Optimum Energy Harvesting and Management Technique for Smart Home Automation Using Iot

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***Abstract*—This paper proposes an smart home automation system which uses IoT which integrates demand- based optimum energy harvesting and management technique. This system uses sensors and actuators to monitor and control energy usage in real-time, optimizing energy efficiency and reducing waste. Advanced algorithms and machine learning techniques are employed to predict energy demand and adjust energy harvesting from renewable sources accordingly. The proposed system also incorporates energy storage and grid management capabilities to ensure a stable and reliable energy supply. The proposed system aims to provide a sustainable, efficient, and automated solution for smart homes, reducing energy consumption and carbon footprint while enhancing user comfort and convenience.**

***Index Terms*—Automation, Arduino Uno, IoT, Optimum energy,**

I. INTRODUCTION

The integration of Internet of Things (IoT) technology in smart home automation revolutionizes how we manage our living spaces. By connecting devices such as lighting, heating, security systems, and appliances through a centralized platform, homeowners can enjoy enhanced convenience, security, and energy efficiency. Smart systems enable real-time monitoring and control, allowing users to optimize their environments based on preferences and occupancy patterns, ultimately leading to a more streamlined and comfortable living experience.

As global energy consumption continues to rise, optimizing energy use in residential spaces has become imperative. Energy harvesting and management techniques aim to harness renewable energy sources such as solar, wind, and thermal energy while ensuring their optimal utilization. Combining smart automation with demand-based energy harvesting provides a holistic solution for reducing power wastage and increasing the sustainability of modern homes. Coupled with demand-based optimum energy harvesting and management techniques, IoT in smart homes can significantly improve energy consumption practices.

This approach focuses on efficiently capturing energy from renewable sources like solar and wind while adapting to real- time demand. By utilizing adaptive algorithms and energy storage solutions, these systems ensure that energy is harvested and utilized in the most efficient manner, reducing costs and promoting sustainability. The combination of IoT based automation and demand-driven energy management not only enhances user experience but also contributes to environmental sustainability. Home owners can significantly lower their energy costs while reducing their carbon footprint by harnessing clean energy sources and optimizing usage. As smart home technologies continue to evolve, the integration of intelligent energy management solutions will play a pivotal role in promoting greener living spaces, making them not only smarter but also more responsible in terms of energy consumption.

Smart homes face challenges in managing daily tasks efficiently, leading to time consuming routines for users. Traditional security measures often lack real-time monitoring, leaving homes vulnerable to threats. High energy consumption from appliances increases utility costs and contributes to a larger carbon footprint, despite the potential benefits of solar energy. Addressing these issues is essential for enhancing convenience, energy efficiency, security, and comfort in modern living spaces.

The main objectives is to simplify daily tasks by allowing remote control and automation of household devices, making it easier for users to manage their home environment, optimize energy consumption by automating the operation of appliances, lighting systems, leading to reduced utility costs, improves home security through the integration of smart locks, enabling real time monitoring and alerts to enhance safety, creates more comfortable living space by allowing customization of setting for lighting and entertainment systems based on personal preferences.

II. RELATED WORK

Jaihar et al. (2020) provide valuable insights into the role of machine learning in enhancing smart home automation. By optimizing energy management and personalizing user experiences, machine learning algorithms can significantly improve the efficiency and functionality of smart homes. This study serves as a foundation for further exploration in the intersection of IoT, machine learning, and home automation, highlighting the potential for smarter, more sustainable living environments. Iqbal et al. (2021) provide significant insights into the application of IoT technology for energy management in smart homes, particularly in the context of demand response actions within a smart grid framework. Their proposed strategies highlight the potential for optimizing energy consumption while contributing to overall grid efficiency. This research lays the groundwork for further advancements in smart home energy management and the broader implementation of IoT solutions in sustainable energy practices. Kazmi et al. (2019) investigate the optimization of met heuristic algorithms for IoT enabled smart homes, focusing on achieving a balanced demand and supply of energy. The authors propose novel algorithms designed to enhance energy management in smart homes by efficiently allocating resources. They analyze various factors influencing energy consumption and highlight the role of IoT in facilitating real-time data monitoring. The study demonstrates how optimized algorithms can lead to improved energy efficiency and cost savings for homeowners. This research contributes to the ongoing efforts to integrate advanced computational techniques into smart home energy management systems. Wang et al. (2021) propose a multi-objective home energy management system leveraging Internet of Things (IoT) technology and optimization algorithms. The study focuses on balancing energy consumption, cost efficiency, and user comfort in residential settings. The authors develop a framework that integrates real time data from IoT devices to optimize energy use effectively. Through simulations, the proposed system demonstrates significant improvements in energy management outcomes. This research highlights the potential of combining IoT and optimization techniques to enhance the sustainability of smart homes.

III. METHODOLOGY

This power production is used as the main source of energy for the system. Under sufficient sunlight conditions, the solar panel can bring the system components with a direct power supply. Nevertheless, in the low light or overnight, the system supports the conversion to the AC backup power. The use of this dual power strategy allows constant operation with the highest possible generation of renewable power. Arduino Uno is used to regulate energy usage, validate data from sensors for intelligent control of devices.

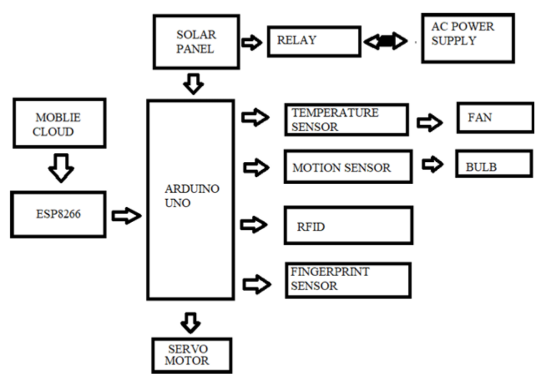


Fig 1: Block diagram of the proposed system

3.1 Working principle of the system

Fig 1. Shows the block diagram of the proposed model. In this system the solar power is basically the only energy supplier supported by an AC power supply. The power of the solar panel is applied to the system components. Arduino Uno is the main controller of the system, processing data from sensors such as that of temperature and movement. Using this data, it is possible to control devices like fans and lights in a smart way, and optimize energy consumption. The system is also connected to a cloud platform through an ESP8266 module to conduct remote monitoring, remote control, and data analysis. This enables users to monitor energy usage, make changes, and see notifications.

3.2 Flow Chart:

The Flowchart of the Arduino Uno showed in Fig 2, which defines a set of instructions to be executed in certain order to get the desired output. It starts by checking for motion and turns on a bulb if detected. Then it checks for valid RFID/Fingerprint authentication. If RFID/Fingerprint is detected, grant access. If not detected, deny access finally, the algorithm controls the door's opening or closing based on the authentication result. If access is granted, open the door. If access is denied, keep the door closed.

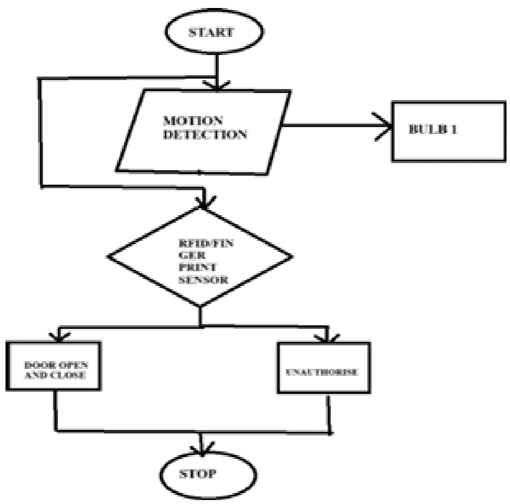


Fig 2: Flowchart of Arduino Uno

The Flowchart of the ESP8266 showed in Figure.3, which defines a set of instructions to be executed in certain order to get the desired output. Communication is initiated with the ESP8266 module, which acts as the gateway for cloud communication. It then continuously monitors for signals or commands originating from the cloud. Based on the received cloud signal, the algorithm decides whether to turn the bulb ON or OFF. Once the action is taken, the algorithm enters a waiting state, ready to receive and process the next cloud signal.

3.3 Components in the system:

3.3.1 Arduino Uno:

It is based on the ATmega328P microcontroller and provides a platform for designing interactive objects or environments that respond to inputs from sensors and switches. The key specifications of Arduino Uno include an operating voltage of 5V, a recommended input voltage range of 7-12V, and 14 digital I/O pins (6 of which provide PWM output). It also has 6 analog input pins, 32 KB of flash memory, and a clock speed of 16MHz. The board can be programmed via a USB connection and powered through either the USB or an external power source.

3.3.2 Node MCU:

The Node MCU is a popular open-source IoT development board that is based on the ESP8266 Wi-Fi module. It integrates a microcontroller and a built-in Wi-Fi capability, making it ideal for smart home automation and other IoT applications requiring wireless communication. The board supports the Arduino IDE programming environments, providing flexibility for developers. The key specifications of Node MCU include an operating voltage of 3.3V and a microcontroller clock speed of 80 MHz (expandable to 160 MHz). It features 11 digital I/O pins, 1 analog input pin (0 to 3.3V), and a USB-to-serial converter for easy programming. The built-in Wi-Fi (IEEE 802.11 b/g/n) allows seamless connectivity to local networks and cloud services. Node MCU also supports protocols such as I2C, SPI, and UART, making it suitable for a wide range of sensor and device integrations.

3.3.3 Motion Sensor:

Motion sensors are critical components in smart home systems, enabling automated control of lights, security alarms, and other devices based on detected movement. PIR sensors detect infrared radiation emitted by warm objects, such as humans or animals, within their field of view.

3.3.4 Temperature Sensor:

Temperature sensors are widely used in smart home automation for monitoring and controlling environmental conditions. These sensors detect and measure temperature levels, providing crucial data to heating, ventilation, and air conditioning (HVAC) systems to maintain optimal indoor climates. In this project, temperatures sensors help regulate energy consumption by dynamically adjusting devices based on temperature fluctuations.

3.3.5 Solar Panel:

A solar panel is a device that converts sunlight into electricity using photovoltaic (PV) cells made of semiconductor materials, typically silicon. When sunlight strikes the cells, it generates direct current (DC) electricity, which can be used directly or converted to alternating current (AC) for home and industrial use.

3.3.6 Fingerprint Sensor:

A fingerprint sensor is a biometric device that captures and analyzes unique fingerprint patterns for identification and authentication. It works by scanning the ridges and valleys of a fingertip to create a digital representation, ensuring secure access to systems or devices. The sensor integrates a durable optical scanner with an advanced image- processing algorithm to enhance performance even under varying environmental conditions. It features a UART interface for seamless communication with microcontrollers or computers, making it ideal for access control, attendance systems, and IoT based automation.

3.3.7 RFID Reader:

An RFID (Radio Frequency Identification) reader is a device used to read data stored in RFID tags, which are small electronic devices containing unique identification information. These tags communicate with the RFID reader using radio waves. The RFID reader emits a signal that activates the tag, which then transmits its stored information back to the reader. The reader processes the data sent from the tag and transmits it to a computer system or database for further processing.

3.3.8 Relay Module:

A relay module is an electrically operated switch widely used in electronic and electrical circuits for controlling high-power devices with low-power signals. It consists of an electromagnet, a movable armature, a set of contacts, and a spring. When a small current flows through the coil of the electromagnet, it generates a magnetic field that moves the armature to either open or close a connected circuit. This mechanism allows the relay to act as a bridge between low-power control systems (like microcontrollers or logic circuits) and high-power devices (such as motors, lights, or heaters) without direct electrical connections between them.

3.3.9 Lithium-ion battery:

Lithium-ion batteries are widely used rechargeable power sources known for their high energy density, low self-discharge rate, and long lifespan. They consist of a cathode (typically lithium metal oxide), an anode (usually graphite), an electrolyte for ion transfer, and a separator to prevent short circuits. During charging, lithium ions move from the cathode to the anode, and during discharging, they flow back to generate electricity.

3.3.10 Power converter:

A power converter is an electrical device used to change the characteristics of electrical energy to match the requirements of a specific load or system. It typically transforms voltage levels, frequency, or current type (AC to DC or vice versa). Converters integrate advanced control technologies to enhance performance, reduce energy loss, and ensure protection against overvoltage, short circuits, and thermal issues.

3.3.11 Power down Module:

A power-down module is an electronic component or circuit designed to reduce power consumption in devices by efficiently managing power states during periods of inactivity or low demand. It typically works by disabling or reducing power to non-essential parts of a system while keeping critical functions operational. Power-down modules are integral in battery-operated and energy-conscious systems, such as portable electronics, IoT devices, and industrial equipment, where optimizing power usage directly impacts battery life and efficiency.

3.3.12 Current and Voltage indicator:

A current and voltage indicator is an electrical measuring device used to display real-time values of current (in amperes) and voltage (in volts) within a circuit. These indicators provide critical information about the performance and safety of electrical systems by ensuring that voltage and current levels remain within specified limits. They are commonly integrated into control panels, power supplies, battery management systems, and industrial machinery, offering visual or digital readouts for easy monitoring. Some advanced indicators also include alarms or warning signals to alert users to abnormal conditions such as overloads or under voltage.

3.3.13: Software Arduino IDE:

The software is developed using Arduino IDE and code is written in C for Arduino. DHT libraries are used for sensors like LDR, PIR to integrate sensors and I2C and SPI communication protocol is used. Sensors data is used to turn ON/OFF to optimize energy usage based on sensor inputs and energy availability. Software tracks real time solar energy generation, battery charge levels and grid usage. The algorithm used to manage energy based on demand, availability and time of day. MQTT or HTTP protocols are used for cloud platform and can be interfaced with mobile and web applications. Debugging can be done using serial communication. Low power is used and used for error handling and also gives alert messages during malfunction.

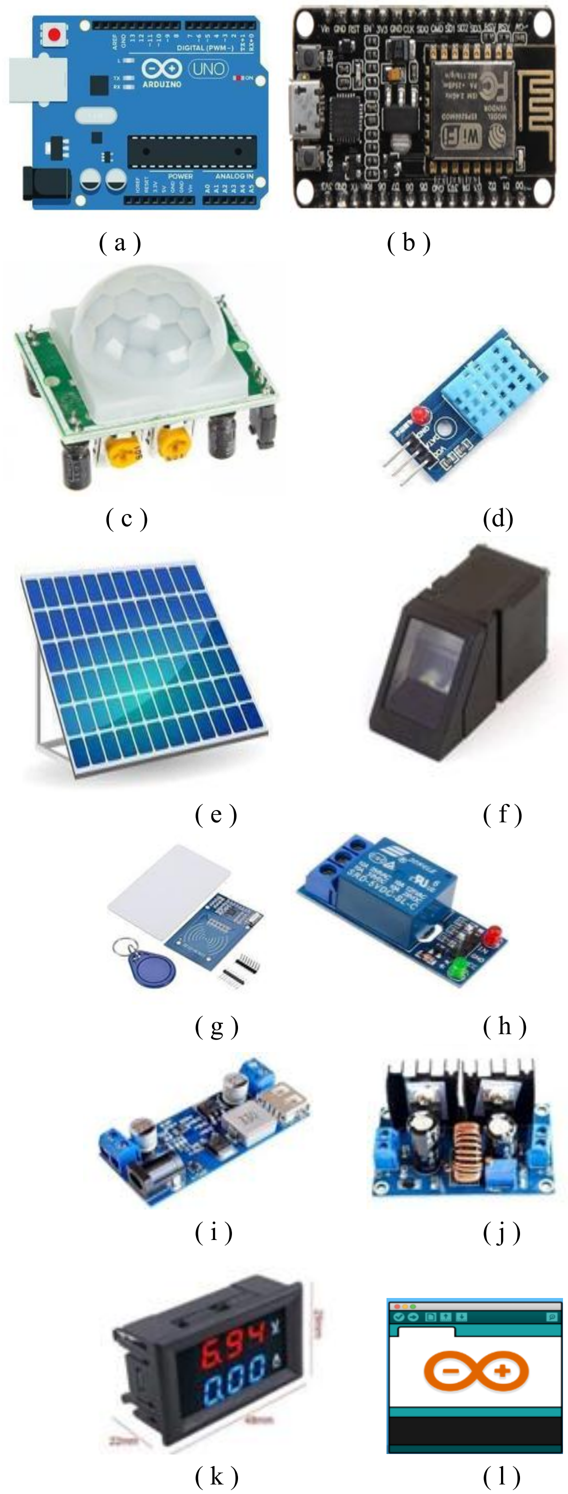
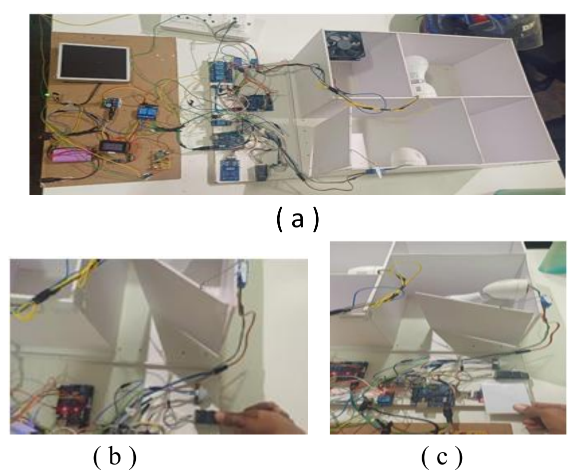
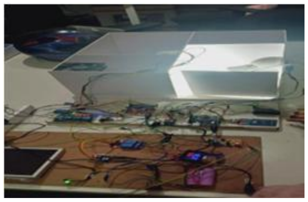


Fig 3: Components: (a) Arduino Uno (b) Node MCU (c) Motion Sensor (d) Temperture sensor (e) Solar panel (f) Fingerprint sensor (g) RFID reader (h) Relay (i) Power converter (j) Power down Module (k) Voltage and current indicator (l) Arduino IDE

IV. RESULT

This system illustrates a home automation system designed with energy efficiency and sustainability in mind. At its core, the system leverages solar power as its primary energy source, supplemented by an AC power supply for backup and during periods of insufficient sunlight. The solar panel generates DC power, which is then used to operate the various components of the system. The system's intelligence lies in its ability to automate home functions and manage energy consumption efficiently. Sensors like temperature and motion detectors gather real-time data, which is processed by the Arduino Uno microcontroller. This data is then used to control devices like fans and lights, optimizing energy usage based on environmental conditions and occupancy. Furthermore, the system integrates cloud connectivity via an ESP8266 module. This enables remote access and control through a mobile cloud platform. Users can monitor energy usage in real-time, access historical data, and remotely control various aspects of the system. For example, users can adjust temperature settings, control lights, and even check the status of devices from anywhere with an internet connection. This level of control allows for fine-tuning energy management strategies and maximizing the utilization of harvested solar energy.





(d)

Fig 4: (a) Proposed system (b) Fingerprint recognition (c)RFID reader (d) Motion detection Fig.4(b) shows fingerprint-based door lock system. If its match with its data it will open. if it's not match with its data, it will not open. Fig.4 (c) shows RFID based door lock system. If its match with its data it will open. if it's not match with its data, it will not open. Fig 4(d) shows the motion detection. If a motion sensor detects the movement, bulb will glow. If movement is not detected, bulb will not glow.

V. CONCLUSION & FUTURE SCOPE

IoT-based smart home automation using solar energy offers a sustainable and cost- effective pathway to a more energy-efficient and environmentally friendly future. By integrating advanced technologies and intelligent systems, we can create homes that are not only comfortable but also environmentally responsible. The integration of IoT home automation with optimal energy harvesting using solar technologies represents a powerful solution for creating more efficient, sustainable, and intelligent living environments. IoT enables seamless connectivity and automation of home systems, enhancing convenience, security, and energy management. By combining this with solar energy harvesting, home owners cannot only reduce reliance on non-renewable energy sources but also optimize their energy consumption in real time.

The future of home automation envisions a seamless integration of AI and machine learning. Predictive maintenance will become commonplace, with systems anticipating and preventing appliance failures. Personalized comfort will be the norm, as AI learns individual preferences and adjusts settings accordingly. Moreover, energy optimization will be driven by AI algorithms that analyze usage patterns, identify areas for improvement, and suggest adjustments to reduce consumption. Increased interoperability and standardization will also be key, allowing for seamless integration of devices from various manufacturers and creating a more unified user experience. Advancements in renewable energy harvesting will further revolutionize the field. Increased solar panel efficiency, coupled with improved energy storage solutions, will ensure a reliable and sustainable power supply. Innovative harvesting methods, such as piezoelectric materials and thermoelectric generators, will explore new avenues for capturing energy from everyday activities. Furthermore, a strong focus on sustainability and environmental impact will guide future developments. Smart grid integration, carbon footprint tracking, and robust cyber security measures will be crucial in creating a future where home automation contributes to a greener and more sustainable living environment.

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