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Enhancing the performance of sustainable energy management of buildings in smart cities

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ABSTRACT

Energy utilization has been the most influential parameter in recent decades, especially in the smart city model. The energy management system has been a more attractive research problem due to its utility, ability, and applications. This paper has an objective that the article discusses innovative energy management methods for sustainability and highlights the potential for integrated smart energy sources. The discussion also touches on the understanding of energy management and production, various storage systems, and their potential future applications. This paper explores challenges in sustainable smart energy management, focusing on methodologies like smart energy systems, PV calculations, electric grid models, and energy management strategies in smart cities. The passive infrared receiver (PIR) sensor has been used in real-time energy management systems to integrate these methodologies into the city's infrastructure. The energy management design aims to coordinate electrical appliances such as fans and lights to minimize energy consumption. The article proposes new energy management and security techniques based on data sources to enhance city intelligence, adaptability, and sustainability by reducing human involvement in controlling electrical appliances in residential buildings. The proposed design and development system optimizes energy utilization more efficiently and effectively than conventional systems, meeting real-time energy management objectives.

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1. INTRODUCTION

Since the last few decades, the usage of fossil fuels in the electricity field worldwide has been reduced due to environmental pollution in terms of carbon emission and surplus products. As the population is increasing exponentially, it shows the impacts on the usage of residential power consumption. With rapid population growth in India, electricity utilization is also increasing, and the demand for urbanization has increased by 6% this year. Generally, urban areas will produce carbon emissions between 50% and 60% of the world's total emissions of greenhouse gases. By 2050, India's urban population is expected to increase from 32% to 60%, which will have additional burdens on energy consumption patterns associated with GHG emissions. Due to these additional burdens, installing more power plants and integrating renewable energy sources is necessary, which also aims to reduce carbon emissions and turn into a green and clean power sector.

The integration of power industries requires power management and is connected to the residential or commercial utilities. Then, residential energy management technology became the most effective system connecting electrical/electronic devices with sensors. This makes the system more innovative and emotional with the communities in the entire world. The development of ecologically friendly and long-lasting infrastructure and waste management must be utilized by smart energy management (SEM). It is now essential to support energy rules by boosting structures of residential energy efficiency. Reducing the energy consumption in residential buildings is the main target to minimize the environmental impact of the buildings. Smart homes use a lot of energy in proficiently using their appliances, leading us to. Energy management equipment like sensors will provide solutions for smart energy management, public safety, disaster management, information collection, security and privacy, and energy consumption [1]. The architecture of hybrid energy management systems (HEMS) and their capabilities, such as monitoring, logging, control, management, and alerts, are briefly explained in this article [2]. The author stated that HEMS easily monitor and control household appliances. Still, due to the hybrid system in a home, the frequent changes in the RES, and the conventional system, the home appliances may be out of control, which causes economic losses to the consumer. At the same time, the authors stated in [3] that this development could be reasonable for low-cost homes or industrial appliances, especially in manufacturing. Stochastic minimization may give an idea about these uncertainties, but that also needs an evaluation of the suitable probabilities of the casual parameters.

The motivation for the proposed problem is this research work was motivated by the following:

- The goal is to create a more cost-effective and sustainable energy ecosystem by implementing efficient energy management practices across the entire energy supply chain, from generation to transmission and consumption. This involves leveraging technology, optimizing infrastructure, promoting energy-efficient behaviors, and integrating renewable energy sources into the overall energy mix.
- Possibility of extending the lifespan of power system components and consumers' appliances.
- Concern for the growing energy consumption and the associated Environmental impacts.

The objectives of incorporating energy management equipment, such as sensors, in smart homes are multifaceted and encompass various aspects of efficiency, safety, disaster management, information collection, security, privacy, and energy consumption. Some of the key objectives are optimize energy consumption, smart energy management, real-time monitoring, load balancing, public safety, emergency response, disaster management, information collection, security and privacy, privacy protection, energy consumption awareness, user education, feedback mechanism, integration and interoperability, interconnected systems, cost savings, environmental impact, reduce carbon footprint. By addressing these objectives, the integration of energy management equipment in smart homes aims in this paper to create a holistic and efficient living environment that enhances convenience and contributes to resource conservation, safety, and sustainability.

Diyan *et al.* [4], the author proposed that energy management in the home is implemented to minimize energy consumption and reduce the burden of peak to average ratio on the smart grid using the hybrid energy management systems by 10%. An IoT provides the solution for these types of applications, which are related to smart homes. The energy systems and components explore intelligent energy management in smart home appliances, building energy management systems, consumer, energy storage, electric cars, and microgrids, according to economics, environment forecasting, energy utilities, and engineering applications. This methodology focuses on an optimization-based IoT-based approach to energy management that can be used in smart homes.

A connection between the smart home's power-consuming appliances and the utility grid is made by energy management. A new strategy for energy optimization that involves moving electric appliances and creatively rewarding customers for scheduling smart home appliances [5]. The grid was the only source of electricity for household appliances, and the report did not discuss the advantages of using renewable energy sources. Both smart home energy management systems and a model that switches between various energy sources based on the load value are being studied [6]. Yet, the cost of energy savings could increase because the price of the electricity was predetermined in the paper regardless of when it was utilized. Zhang *et al.* [7], real-time and day-ahead energy marketplaces utilize actuating energy prices and the best energy management strategies for smart homes. The technique was used to control the energy use of a smart home connected to PV and battery storage systems. The authors have described in [8] an optimization strategy for controlling energy in smart homes. Renewable energy sources, energy storage systems, and modern home appliances were all under the direction of the planned management system. Paudyal and Ni [9], the authors have presented a way to control energy in a smart house. The strategy attempted to determine the optimum way to meet the appliances' needs while considering the time-of-use price and various constraints. The issue was solved in a short amount of time using a mixed-integer non-linear programming problem. Although demand response and customer comfort could impact both consumer comfort and energy cost, in articles [10], a constant electricity price was assumed independent of the usage time. To reduce the quantity of energy used in smart homes, various studies have explored artificial intelligence-based solutions. Fuzzy logic and optimization were applied to minimize costs and reduce energy usage, as illustrated in [11]. Fuzzy logic was applied to manage the interruptible home appliances. Additionally, metaheuristic optimization algorithms are used to manage the energy optimally, such as the BAT Optimization algorithm, and flower pollination-based algorithms are used in IoT. The authors employed an AI optimization technique for scheduling moveable appliances and categorized them based on their energy consumption patterns. However, they failed to take into account the fluctuating cost of electricity. Moreover, they didn't look at the effects of dividing the cost of providing the home with electricity between renewable and conventional sources. The algorithm was illustrated in [12] as an alternative to the traditional direct programming model to reduce the overall energy usage in a smart home. A suggested metaheuristic method integrating the algorithms for differential evolution and harmony search was provided in [13] for controlling energy in smart homes. The method was used to maximize energy consumption and minimize the energy use rate within certain stated restrictions. IoT is a technology that permits online data sharing between electric appliances and other home electronics [14]. An excellent strategy for IoT-based home energy management systems was put forth by [15]. In addition to various renewable energy sources, batteries, and the electric grid were used to power the home. The results weren't tested using other optimization methods but only the standard consumption system. Zhou *et al.* [16] proposes a system for regulating home appliances to increase the energy efficiency of the smart home.

This paper aims to develop a program for energy management to lower energy consumption in "IoT-based smart houses." In the study, the energy management systems of IoT-based smart houses were optimized using the harmony search (HS) optimization algorithm, a fresh and successful approach. The smart home can be powered by various energy sources, including solar, wind, and battery storage, and the electrical grid, which reduces energy prices and CO_2 emissions from the energy utilized. This study also significantly contributes to this goal.

AI-enabled smart cities: smart homes predict the output values using datasets as input with the support of machine learning technology. Smart homes are built with sensors and programmed with machine learning to collect node data. Home energy management systems make use of automated switches. Making switching decisions that successfully shift the load to renewable energized systems a sort of local energy storage that consumes less power than conventional energy sources. In a simulated examination, the output of these machines performs artificial neural networks in terms of convergence time and peak-to-peak ratio [17]. The IoT and 802.11 local area network connectivity enable information sharing between sensor nodes in smart homes. Three components make up the suggested model: Raspberry Pi, Google Colab, and Matplotlib are the top three. Each home appliance's information is read by a smart plug powered by a Raspberry Pi, and Google Colab monitors the trained and saved data. Matplotlib keeps track of end-user energy usage, and in terms of accuracy, the suggested model performs better [18].

Energy management in smart cities: the idea of "smart homes" is created by integrating numerous gadgets and applications, and new trends in this field will address security and data privacy. Secrecy, authenticity, availability, and authority are essential long-term objectives [19]. A security protocol is used by the demand-side component of an intelligent grid to govern a local home area network abstractly (LHAN). End-user internet access immediately exposes security, which supports the need for secure communication through the LHAN network [20].

The architecture of the smart home using an IoT: The structure of the smart home integrates numerous services through a system to get all of the requirements for the home's automation and to afford additional user control and usage of energy management. IoT, computer, control, and communication technology are all used in this process. A graphic representation of smart grid-integrated RES is shown in Figure 1.

Smart house buildings provide a better, more pleasurable, and more creative environment for people because of sophisticated environments and striking management. ZigBee is the most energy-efficient wireless technology shown in Figure 2. It was therefore selected for the smart house in this study since it can help lower the home's energy usage [21]. It is, therefore, suitable for smart homes. It can gather energy evidence and afford innovative and effective running of domestic usage in practice.

After implementing the system, the main panel will collect the data on consumed power by the automated home appliances and prepare the schedule of the best demand dispatch. In practice, smart meters work as a cooperative communication link between the smart home and the electrical grid. This study uses battery-storage-enabled renewable energy sources to supply the electricity required to run the home. Collaborating productive management and processes within the household may make the most of these energy resources. Energy storage systems should be utilized in conjunction with renewable energy sources to preserve the dependability of the energy system [22].

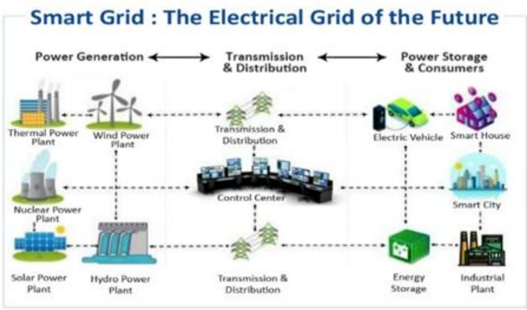

Figure 1. Graphic representation of smart grid integrated RES

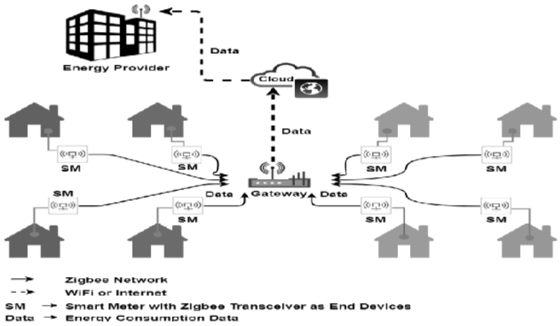

Figure 2. IoT based energy efficient smart metering system using ZigBee network

IoT technology is also used to link the energy management system of the smart home hub with all smart home appliances [23]. The primary IoT platform comprises several layers for data collection, energy monitoring, and management. All energy sources and home appliances are integrated into this platform and connected. Figure 3 shows the layers that make up the primary platform. One of the fundamental operations of the system is handled by each layer. The equipment itself monitors and manages every appliance in the house. The communication network layer is the protocol that governs the connection between home appliances and the Internet. This layer also analyses the collected data to use it best. Figure 4 depicts the suggested collaborative execute-before-after dependency-based requirement of the Electricity grid model using IoT. The various types of loads in a home known as home appliances have different power ratings of time as clearly shown in Table 1. Table 2 compares the ideal value and practicle values of power unit voltages.

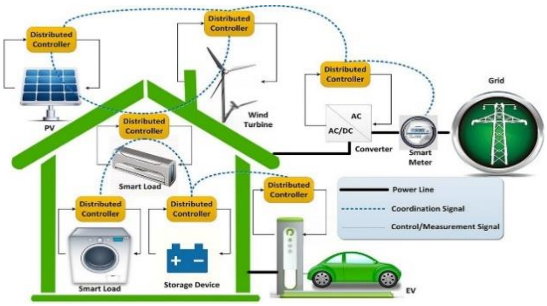

Figure 3. Smart energy management system with renewable energy systems

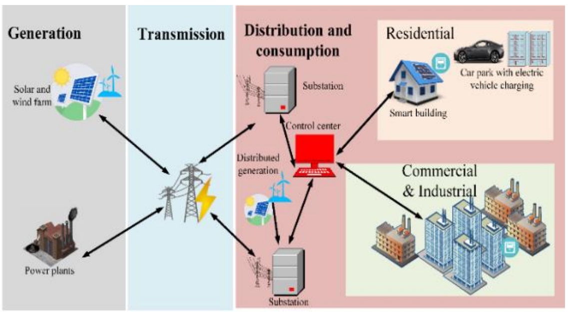

Figure 4. Schematic diagram of electricity grid model using IoT

Table 1. Various loads with their power ratings per time

Lode type	Device	Power ratings (kW)	Daily power consumption in hours
Fixed load	Refrigerator	0.25	24
	Computer/Laptop	0.2	05
	Air condition	3	06
	Heater	2.5	01
	Television	0.2	06
	Other electronics	0.1-0.3	02
	Security camera	0.1	24
Constant load	Washing M/c	3	04
	Microwave	1.2	02
	Dish washer	2.5	04
	Mixer grinder	0.75	01
	Cloth dryers	3.4	02
Variable load	Kettle	1.9	01
	Geyser	3.5	03
	Vacuum cleaners	1.6	02

Table 2. Power unit voltages

Measurement	Voltage type	Ideal value	Practical values
The primary side of the power supply	AC	230	225
Transformer side	AC	12	11.4
Side of the rectifier	DC	12	11.5
Regulator side	DC	5	5.09

2. METHOD

As noted above, this study's foremost target is to afford an HS algorithm for optimal energy use in smart homes. To reach the requirements of the load, the established technical limits, and the environmental criteria, it is compulsory to reduce the utilization of energy costs. This paper aims to explore and comprehend the fundamental types and functions of sensors and networks used in smart homes and to pinpoint load demand and electricity difficulties associated with IoT and its applications in smart homes [24]. Lastly, use a suitable optimization technique to tackle this issue. The fact that electricity costs are higher during times of high demand is well recognized. In this instance, RES and ESS are interconnected with the grid and supply the bulk of the smart home's load. Furthermore, the agreement enables the electric grid to purchase energy from savvy households, increasing the system's reliability. Because of the signal value, the grid cost Cg is given as:

$$C_g = \sum_{t=1}^{T}\left[E_{gc}(t) - E_{gs}(t)\right]\lambda(t) \quad (1)$$

the price of the generators will be shown as C_{emg} ($);

$$C_{emg} = \sum_{t=1}^{T}\left[\alpha\left(P_{gc}\,(t)\right)^2 + \beta\, P_{gc}(t) + \gamma\right] \quad (2)$$

where $Egc(t)$ is grid (kWh) energy cost per time t (hours), $Egs(t)$ is the excess power produced by the smart home, which will be traded to the power grid per total time t in kWh, and $\lambda(t)$ is the signal of ToU energy in $/kWh at time t. From the (2), $\alpha.\ \beta.$ and γ are the thermal generator coefficients

The PSO is crucial in a smart grid since it offers the best option. Yet, CDBR is the ideal method for securing the communication channel to have a superior decision support system. CBDR uses PSO to improve performance, and Equations determine the degree of disagreement between two priority value pairs (3)–(5).

$$dr_d = \begin{cases} 0 & \text{if } |D_i - P_i| > 0 \\ 1 & \text{if } |D_i - P_i| = 0 \end{cases} \quad (3)$$

$$\text{disagree}_d = \sum_{i=1}^{n} d_{r_i} \quad (4)$$

Here, the values of (1) and (2) will calculate between two standard values (Pi and Si).

$$dr_s = \begin{cases} 0 & \text{if } |S_i - P_i| > 0 \\ 1 & \text{if } |S_i - P_i| = 0 \end{cases} \quad (5)$$

$$\text{disagree}_s = \sum_{i=1}^{n} d_{s_i} \quad (6)$$

Disagree= disagree_d + disagree_s in. (4) and (5) compute overall disagreement.

V(i+1) =W x V(i) +C_1 x rand () x (Pbest –present(i)) + C_2 x rand () x (Gbest – present(i)) (7)

Present (I + 1) = present(i) + V(i) (8)

The current solution symbolizes the primary concern list, which is a prerequisite for all practicable repetitions of the classification using the position vector. The best solutions that could be found individually are Pbest and gbest, where V is the particle velocity. Using two factors, cognition (c_1) displays the most recent location a particle visited, and social (c_2) provides information on the vicinity of the ideal position.

2.1. Renewable energy system (RES)

RES include solar photovoltaic (PV) systems, which convert sunlight into electricity using semiconductor materials. These systems are environmentally friendly and sustainable, distinguishing them from finite non-renewable sources like fossil fuels, which contribute to environmental issues. Solar photovoltaic systems are regarded as RESs in this article. A typical solar cell design can be represented in Figure 5.

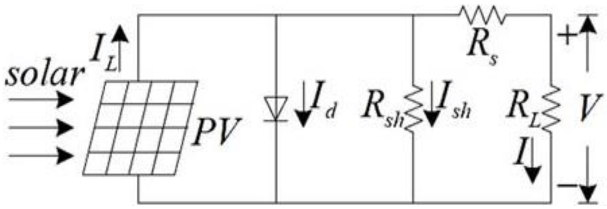

Figure 5. Circuit diagram of RES model

The fundamental of the solar cell equation describes the I-V characteristics:

$$I = I_{PV\ cell} - I_{Ocell}\left[exp\left(\frac{qV}{akT}\right) - 1\right] \quad (9)$$

From the above equation, solar current will be calculated as:

$$I = I_{pv} - I_0\left[exp\left(\frac{V+R_SI}{V_t\,a}\right) - 1\right] - \left(\frac{V+R_SI}{R_p}\right) \quad (10)$$

where,
I_{pv} : the current of the array and is represented as, $I_{pv}=I_{pv,cell}\,N_{p.}$
in I_o : the current of the array and is represented as $I_o=I_{o,cell}N_{p.}$
V_t : is known as thermal voltage, $V_t=N_{sk}T/q$.
N_s : is the number of systems connected in series.
N_p : is the number of systems connected in parallel.
R_s :represented as resistance in series.
R_p : represented as resistance in parallel.
a : is selected as a subsystem. Frequently $1 \leq a \leq 1.5$, the other parameter will be shown in the I-V model: the light-generated current of a solar cell is:

$$I_{pv} = \left(I_{pv,n} + K_I\Delta_I\right)\frac{G}{G_n} \quad (11)$$

where,
Ipv,n light produced by current at 25 ^{0}C and 1,000 W/m^2, *ΔT* is known as the temperature difference between the actual and practical, *KI* co-efficient of current, *G* = device surface irradiation, *Gn* = irradiation in the form of nominal.
The current saturation of the diode and the dependence on the temperature shall be shown as:

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 exp\left[\frac{qE_g}{ak}\left[\frac{1}{T_n} - \frac{1}{T}\right]\right] \quad (12)$$

where,
Io,n is the insignificant saturation current given by:

$$I = \left[\frac{I_{sc,n}}{exp\left(\frac{V_{oc,n}}{aV_{t,n}} - 1\right)}\right] \quad (13)$$

where,
Eg : gap of the semiconductor energy band.
Vt,n : minimum temperature of a thermal voltage *Tn.*
Voc,n: minimum temperature of the open-circuit voltage.
Isc,n : minimum temperature of the current in short-circuit.

Solar energy is converted into DC power by the PV panels bus coupling the DC/DC converter through the DC bus system. The probability distribution of the solar radiations in PV cells and its non-linear properties, the maximum power tracking system is always ready to implement to get the maximum energy from the solar cells. There are several methods in MPPT to get the maximum operating circumstances, and the suggested method is perturb and observe.

2.2. Strategies of energy management

The EMS is an all-encompassing control system that efficiently and adaptably controls power flows to and from power sources, as well as to sensors, loads (AC, DC), and the utility grid. It manages the essential real-time parameters for every power parameter from the SG system and other controllers. Controlling the voltage and balancing the power in the SG system can be accomplished with the provided method. In this configuration, the SMPS controls the charging and discharging procedures using a bidirectional DC/DC converter, and the DC/DC boost converter connects the sensors to the DC bus. The hardware design and development of the PIR sensor are shown in Figure 6, and the voice control of an Android phone, and an Arduino microcontroller was examined for home automation. A Bluetooth module was used to enable the system from various locations inside the house; remote street light monitoring was used for energy management and cost savings on maintenance. The effectiveness of energy management is validated by building automation and control systems. For monitoring and control, PIR sensors have been used in a range of applications. Some of its key applications include automatic surveillance activity detection, efficient energy management, and intelligent video recording system triggering. According to a literature review, PIR sensors are often used for automatic lighting load management. This investigation will use the PIR sensor to measure the overall household load.

Figure 6. Hardware structure of energy management system using sensors

The DC voltage across the load is:

$$V_{DC} = \frac{2v_{pp}}{\pi} \tag{14}$$

the Vrms is the output of the transformer's secondary side with 12V so that the peak value of the AC is (V_{pp}):

$$V_{pp} = V_{rms} X\sqrt{2},\ V_{pp} = 12X\sqrt{2},\ V_{pp} = 16.97\ V \tag{15}$$

The voltage drop at the output voltage is (2×0.7=1.4 V) smaller than the input voltage because the current passes through two diodes twice during each half cycle. With the supply frequency now being 50 Hz, the ripple frequency is 100 Hz, and the ripple voltage is 10% V_{pp}. The peak-to-peak voltage after rectification (V_{pp}^*) hence;

$$V_{pp}^* = 16.97 - 1.4 = 15.57V \tag{16}$$

Substitute and calculate in V_{DC} = 9.91V = 10 V

It is essential to think of every way we can reduce carbon dioxide emissions since daylight change is constantly changing how we see light. Buildings often utilize more than 40% of primary energy, which results in significant carbon dioxide emissions. Considering measures to reduce energy use in residential and business structures is crucial. The internet of things (IoT) can answer the climate change issue through technologies that can assist users in optimizing energy use [25]. The operation of the energy management system is shown, and the flow chart is shown in Figure 7.

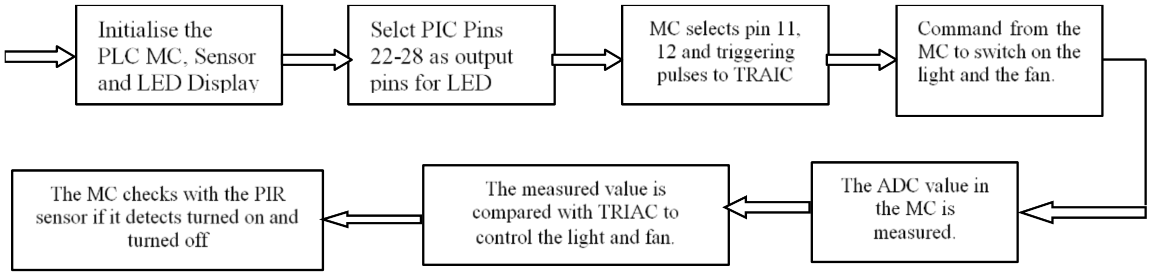

Figure 7. The process flow for the operation of the energy management system is shown the flow chart

A motion sensor is one of the internet of things gadgets that can increase energy efficiency. Users can link the motion sensor to other smart home components for energy-saving purposes because it is simple to integrate into home automation systems. Users can conserve energy by coupling the motion sensor to the lights while using it to detect occupancy. When people arrive and leave the room, the lights will turn on and off so that energy is only used when required. Beneficial is the motion sensor in spaces where people frequently leave the lights on. Also, working together, the PIR sensor and light sensor prevent the lights from automatically turning on when someone enters the room. The lights will only come on to further reduce energy consumption if the space requires more lighting [26].

2.3. Energy storage system model

In this study, the load times are supplied by a battery energy storage system, which also helps to reduce the variations that RESs cause. Since Li-ion batteries have a high energy density, they are utilized in this investigation. Battery charging and discharge decisions are made under the price signal received from the grid. As a result, the batteries' stored energy can be visualized as follows:

$$E_s(t) = E_s(t-1) + T_s \eta_C P_{ch}(t) - \frac{T_s P_{dch}(t)}{\eta D} \quad (17)$$

Ts is the time in hours, C, and Es(t) is the amount of energy (in kWh) stored in the batteries at time t. D and $P_{ch}(t)$ are the percentage efficiency of the charging and discharging of batteries, respectively. $P_{dch}(t)$ is used for charging and discharging at time t. (kW). Maximum and minimum charge borders must be considered operating restrictions to prevent battery overcharging and deep draining. These restrictions can be stated as:

$$P_{ch}^{min} \leq P_{ch}(t) \leq P_{ch}^{max} \quad (18)$$

$$P_{dch}^{min} \leq P_{dch}(t) \leq P_{dch}^{max} \quad (19)$$

$$E_s^{min} \leq E_s(t) \leq E_s^{max} \quad (20)$$

where:
$P_{dch}^{min}, P_{dch}^{max}$ are represented for the charging and discharging of the power in (kW), and $Es\ E_s^{min}, E_s^{max}$, is the energy storage in maximum and minimum quantities (kWh). The range in the cost of the batteries for normal operational and degradation can be expressed as;

$$C_b = \frac{1}{2} \frac{[C_{b\,inv} + \sum_{i=1}^{n} C_{b\,om} [1+D_r]^{-i}](1+{D_r}^n) - SV}{(1+D_r)^n X_{Tf} X_{Tc} X_{Dc} Y_{Rc} E_{Rb}} \quad (21)$$

$$C_{b\,op} = \sum_{t=1}^{T} C_b \left(\eta_C P_{ch}(t) + \frac{P_{dch}(t)}{\eta} \right) \quad (22)$$

Where $C_{b\ inv}$ will be represented as the speculation cost of the batteries in dollars ($), and $C_{b\ om}$ also represented as O&M cost in dollars ($), SV can be shown as total life period of the batteries, X_{Tfi}s is power factor which depends on a temperature, X_{Tc} can be represented as the fading factor of the capacity, X_{Dc} can be shown as the discharge depth (DD), Y_{Rc} will be represented as the life cycle of the batteries, and also E_{Rb} will be known as the batteries rated capacity. Therefore, the final rate of the batteries is expressed as:

3. RESULTS AND DISCUSSION

The results and discussions clearly state that the comparison between the existing and proposed methods shows that the proposed methods are better. These results fill the research gap between the existing methods and the proposed methods. It is very much needed to compare the results with the desired methods. Firstly, these papers compare and explain how the proposed method is efficient with the existing methods, such as energy management strategies. This IPR sensor is designed and developed with the various sensors and LCD of the device to estimate the compliance with the desired output. After the device was built, it was put through various tests to check if it worked as intended on both the input side, is designed with the different types of sensors and the power circuit, and the output side, the LCD and load will be connected. The regulator is grounded and measures its output as 5V, and simultaneously, the input will be measured to be 220 V with a frequency of 50Hz. This proves that the transformer's attempt to step down the 220V supply was adequate and that the modification and leveling procedures used to create direct current worked as intended. The PIR sensor arrangement efficiently used the device's motion detection features to detect occupant occupancy. The sensitivity of the light sensing was reduced steadily by making the bulb automatically ON and OFF. The digital thermostat's responsiveness to temperature change was demonstrated by repeatedly turning the lamp on and off. In this test, the LCD successfully showed sensor activity, satisfying the requirement for control. The LDR was designed and tested in the light test. When the LDR is in the off mode, the resistance is higher, and the voltage shown in the voltmeter/multimeter is very low (almost near 1.5V 3V). When the light is on the LDR, the resistance of the LDR will reduce, and the voltage measured by the meter will be near 3V to 4.5 V. The same sensor is replaced with the motion sensor in the IPR sensor place. No work change exists, but the difference is only in the image movement. This motion sensor also detects the image with a certain distance and blow. So, in this way, the LDR or motion sensor test will work and be successful in the detection ability of the design setup. This is one of the methods to manage the energy usage in the smart cities and industries.

The second comparison test was implemented in MATLAB and successfully simulated the designed model. The main goal of this test is to provide constant load power and EV; because of this, energy storage in the SG environment is attained [27]. With this model, several operational scenarios and case studies can be created. Ensuring the modeling, a PV array with irradiation of 1,000W/m^2 and a V_{MPPT} of 400V produced 168 kW of power exchanged between loads on the grid. According to demand, the PV array generates about 168 kW of power while working in MPPT mode, according to Figure 8. This is the initial mode of operation. Mode 1 and mode 2 of the PV module compare the battery when charging and when it is in discharging mode. In mode 1, the PV system will generate more power than demand. Then, the extra power is given to the grid, and the inverter will operate bi-directionally. In mode 2, the PV system generates less power than the demand, and then the power is taken from the grid to store the power in the battery. Figures 9-11 are the graphical values of the power in mode 1 and mode 2 at 168 kW and 170 kW capacity, respectively. The results of this total concept are designed for grid power at various loads and energy utilization and manages the energy. This attainment in improving RES and using EVs for transport reduces CO_2 emissions very effectively. This data may be trained using machine learning and IoT strategies for practical energy usage in the above two methods/tests. The following steps can be used to summarise the technique of IoT strategies utilized to accomplish these objectives:

– Gather the essential data, including the time and values associated with energy usage, the location of the smart home, and the wireless communication protocols.
– Decide on an appropriate structure for the smart home and specify the appliances and lighting used there.
– Determine the sensors, monitoring equipment, and interfaces necessary for home automation and remote control.
– Determine the necessary wireless sensor networks for communication while using IoT.

Making use of an optimization technique to find a smart home's best ideal point for energy savings while still meeting load demand.

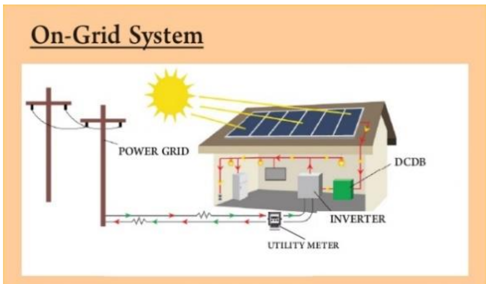

Figure 8. Solar roof top 168 kWh with MPPT design

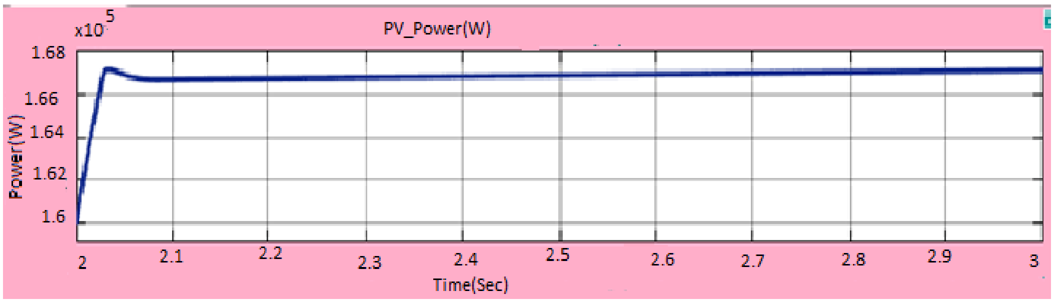

Figure 9. Power flow in 168 kWh solar roof top with MPPT design

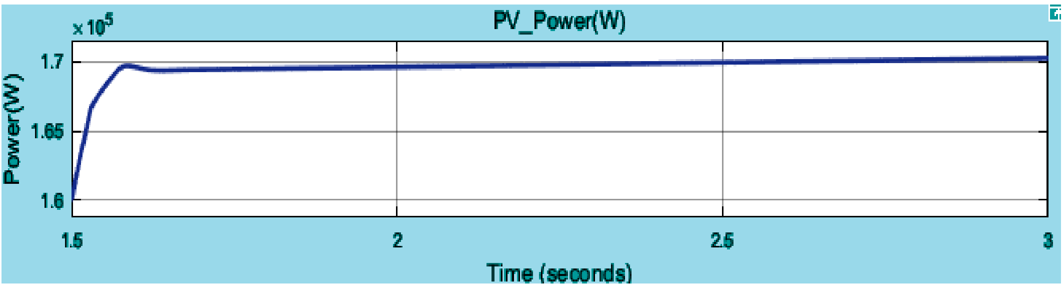

Figure 10. Modes of operation in mode 1

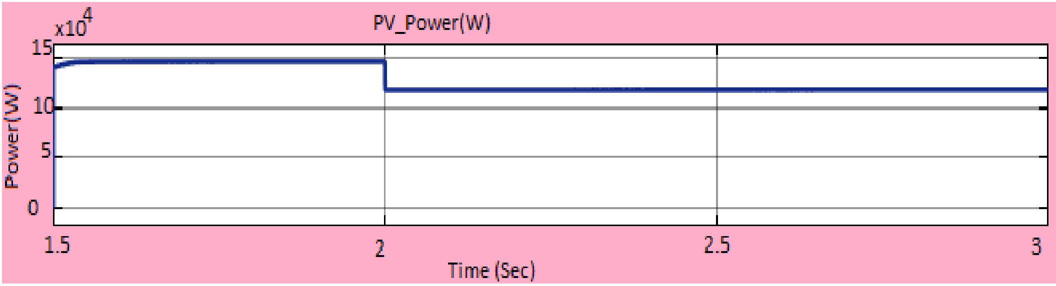

Figure 11. Modes of operation in mode 2

4. CONCLUSION

This proposed methodology provided an optimization algorithm for novel technology-based smart homes' energy management. The suggested method was designed to reduce energy costs while improving operational performance. Various energy sources, including solar panels, battery storage, and PIR sensor technology, were used and analyzed to manage the time of use of home appliances to the electrical grid. The suggested technique has been implemented with the LCD lights, and the energy management achieved by the electronic devices in the proposed hardware system was mentioned. The second test was implemented successfully using PV cells and proved to be the best method compared to the existing one. Novel Outcomes of the proposed methodologies have demonstrated the effectiveness of the suggested novel optimization strategy in smart homes for energy conservation and cost reduction while satisfying the necessary limitations. Also, the developed energy management strategy (EMS) is used in a Smart grid environment, where various load types have all types of data to minimize the dependency on the grid using the IoT and other AI techniques. In test condition 1, the sensor identifies the room temperature to manage the energy by turning the switch on and off. Then, the LCD will work accordingly. The test was conducted at various levels, and it was found that the system reduced energy consumption very effectively and efficiently. A promising topic of study on smart cities must offer affordable and practical solutions to ensure people are comfortable. A smart grid, or energy management, is one such approach. With the available data, it is accomplished by employing machine learning algorithms to determine the demand-to-supply ratio in a specific area. In terms of quick convergence, the technique significantly improves simulation-based findings. Four AI algorithms were used to compare the performance of the suggested method.

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