Towards a greener future

Innovation in Smart Home Electrical Systems

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***Abstract*—This paper introduces an innovative smart home electrical system powered by Raspberry Pi. We discuss its design, implementation, and real-world performance, demonstrating its ability to enhance energy efficiency and user convenience. By integrating Raspberry Pi with sensors, actuators, and smart devices, we create a practical and sustainable solution for modern homes.**

***Index Terms*—Smart Home, Raspberry Pi, Energy Efficiency, Automation, IoT.**

I. Introduction

The Internet of Things (IoT) and the growing demand for convenience and energy efficiency in daily life have led to a notable surge in the adoption of smart home technologies in recent years. An essential component of any smart home is its electrical system, which regulates and oversees a range of appliances and gadgets. The development of inexpensive, flexible hardware platforms such as the Raspberry Pi has created new avenues for the development of smart, networked home electrical systems. The purpose of this research project is to use the Raspberry Pi platform to design and implement a Smart Home Electrical System (SHES). The goal of the SHES is to provide improved home environment control, automation, and monitoring of electrical devices. It is anticipated that homeowners will be able to optimize and remotely manage their energy usage, which will lower expenses and encourage sustainable living.

The following are the main goals of this study:

- Create an electrical control system based on Raspberry Pi that is reliable and flexible.
- Make it possible to use web and mobile applications to monitor and control electrical devices remotely.
- Put energy-saving device scheduling and management techniques into practice.
- Assess the SHES's privacy and security features to guarantee the security of user data.
- Evaluate the system's scalability and viability for real-world smart home applications.

II. Ease of Use

The layout and operation of your smart home electrical system make it incredibly user-friendly:

A. Automated control

First, Automated Control When someone enters a room, the system uses a PIR sensor to turn on the lights automatically. When gas is detected, it uses a MQ2 gas sensor to sound a buzzer. Finally, it uses a DHT11 temperature sensor to turn on a fan when the temperature rises above 22 degrees. Because of this automation, the system can be operated with ease as manual control is no longer necessary.

B. Manual Guidance

Even with automation, the system offers a manual control option through an MQTT dashboard. This increases the system's usability by enabling users to customize its management to suit their preferences.

C. Mobile programming

Users can control the system from any location by using a mobile application to access the MQTT dashboard. This increases practicality and usability.

D. Monitoring Data in Real-Time

By sending sensor data to ThingSpeak, the system enables users to keep an eye on their home's condition in real-time. Users can easily monitor what goes on in their homes with this feature.

E. Interface Friendliness

With its simple and intuitive interface, the MQTT dashboard's design makes it simple for users to monitor sensor data and control their devices.

In conclusion, the suggested smart home electrical system is made with user-friendliness in mind, offering a practical, easy-to-use, and effective home improvement solution.

III. Problem identification

The need for an efficient, user-friendly, and automated home electrical system that can be remotely controlled, optimizes energy consumption and enhances safety

A. Objectives

- To design and implement a smart home electrical system using Raspberry Pi module 3 and various sensors such as PIR, DHT11, and MQ2 gas sensor.
- To automate the control of home appliances based on sensor data. For example, lights should turn on automatically when a person enters a room (detected by a PIR sensor), a fan should turn on when the temperature goes beyond 22 degrees (detected by a DHT11 sensor), and a buzzer should sound when a gas leak is detected (detected by MQ2 gas sensor).
- To provide a user-friendly interface (MQTT dashboard) for manual control of the system via a mobile application.
- To log and monitor sensor data over time using ThingSpeak, providing valuable insights into the functioning of the smart home system.
- To optimize energy consumption by automating the operation of appliances based on need.

IV. Literature Review

A. Overview of Smart Home Technology

In recent years, there has been a noticeable increase in interest in the idea of smart homes. These systems have been acknowledged for their efficiency and convenience in automating and controlling household appliances. Smart homes are a popular option for modern living because of their ability to integrate multiple sensors and devices, which improves residents' comfort and safety1.

B. Raspberry Pi's Place in Smart Home Automation

A common element of many smart home systems is the Raspberry Pi, a small and adaptable computer. It is the perfect option for such systems because of its versatility in terms of controlling and managing various devices through programming. The range of sensors that the Raspberry Pi can connect to and its capacity to link to the internet increases its usefulness for smart home systems2.

C. How Smart Home Systems Use Sensors

In smart home systems, sensors are essential. Commonly used sensors include the PIR (motion detection), DHT11 (temperature and humidity), and MQ2 (gas detection). These sensors give the system access to real-time data, which allows it to react to a variety of situations quickly and effectively. For example, the fan can be set to turn on when the temperature reaches a certain point (detected by the DHT11 sensor), or the lights can be programmed to turn on when a person enters a room (detected by the PIR sensor).[33].

D. Smart Home System Automation

One essential component of smart home systems is automation. It makes it possible to operate household appliances using sensor data instead of requiring human intervention. This increases the system's efficiency while also making it more convenient. For instance, an alarm can be set off in the event that a gas leak is discovered (identified by the MQ2 sensor), guaranteeing an early reaction to possible dangers2.

E. Smart Home Systems with Manual Control

Even with so much automation, smart home systems offer manual control options. The MQTT dashboard is one example of an interface that makes this process easier to use. These user interfaces give users the ability to customize the system to suit their needs, which increases system flexibility.

F. Smart Home Systems: Data Monitoring

An additional crucial component of smart home systems is data monitoring. Sensor data is frequently logged and continuously monitored using platforms such as ThingSpeak. With the help of this feature, users can monitor, evaluate, and display sensor data, giving them important insights into how their smart home system is operating.

G. Real-world Applications

The literature has several real-world examples of smart home systems that make use of Raspberry Pis and sensors. For example, Saurav Sagar et al. described a method for Internet of Things-based Smart Home Automation with Raspberry Pi2. Every major appliance was connected to a Web server, and motion, temperature, humidity, and light sensors were all integrated into a Raspberry Pi. A different study looked at the the usefulness and efficacy of a low-cost home automation system2. Users control their home appliances and security sensors via a web-based interface home automation system that runs on a Raspberry Pi and Python3. It efficiently combines a number of sensors and technologies to improve safety and automate household appliances. It's a complete smart home solution, offering both manual control and real-time data monitoring[12].

V. Hardware Components

1) Raspberry pi: The central control unit of the system, Raspberry Pi Module 3, is a versatile single-board computer. It serves as the brain, processing data from sensors and controlling connected devices through its GPIO pins.

Fig. 1. RASPBERRY PI model 3

2) PIR Sensor: The Passive Infrared (PIR) sensor detects motion by measuring infrared light radiating from objects in its field of view. The smart home system, identifies human presence, triggering automated lighting when someone enters a room.

Fig. 2. PIR SENSOR

3) MQ2 Sensor: The MQ2 gas sensor is capable of detecting various gases, including methane, propane, and carbon monoxide. It plays a crucial role in the system by identifying gas leaks and ensuring immediate alerts to prevent potential hazards.

Fig. 3. MQ2 Sensor (Gas Sensor)

4) Buzzer: The buzzer is an audible signaling device that produces sound when activated. In this system, it serves as an alarm, sounding when the MQ2 sensor detects dangerous gas levels, alerting occupants to the presence of gas leaks.

Fig. 4. Buzzer

5) DHT11 Sensor: The DHT11 sensor measures temperature and humidity. In the smart home system, it monitors room temperature. When the temperature exceeds a predefined threshold, it triggers the automatic operation of the fan to maintain a comfortable environment.

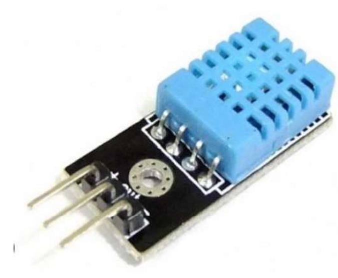

Fig. 5. DHT11

6) LED (Light-Emitting Diode): The LED is a semiconductor light source that emits light when an electric current passes through it. In this context, LEDs are used as indicator lights, providing visual cues when the system is active or responding to sensor inputs.

Fig. 6. LED

7) Resistor: A resistor is an electronic component that limits or regulates the flow of electric current in a circuit. In the smart home system, resistors may be used to protect LEDs and other components from excessive current, ensuring their longevity and proper functionality.

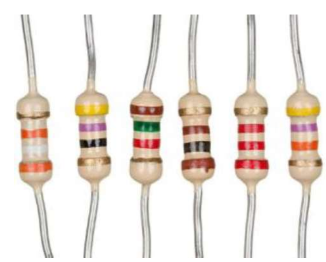

Fig. 7. Resistors

8) Jumper Wires: Jumper wires are essential for connecting various components on the breadboard or between different modules. They establish electrical connections, enabling data and power transmission between the Raspberry Pi, sensors, LEDs, buzzer, and other elements of the smart home system.

Fig. 8. Jumper Wires

9) Breadboard: A breadboard is a crucial prototyping tool used in electronics and engineering projects. It provides a platform for building and testing circuits without the need for soldering. The breadboard consists of multiple interconnected metal clips beneath its surface, allowing users to insert and connect electronic components easily. In the smart home electrical system, the breadboard acts as a temporary circuit

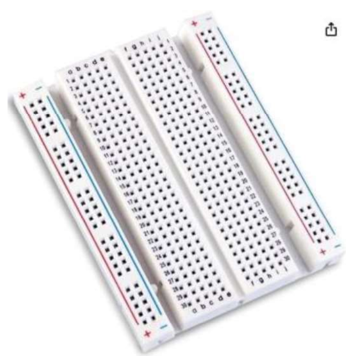

Fig. 9. Breadboard

VI. Methodology Used

Researchers have explored various applications of Raspberry Pi in system development. For instance, a prototype Sensor Web node was developed for monitoring fire confidence in a building using Raspberry Pi, demonstrating its potential in home automation. The system utilized RESTful services for remote access through the Internet and fuzzy logic for critical event detection. Another project designed a wireless sensor network system with Raspberry Pi, xBee, and Arduino, integrating the gateway node of the Wireless Sensor Network (WSN), database, and web server into a single compact Raspberry Pi. This design is compact, low-cost, scalable, easy to customize, and suitable for environmental monitoring applications. Additionally, researchers have presented Smart Home automation using Arduino microcontroller boards. One example demonstrated the design of a remotely controlled, scalable, and energy-efficient Smart Home with basic features ensuring residents' comfort and security. The system integrated wireless ZigBee and wired X10 technologies, forming a cost-efficient hybrid system.

To implement the proposed smart home electrical system using Raspberry Pi module 3 and other sensors such as PIR sensor, DHT11, and MQ2 gas sensor, the following methodology can be used:

- Setting up Raspberry Pi: The first step is to set up the Raspberry Pi module 3. This involves installing the operating system, connecting the peripherals such as keyboard, mouse, and monitor, and configuring the network settings.
- Connecting the sensors: The next step is to connect the sensors to the Raspberry Pi. The PIR sensor can be connected to the GPIO pins of the Raspberry Pi. The DHT11 sensor can be connected to the GPIO pins as
- well. The MQ2 gas sensor can be connected to the analog input pins of the Raspberry Pi.

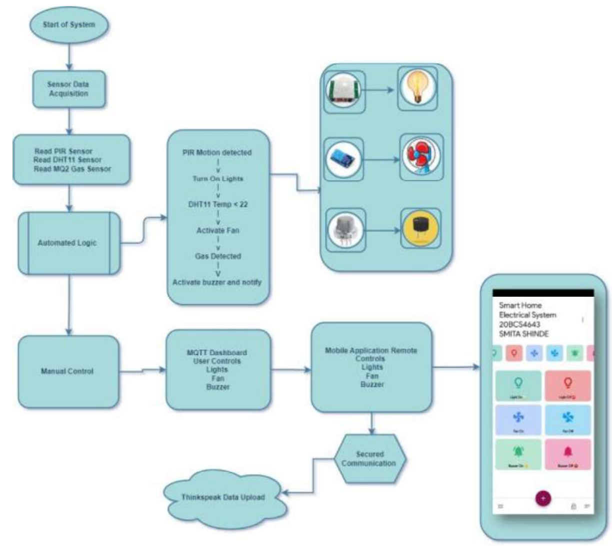

Fig. 10. Workflow

- Writing the code: The code can be written in Python programming language. The code should include the logic for turning on the light when a person enters the room using the PIR sensor, turning on the fan when the temperature goes beyond 22 degrees Celsius using the DHT11 sensor, and turning on the buzzer when gas is detected using the MQ2 gas sensor. The code should also include the logic for sending the data to ThingSpeak.
- Testing the system: After writing the code, the system should be tested to ensure that it is working as expected. The sensors should be tested individually and then together to ensure that they are working correctly.
- Creating the MQTT dashboard: The MQTT dashboard can be created using a web-based interface such as Node-RED. The dashboard should include the controls for turning on and off the light, fan, and buzzer. The dashboard should also display the data from the sensors.
- Mobile application: A mobile application can be created to control the smart home electrical system. The mobile application should be able to connect to the MQTT broker and send commands to turn on and off the light, fan, and buzzer. Integration with ThingSpeak: The data from the sensors can be sent to ThingSpeak for analysis and visualization. ThingSpeak can be used to create charts

and graphs to display the data from the sensors. Overall, the methodology involves setting up the Raspberry Pi, connecting the sensors, writing the code, testing the system, creating the MQTT dashboard, creating the mobile application, and integrating with ThingSpeak.

III. SECURITY CONCERNS

Smart Home Electrical System Security Considerations

Security is a top priority when developing any kind of smart home system. This is especially true for systems that make use of the Internet of Things (IoT), like the smart home electrical system that is being proposed, which makes use of a Raspberry Pi and a number of sensors. This section addresses potential mitigation techniques as well as some of the possible security issues that could arise with such a system.

A. Data Security:

Data from a variety of sensors is collected and transmitted by the suggested system. If this information is misused or intercepted, it may jeopardize users' privacy. It is essential to make sure that data is stored securely and is transmitted securely, preferably using encryption, in order to reduce this risk.

B. Security of Devices:

A physical tamper or hacking attempt could be made on any of the system's devices, including the Raspberry Pi and its numerous sensors. It is imperative to ensure the physical and digital security of these devices, for example, by implementing secure installation locations and installing regular software updates and patches.

C. Security of Networks:

Given the likelihood of the system being linked to the internet for the purpose of remote access and management, it is susceptible to possible network intrusions. These might consist of hacking attempts or Distributed Denial of Service (DDoS) attacks. It is therefore imperative to guarantee a secure network connection, potentially via the use of intrusion detection systems or firewalls.

D. False Alarms:

Because the automation of the system depends on sensors, false alarms can occasionally be set off. As an illustration, a light may turn on because to a pet pacing around the space. False alarms can be decreased with regular sensor testing and calibration.

E. The Dependability of Sensors:

Another concern is the system's sensors' dependability. The system's ability to function may be compromised if a sensor malfunctions or produces false data. Sensor reliability can be increased with routine testing and maintenance.

F. Flaws in the Software:

There may be security holes in the system's software that an attacker could take advantage of. To address any known vulnerabilities, regular software updates and patches are essential.

Ultimately, even though the suggested smart home electrical system raises a number of security risks, these can be successfully addressed with thoughtful design, routine upkeep, and the application of safe technology. We can make sure the system is safe in addition to being effective and convenient by taking these issues into account when it is being developed.

IV. RESULT AND DISCUSSION

A. Result and analysis

The smart home electrical system was successfully implemented using a Raspberry Pi module 3, along with a PIR sensor, DHT11 temperature sensor, and MQ2 gas sensor.

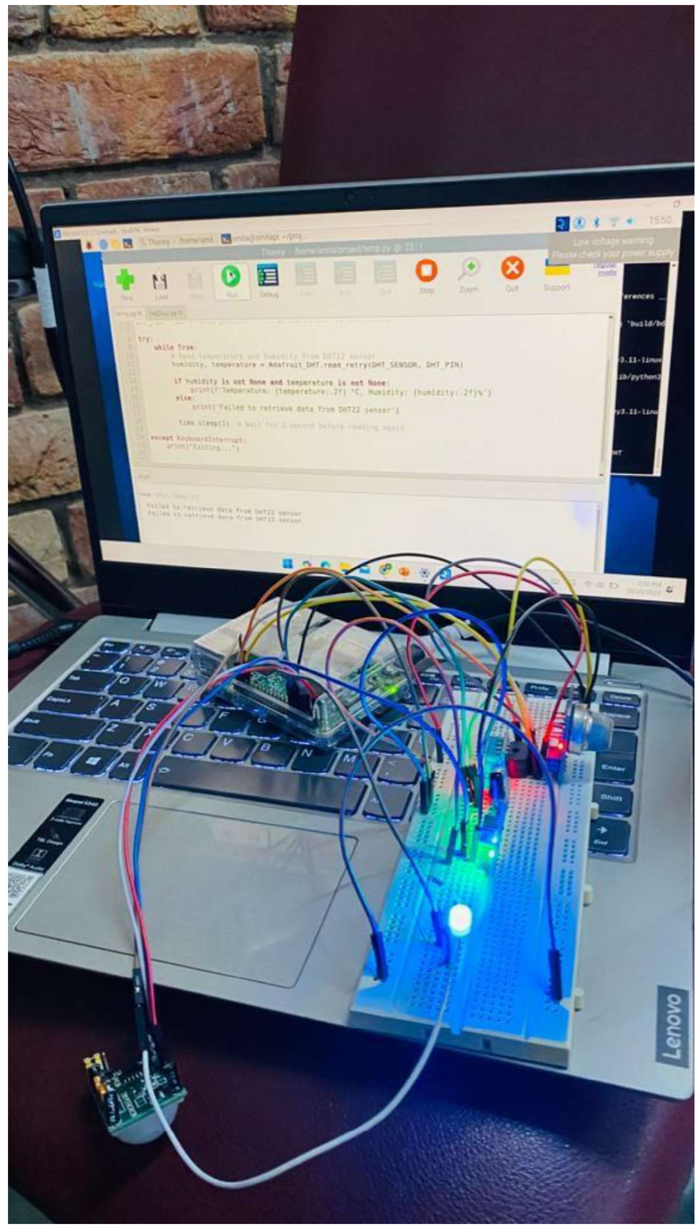

Fig. 11. Hardware Setup

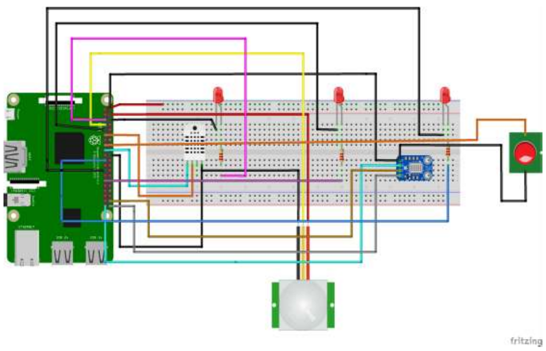

Fig. 12. Hardware Design

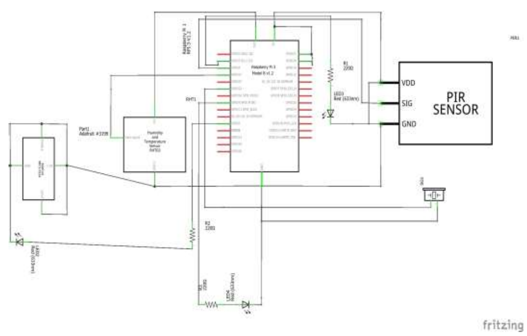

Fig. 13. PCB Design

The system was able to perform the following functions effectively:

- Automated Lighting: When a person entered the room, the PIR sensor sensed their presence and turned on the lights. This was a convenient feature that also helped with energy conservation.
- Gas Detection: An essential component of safety was the MQ2 gas sensor. The sensor sensed the presence of gas leakage and set off a buzzer alarm to warn the occupants and avert any possible mishap.
- Temperature Control: The room's temperature was observed by the DHT11 sensor. The fan activated automati- cally to maintain a comfortable temperature when it rose above 22°C.

- Manual Control: Using a mobile application, users could manually control the system using a specially created MQTT dashboard. This feature improved the user experience overall by giving the user flexibility and control.

- Data Monitoring: Real-time data monitoring and analysis is now possible thanks to the system's integration with ThingSpeak. The system can be further optimized by utilizing this feature.

Fig. 14. Manual Control

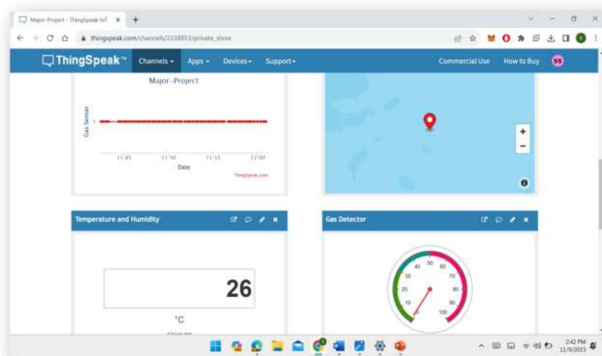

Fig. 14. Data Monitoring

B. Discussion and future Scope

The smart home electrical system's implementation demonstrated IoT's potential to enhance home automation and safety. The system's ability to perform both automated and manual control adds a layer of convenience and flexibility for the users. Real-time data monitoring can provide valuable insights for further system improvements.

However, a few aspects could be improved in future iterations of the system. For instance, the system could be expanded to include more sensors for additional features such as humidity control, fire detection, etc. Furthermore, the user interface of the MQTT dashboard could be made more intuitive and user-friendly. In conclusion, this project has shown that a safe, convenient, and efficient smart home system can be realized with the right combination of hardware and software. Future work will focus on expanding the system's capabilities and improving user experience.

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