous benefits, including but not limited to the following: reduced power usage costs, minimal peak loads, maximum integration of renewable energy sources, and optimization for maximum efficiency in energy consumption. These are just some of the many benefits. As can be seen in Figure 4, the DSM architecture is connected with AMI in order to perform the functions of regulating and recording information regarding appliance management.

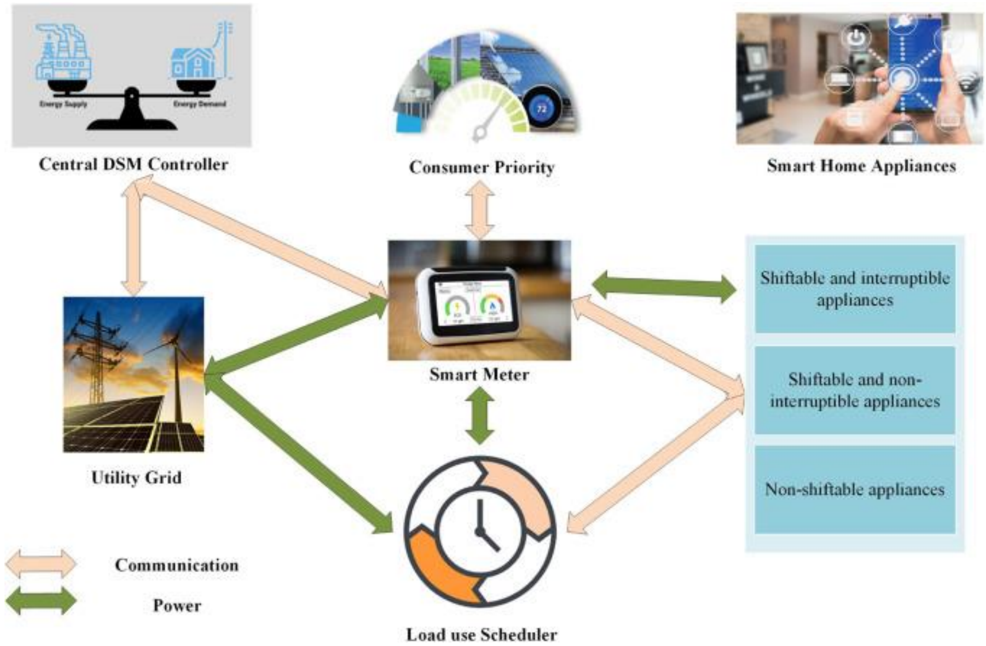


**Fig. 4. DSM architecture incorporating AMI control.**

**Cloud-IoT Home Energy Management System**

**Perception Layer**

While the perception layer makes it possible to gather data through sensors, it also makes it possible for edge devices to perform activities related to data storage and processing. This layer takes into account a number of different physical devices, which are frequently referred to as "things." Some examples of these devices are sensors, smart meters, and smart plugs. Edge devices enables tasks to be performed on things that are located on the edge sub-layer. These tasks include the storage of data, the processing of data, and the performance of actions. The perception layer is an essential component of the architecture that has been suggested. It serves as the initial stage in the process of gathering energy data and as the final step in the process of managing appliances.

- Things Layer: Actuators and sensors make up the entities that make up the things layer. It is possible to gather information on significant measurements of the smart home through the utilization of sensors. For the objective of providing comfort, sensors are utilized. Some examples of these sensors include temperature, humidity, and light detection. There are two new gadgets that have been released in relation to the power usage of appliances: smart meters and smart plugs. Through the use of a smart meter, one is able to gather information regarding the energy consumption of the primary loads in a smart house. In order to determine the amount of power that is being consumed, it makes use of a current transformer (CT) and a voltage sensor. Connecting the electrical line of the house to the plug of the appliance, smart plugs (SP) serve as a kind of intermediary between the two. In addition to being able to manage the amount of energy that is provided to a particular appliance through the use of a relay, the aim of SPs is to gather data regarding the amount of energy that is consumed by a particular appliance.

- Edge Layer: At the edge, the sensors and actuators are located in the closest proximity. This enables the collection of data as well as the execution of command operations on "things." When it comes to available resources, the edge layer takes into consideration a low latency but restricted data storage and processing capabilities. When viewed from the point of view of HEMS, the edge layer is located at the house level. This layer can be utilized as a perception layer in order to collect the data that is of interest.

**Communication Layer**

The connection between the perception layer and the middleware layer is made possible by this layer. The completion of this mission could be accomplished by the utilization of a number of different communication technologies, including WiFi, Zigbee, LoRa, Fiber, and mobile networks such as 4G and 5G. Choosing the appropriate technology involves taking into consideration a number of factors, including the effective range (both short range and long range), cost, coverage, and availability of a particular communication system. It is the responsibility of the network layer to establish a home area network (HAN) that the devices that belong to the perception layer can integrate into. The HAN enables communication between devices, which is often referred to as machine-to-machine (M2M) communication. This communication enables the routing of data from the objects to the edge or from the edge to the middleware layer.

**Middleware Layer**

Middleware is a layer that is associated with cloud-based services that are dependent on the data that they receive in order to carry out certain functions. The most frequent functionalities of a HEMS are the storage of measurements in a database, the execution of data processing activities through the use of microservices, and the provision of an application programming interface (API) for the management of data requests. By utilizing a public cloud, such as Amazon Web Services (AWS), Google Cloud Platform (GCP), or Microsoft Azure (Azure), it is possible to put these services into action. In terms of functionality, the middleware layer is comparable to the edge layer; however, it offers a scalable infrastructure that can accommodate bigger volumes of traffic as well as more demanding processing and storage activities. Developers have access to a number of different technology stacks, which they can use to carry out the necessary implementation in order to accomplish the duties that were specified earlier. Database election, building and deploying the needed cloud architecture, programming language, and/or framework election are some of the issues and decisions that need to be addressed in order to offer a robust system. Other challenges and decisions include programming language and/or framework election. The middleware in this architecture acts as a bridge between the data perspective that is provided by the "things" and the applications or features that are meant to be used in the smart home that are identified in the application layer.

**Application Layer**

A Home Energy Management System (HEM) is designed to supply data to several domains, including the Energy Internet, smart grids, and smart homes. Applications for HEMS that are driven by data include, for instance, demand response, peer-to-peer energy trading, and monitoring energy consumption for the purpose of increasing user awareness. The apps in question constitute the final layer of the proposed architecture, which is the one that is most directly connected to the last user.

**Home Energy Management System Design**

A cloud-based HEMS and a local HEMS are the two case studies that are suggested for the purpose of comparing and contrasting the various methods to HEMS. On the one hand, a local HEMS system makes use of a central computing unit in order to manage the tasks of data storage and processing. A cloud-based system, on the other hand, is able to permit a number of different solutions and apps, and it collects the data through a gateway.

Both of these systems are designed to fulfill the following functions, which make it possible for HEMS to carry out some characteristics of a smart home:

- Monitoring of the energy consumption: In addition to storing information about the primary load of the smart home, HEMS should also save data regarding the power consumption of the appliances that are monitored by the smart plugs.
- Appliance control: A resident should be able to interact with the appliances that are connected to smart plugs in order to supply or deny electricity through the use of HEMS.

The smart house that is being developed for this project incorporates a number of elements that are obligatory for both of the systems. We distinguish two types that constitute common ground for the implementation of such systems, and they are as follows:

- The things: In each of the case studies, the end devices that are utilized are the same: smart plugs and smart meters. It is the responsibility of the smart meter to gather the reading of the total amount of electricity that is consumed by the house. On the other hand, a smart plug is able to calculate the amount of power that is consumed by a single appliance and regulate the amount of power that is given to that device.
- Networking and communications: In terms of communication, we took into consideration the fact that the smart home is equipped with Wi-Fi capabilities, which make it possible for devices to communicate with one another within a home area network (HAN). Smart plugs and smart meters are examples of devices that have the capability to connect to the HAN through the use of WiFi technology. Every device that connects to the network is given a protocol address, often known as an Internet Protocol (IP) address. Telemetry measurements of the energy consumption can be sent to the destination on a regular basis by the items, which have the competence to do so. Requests for direct energy usage can also be made, provided that the message protocol that each device

supports is followed throughout the process. The data that has been collected is transmitted by the devices using MQTT, which is a well-known Pub/Sub (publisher/subscriber) messaging system. In this protocol, each device transmits data over a specific topic.

## METHODOLOGY

The fundamental objective of a house Energy Management System (HEMS) that is constructed on the Internet of Things (IoT) is to maximise the efficiency with which a house consumes energy. This is accomplished via the system's ability to regulate electrical appliances and systems, including but not limited to lighting, HVAC, and much more. The system takes use of sensors, equipment connected to the Internet of Things (IoT), analytics stored in the cloud, and machine learning in order to monitor and control the amount of electricity that is being used.

**Data Collection**:

- **Sensors**: Obtain information in real time from a wide range of Internet of Things devices in the house. These sensors have the ability to detect a wide variety of parameters, including temperature, humidity, light, occupancy, and power consumption, to name just a few.
- **Devices**: Information gathered from networks of interconnected electronic equipment, such as heat pumps, lighting, and refrigerators.
- **Weather Data**: Predictive control may be aided by meteorological data provided by cloud services, including temperature, humidity, and sunshine.

**Data Preprocessing**:

In order to remove unwanted noise from raw sensor data, a data filtering technique is used, such as a moving average.

**Formula:** $\hat{x}(k) = \hat{x}(k-1) + K(k)(z(k) - \hat{x}(k-1))$

Where: $\hat{x}(k)$ is the predicted state, $z(k)$ is the noisy measurement, and $K(k)$ is the Kalman gain.

## RESULTS

**Energy Consumption Prediction**:

- Utilise a mix of internal parameters (such as occupancy and temperature) and exterior elements (such as the time of day and the weather) in order to make an estimate of the future energy requirements.
- One example of a model that might be used in the context of energy demand forecasting is the linear regression model:

**Formula:**

$$E_{\text{demand}}(t) = \beta_0 + \beta_1 T_{\text{indoor}}(t) + \beta_2 T_{\text{outdoor}}(t) + \beta_3 \text{Occupancy}(t)$$

**Where:**

- $E$ demand(t) is the predicted energy demand at time *t*.
- $T$ indoor(t) and $T$ outdoor (t) are indoor and outdoor temperatures at time t.
- Occupancy (t) whether the home is occupied at time t (binary variable).
- $\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$ are regression coefficients determined by machine learning or historical data.

**Optimization Algorithm**:

In order to reduce the amount of energy that is used, the system is designed to optimise efficiency by controlling appliances in accordance with the predicted demand. Two alternative formulations for this optimisation issue are linear programming (LP) and mixed-integer linear programming (MILP). Both of these formulations are described below:

$$\text{Minimize} \quad \sum_{t=1}^{T} P_{\text{appliance}}(t) \cdot \Delta t$$

**Where:**

- $P$ appliance (t) is the power consumption of each appliance at time *t*.
- $\Delta$ *t* is the time interval (e.g., 15 minutes).
- $T$ is the total time horizon for which the optimization is calculated.

**Energy Efficiency and Cost Function**:

Through the use of the cost function, the optimal balance between user comfort (including lighting levels, temperature settings, and so on) and energy efficiency is determined.

$$\text{Minimize} \quad \sum_{t=1}^{T} (C_{\text{electricity}} \cdot E_{\text{demand}}(t) + C_{\text{comfort}} \cdot \text{Comfort level}(t))$$

**Where:**

- $C$ electricity is the cost per unit of electricity.
- $C$ comfort is the comfort cost (penalty for deviating from user preferences).
- Comfort level(*t*) is a function based on indoor temperature and other user preferences.

**Decision Making**:

**Cloud-based Algorithm**: The cloud server is responsible for collecting and processing the data, after which it employs the cost function to find the optimal energy settings and then transmits those settings to the home appliances.

**Edge-based Algorithm**: Edge computing has the ability to analyse local data in real time, allowing for the management of preferences for low-latency control on specific devices.

**Control System**:

**Actuation**: Lights, thermostats, HVAC systems, and other Internet of Things (IoT) devices get real-time or pre-programmed instructions to adjust their settings based on optimisation results.

**Mathematical Model for Energy Management:**

**Total Energy Consumption** at time *t*:

$$E_{\text{total}}(t) = \sum_{i=1}^{n} P_i(t) \cdot \Delta t$$

**Where:**

- P*i*(*t*) is the power consumption of device ii at time *t*.
- *n* is the number of devices in the home.
- Δ *t* is the time step.

**User Comfort** (Temperature control):

The amount of discordance that exists between a user's ideal interior temperature (T desired) and their actual temperature (T indoor) correlates directly to the level of comfort that the user experiences:

$$\text{Comfort}(t) = |T_{\text{desired}}(t) - T_{\text{indoor}}(t)|$$

**Objective Function**:

Keep users comfortable while reducing overall energy usage:

$$\text{Minimize} \quad J = \sum_{t=1}^{T} \left( E_{\text{total}}(t) + \lambda \cdot \text{Comfort}(t) \right)$$

**Where:**

λ is a weight factor that balances energy cost versus user comfort.

The following may be done with the acquired data after the system is up and running:

**Energy Efficiency**:

- The algorithm will calculate the system's overall energy consumption for a specified time frame.
- One way to find out how efficient a system is is to compare its expected and actual energy usage.

**Cost Reduction**:

- The cost of electricity, denoted as C, is the basis for calculating the overall cost of energy use.
- $\text{Total Cost} = \sum_{t=1}^{T} C_{\text{electricity}} \cdot E_{\text{total}}(t)$
- The system lowers energy expenses in comparison to a baseline situation, such as a standard non-smart house, by using optimisation methods.

**Comfort Satisfaction**:

- The degree of comfort may be determined by calculating the departure from the ideal interior temperature.
- Retaining comfort levels while reducing energy use is indicated by a reduced λ weighted cost in the goal function.

**Impact of Weather and Occupancy**:

- An important aspect of the findings will be an examination of the system's ability to adapt energy use in response to changing variables, such as outside weather and occupancy patterns.
- This aids in determining the significance of extraneous variables in residence energy optimisation and the efficacy of forecasting models.

## CONCLUSION

It is possible that current appliances, utility operators, and the grid may all operate at their highest possible efficiency with the assistance of DSM methodologies. worries regarding dependability, security, and the high costs of energy production during peak hours, as well as worries regarding congestion management, have been alleviated as a result of their implementation at both the generating and distribution system levels. In order to make the most of DSM programs, the authors expect that researchers will use the survey to get a better understanding of the various standards, components, and terminology that are associated with them. Additionally, they hope that researchers will highlight areas in which further research is required. They will be able to optimize and develop new DSM systems for households with the help of this information, and if it is required, they will be able to expand these systems to include enterprises and industries.

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