Faculty of Computers and Information Technology (FCIT)

An Intelligent Energy Control System for Home

University of Tabuk

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at University of Tabuk or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"An Intelligent Energy Control System for Home"** was prepared by **Adel Salim Alatawi, Yousef Omer Alsilal, Abdulelah Saeed Alqahtani, Abdullah Saad Alshehri** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Computer Enginiering at University of Tabuk.

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ABSTRACT

The project, "An Intelligent Energy Control System for Home," addresses the critical issue of energy wastage contributing to climate change over the past two decades. As society increasingly relies on energy for powering household and workplace appliances and maintaining comfort levels, the resulting CO_2 emissions from power generation have escalated. Research suggests that a substantial portion—up to 40%—of these emissions can be attributed to energy consumption, with potential savings of about 20% achievable through more efficient energy usage practices. To combat this challenge, strategies such as real-time energy monitoring, behavior modification, and automated energy-saving scenarios have been proposed. The primary objective of the project is to monitor and remotely manage the energy consumption of household electrical appliances, providing users with insights into current usage patterns and enabling electricity consumption management based on individual preferences. By remotely controlling appliances and scheduling their operation, the system aims to optimize electricity usage within the home. Furthermore, the implementation of a smart energy consumption meter offers an effective means to accurately measure the energy consumption of various household appliances, further promoting energy efficiency.

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LIST OF ABBREVIATIONS

IECSH	An Intelligent Energy Control System for Home
AI	Artificial Intelligence
IoT	Internet of Things
ANNs	artificial neural networks
ICs	integrated circuits

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discusses the increasing demand for energy efficiency and sustainability in residential environments, leading to the development of an "Intelligent Energy Control System for Home." This system utilizes technologies like artificial intelligence, IoT, and data analytics to manage energy consumption autonomously, aiming to improve efficiency, reduce costs, and promote sustainability. The text also introduces research objectives, significance, and potential impacts on residential energy management practices.

1.2 Project Objectives

1. Utilize IoT technology to monitor home appliance energy use and display data on the "ubidots" front end.

2. Enable remote device management through ubidots.

1.3 Project Domain

The project primarily targets the environmental system and its preservation, as well as consumers and energy companies in terms of providing a smart and integrated system for energy control, which helps consumers save money and also helps energy companies withstand pressures.

1.4 Project Feasibility

In this section, we will estimate the time and number of team members for each task, as shown in Table 1. The project was divided into 9 phases, namely: Business Requirements, Functional Specifications, Technical Specifications, Data Analysis, Sensors, Circuit Design, Code and Module Testing, System Testing, and Deployment Arduino.

Table 1: Resources Table

<table>
<tr><th>RESOURCE</th><th>Team Resources</th><th>Estimated time</th></tr>
<tr><td>REQUIREMENTS</td><td>4</td><td>1 weeks</td></tr>
<tr><td>FUNCTIONAL SPECIFICATIONS</td><td>3</td><td>2 weeks</td></tr>
<tr><td>TECHNICAL SPECIFICATIONS</td><td>2</td><td>1 weeks</td></tr>
<tr><td>DATA ANALYSIS</td><td>4</td><td rowspan="2">2 weeks</td></tr>
<tr><td>ARDUIN SENSORS</td><td>3</td></tr>
<tr><td>WEB DEVELOPMENT</td><td>3</td><td>2 weeks</td></tr>
<tr><td>CODE AND UNIT TEST</td><td>3</td><td>1 weeks</td></tr>
<tr><td>SYSTEM TESTING</td><td>4</td><td>1 weeks</td></tr>
</table>

Through which all the project is distributed to all members and the quality of work is taken into account, and a periodic meeting will be held with all team members to discuss the course of work, the extent of the project’s achievement and verify the quality of the outputs.

1.6 Report’s Layout

The report of the Emergency system is discussed in five chapters,

- Chapter 1 contains an introduction to the project and its main objectives.
- Chapter 2 will discuss applications and explain the advantages and disadvantages of applications and compare them.
- Chapter 3 will present the project idea implementation plan using (use case, separation diagram, sequence diagram, activity diagram).
- Chapter 4 contains simple application design interfaces.
- Chapter 5 contains a recommendation and conclusion, and finally it will provide references to some of the sites that helped us gather information.

CHAPTER 2

BACKGROUND AND RELATED WORKS

2.1 Introduction

This chapter discusses the urgent need to manage energy consumption efficiently in residential areas, driven by demand for sustainable solutions. Researchers are exploring methodologies and technologies for intelligent energy control systems. It provides an overview of background information, focusing on advancements in residential energy management. By reviewing existing literature, it aims to establish a foundation for developing tailored systems. The chapter sets the stage for analyzing the proposed system by exploring key concepts and findings.

2.2 Introduction of IoT

The rapid development and implementation of smart and IoT (Internet of Things) based technologies have allowed for various possibilities in technological advancements for different aspects of life. The main goal of IoT technologies is to simplify processes in different fields, to ensure a better efficiency of systems (technologies or specific processes) and finally to improve life quality. Sustainability has become a key issue for population where the dynamic development of IoT technologies is bringing different useful benefits, but this fast development must be carefully monitored and evaluated from an environmental point of view to limit the presence of harmful impacts and ensure the smart utilization of limited global resource.

2.3 Related Works

Shareef, Ahmed, Mohamed, & Al Hassan (2018) conducted an intriguing study examining load scheduling controllers that integrate various AI techniques. These techniques include artificial neural networks (ANNs), fuzzy logic, adaptive neural fuzzy inference, and heuristic optimization As shown in Figure 1. Their research delved into the efficacy of these controllers in managing and optimizing energy consumption within residential settings [1].

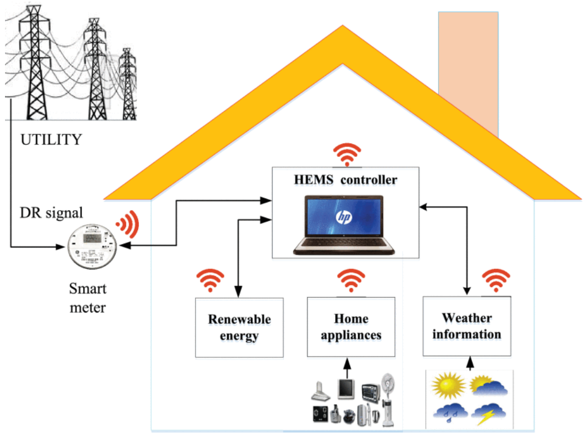

Figure 1 Architecture of home energy management **[1]**

Al-Ani & Das (2022) conducted a comprehensive survey focusing on the utilization of Reinforcement Learning (RL) and Deep Reinforcement Learning (DRL) techniques in home energy management systems (HEMS). Their study encompassed an analysis of multiple RL algorithms, their specific objectives, and the diverse testing environments in which they were evaluated. Despite the potential shown by RL and DRL methods, their research revealed a significant bottleneck: the sluggish training speed of these algorithms As shown in Figure 2. This limitation has led to only 12% of these approaches being tested in real-world scenarios [2].

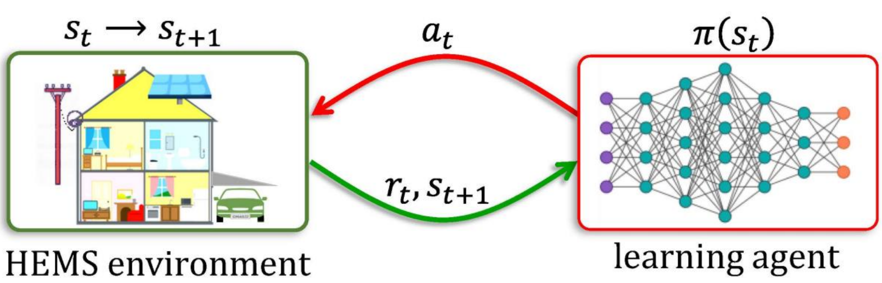

Figure 2 Theory and Applications in HEMS [2]

Similarly, Mason & Grijalva (2019) conducted an exhaustive review of RL applications within the realm of autonomous building energy management. Their analysis underscored the substantial energy efficiency enhancements achievable in domestic environments through the adoption of RL algorithms. Notably, they observed a prevailing preference for DRL algorithms over their RL counterparts. However, the researchers highlighted a notable gap in the field: while many RL approaches exhibit promising results within simulation platforms, their deployment in real-world scenarios remains limited. This limitation emphasizes the critical importance of accurate simulation design before practical implementation [3].

An illustrative example of a DRL algorithm is presented by Lissa, et al (2021). In their study, they devised an innovative algorithm designed specifically for indoor and domestic hot water temperature control. The primary objective of their research was to reduce total energy consumption by optimizing the utilization of solar-produced energy. Through their work, they aimed to bridge the gap between theoretical advancements in DRL and practical applications in real-world energy management systems As shown in Figure 3 [4].

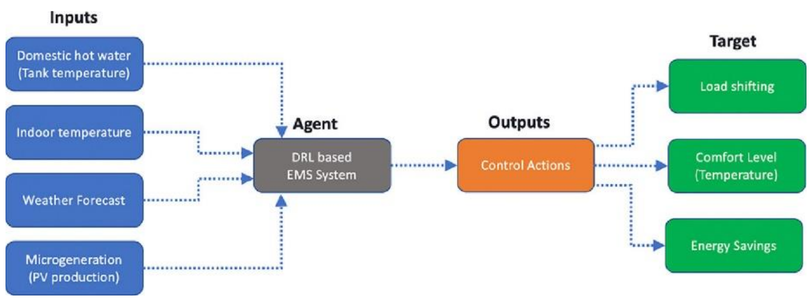

Figure 3 Deep reinforcement learning for home energy **[4].**

Leitao, Gil, Ribeiro, & Cardoso (2020) conducted an in-depth survey delving into the realm of home energy management systems, with a particular focus on demand-side management strategies as shown in Figure 4. These strategies encompass a wide array of techniques aimed at curbing energy costs and bolstering efficiency directly from the consumer's standpoint. Additionally, the researchers explored various scheduling methodologies prevalent in the field, categorizing them into five distinct groups for clearer understanding and analysis [5].

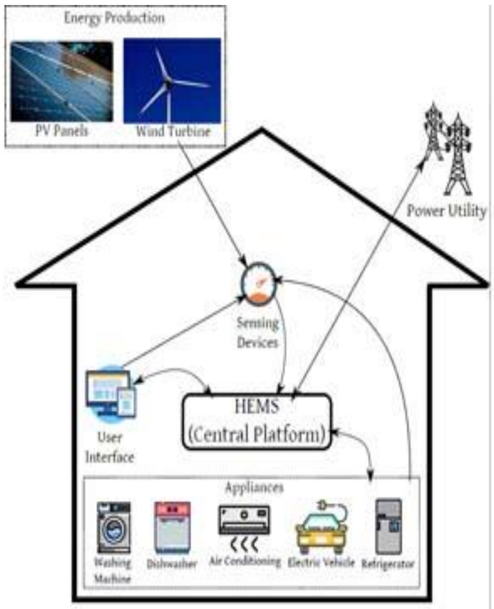

Figure 4 A Smart home with some of its main features **[5].**

In a complementary vein, Mir, Abbasi, Mir, Kanwal, & Alamri (2021) expanded upon the existing discourse by introducing a plethora of additional energy-saving methodologies. These encompassed a diverse range of approaches, spanning from statistical models to cloud computing-based solutions, fog computing, smart metering-based architectures, and innovative solutions inspired by the IoT as shown in Figure 5 [6].

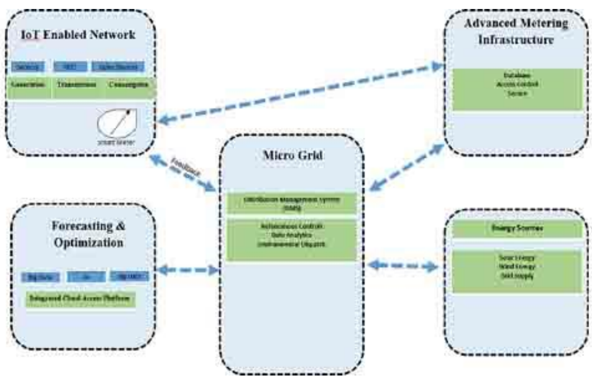

Figure 5 A self-managing energy system architecture **[6]** .

Turning to the insightful work of Beaudin & Zareipour (2017) they meticulously reviewed the methodologies employed for modeling the multifaceted aspects of residential energy management systems. Their comprehensive analysis not only addressed the intricacies inherent in such systems but also provided a comprehensive overview of scheduling techniques. These techniques were systematically classified into three distinct categories: mathematical programming, meta-heuristic search, and heuristic scheduling, each offering unique benefits and applications in the domain [7].

In a more recent study Ali, Prakash, Hossain, & Pota (2021) shed light on the vast array of research opportunities that stem from the unresolved challenges within the field. These encompassed a wide spectrum of emerging trends and technologies, including blockchain-enabled IoT platforms for distributed energy management, deep learning models tailored for the handling and analysis of extensive energy data sets, peer-to-peer energy trading, demand-side energy management strategies, context-aware pervasive future computing methodologies, resilience-oriented energy management approaches, forecasting models for energy consumption, user comfort optimization, real-time feedback systems, and the burgeoning field of Internet of Energy (IoE)-based energy management. Through their analysis, they emphasized the immense potential for innovation and advancement within the domain, offering a roadmap for future research endeavors [8].

Despite this, we have created a comparison table that shows the advantages and disadvantages of each of the previous research, as shown in Table 2.

Table 2 Advantages and disadvantages of previous research

Research	Advantages	Disadvantages
(Shareef, Ahmed, Mohamed, & Al Hassan, 2018)	Integration of various AI techniques such as artificial neural networks (ANNs), fuzzy logic, and heuristic optimization offers versatile solutions for energy management.	Limited scope in comparison to other studies, focusing primarily on load scheduling controllers without addressing broader energy management aspects.
(Al-Ani & Das, 2022)	Analysis of multiple RL algorithms and their objectives helps in understanding their suitability for different scenarios.	Sluggish training speed of RL and DRL algorithms limits practical deployment, with only a small percentage of approaches tested in real-world scenarios.
(Mason & Grijalva, 2019)	Substantial energy efficiency enhancements achievable through the adoption of RL algorithms in autonomous building energy management.	Deployment of RL approaches in real-world scenarios remains limited despite promising results in simulation platforms.
(Lissa, et al., 2021)	Innovative DRL algorithm designed for indoor and domestic hot water temperature control aims to optimize energy consumption, particularly from solar-produced energy.	Limited focus on broader energy management aspects beyond hot water temperature control.
(Leitao, Gil, Ribeiro, & Cardoso, 2020)	In-depth survey explores demand-side management strategies aimed at curbing energy costs and bolstering efficiency from the consumer's standpoint.	Lack of specific focus on AI or advanced techniques for energy optimization.
(Mir, Abbasi, Mir, Kanwal, & Alamri, 2021)	Introduction of a wide range of energy-saving methodologies, including cloud computing-based solutions and IoT-inspired innovations, expands the discourse on energy management.	Limited depth in the exploration of each methodology due to the broad scope of the study.
(Beaudin & Zareipour, 2017)	Meticulous review of methodologies employed for modeling residential energy management systems offers comprehensive insights.	Lack of emphasis on emerging AI or advanced techniques for energy optimization.
(Ali, Prakash, Hossain, & Pota, 2021)	Identification of numerous research opportunities in energy management, including blockchain-enabled IoT platforms and deep learning models, offers a roadmap for future endeavors.	Broad spectrum of topics covered may result in a lack of depth in the exploration of each opportunity.

2.4 Chapter Summary

In summary, the review of previous works has provided valuable insights into the current state of research in the field of home energy control systems. The studies discussed have highlighted various methodologies, technologies, and approaches utilized to address the challenges of energy consumption and management within residential settings. While many studies have made significant contributions to the field, there remain several gaps and areas for further investigation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology chapter serves as a crucial component in any research or development project, providing a comprehensive overview of the approach taken to achieve the project's objectives. In the case of "An Intelligent Energy Control System for Home," the methodology chapter outlines the specific methodology employed throughout the development process. In this introduction to the methodology chapter, we highlight the utilization of the waterfall methodology as the primary approach in the system's development. For the development of the "Intelligent Energy Control System for Home," Figure 6 the waterfall methodology was chosen due to its structured and systematic approach, which aligns well with the project's scope and objectives. By adhering to a sequential progression of phases, the waterfall methodology enables a clear delineation of project tasks, facilitates thorough documentation at each stage, and ensures a methodical approach to problem-solving and decision-making [9].

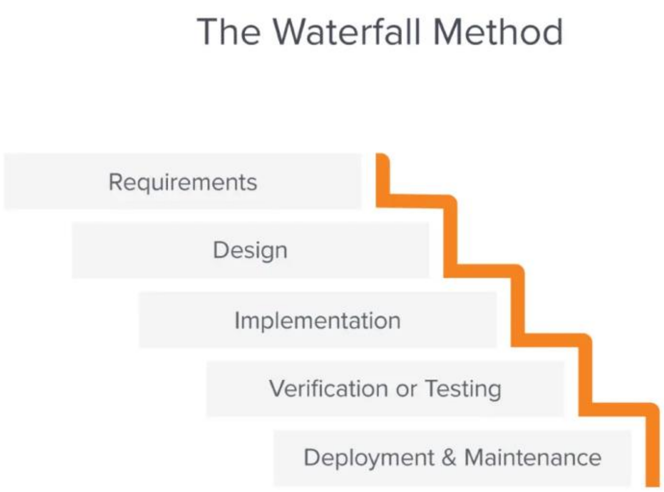

Figure 6 waterfall methodology [9].

3.2 Requirement

3.2.1 Functional Requirements:

- User Authentication:

  - The system shall provide secure user authentication mechanisms, including username/password and biometric authentication.

- Energy Monitoring:

  - The system shall monitor energy consumption in real-time, including electricity, gas, and water usage.

- Remote Access:

  - The system shall provide remote access capabilities, allowing users to monitor and control energy usage from anywhere via web or mobile applications.

3.2.2 Non-Functional Requirements:

- Performance:

  - The system shall be responsive and capable of handling simultaneous user interactions and data processing tasks efficiently.

- Security:

  - The system shall implement robust security measures to protect user data, including encryption, authentication, and authorization mechanisms.

- Reliability:

  - The system shall be reliable and available 24/7, with minimal downtime for maintenance or upgrades.

- Scalability:

  - The system architecture shall be scalable to accommodate future growth in users, devices, and data volume.

4. User Interfaces:

- Web Interface:
- The system shall provide a web-based interface accessible via standard web browsers.
- The web interface shall be intuitive, user-friendly, and responsive across different devices and screen sizes.

5. System Integration:

- The system shall integrate with existing energy infrastructure, including smart meters, sensors, and IoT devices, to collect real-time energy data.
- The system shall support interoperability with third-party energy management systems and platforms through standard protocols and APIs.

3.3 Design

3.3.1 System Architecture:

- The system architecture shall follow a client-server model, with a centralized server responsible for data processing, analytics, and control logic.
- Client applications, including web and mobile interfaces, shall communicate with the server over secure channels to access system features and functionalities.

3.3.2 Hardware Components:

- The system shall utilize a combination of hardware components, including:
- Actuators such as relays and smart switches for controlling energy-consuming devices.
- Communication modules such as Wi-Fi or Ethernet shields for connecting to the internet and the central server.

3.3.3 Software Components:

- The server shall handle user authentication, data storage, real-time data processing, and integration with external services and APIs.
- The system shall utilize a MYSQL database to store user profiles, device configurations, historical energy data, and system logs.

3.3.4 Communication Protocols:

- Secure communication channels shall be established using SSL/TLS encryption to protect sensitive data during transmission over the internet.

3.3.5 User Interface Design:

- The user interface shall be designed with a focus on usability, accessibility, and aesthetics, following principles of responsive web design and mobile app design.

3.3.6 Integration and Interoperability:

- The system shall support integration with third-party smart home devices and platforms, including smart thermostats, lighting systems, and voice assistants.

3.3.7 Security and Privacy:

- Robust security measures shall be implemented at various levels of the system, including data encryption, access control, and intrusion detection.
- User data shall be protected according to industry standards and regulations, with privacy controls and consent mechanisms provided to users.

3.4 Implementation

3.4.1 Backend Server Implementation

- Set up a cloud-based server environment using a platform such as apache.
- Develop server-side APIs for user authentication, data storage, and system control functionalities.

3.4.2 Database Setup

- Choose a database solution based on project requirements, such as MySQL, or Firebase Realtime Database.

3.4.3 Frontend Application Development

- Design user-friendly dashboards and control panels for monitoring energy usage, controlling devices, and accessing system settings.

3.4.4 Hardware Integration

- Set up NodeMCU or similar microcontrollers to interface with sensors (e.g., energy meters, temperature sensors) and actuators (e.g., relays, smart switches).

3.4.5 Security and Authentication

- Apply HTTPS encryption to secure communication between clients and the server, preventing eavesdropping and data tampering.

3.4.6 Testing and Quality Assurance

- Conduct unit tests, integration tests, and end-to-end tests to verify the functionality and reliability of the system components.

3.4.7 Deployment and Maintenance

- Deploy the system to production environments using continuous integration.
- Regularly update and maintain the system to address security vulnerabilities, performance issues, and feature enhancements.

3.5 Verification or Testing

3.5.1 Unit Testing

- Test individual components such as backend APIs, frontend UI components, hardware firmware, and database queries.

3.5.2 Integration Testing

- Test the integration of frontend components with backend APIs to ensure seamless communication and data exchange.

3.5.3 End-to-End Testing

- Conduct end-to-end tests to validate the entire system workflow from user interaction to backend processing and hardware control.

3.5.4 Performance Testing

- Measure system performance under normal and peak load conditions to ensure scalability and responsiveness.

3.6 Deployment and Maintenance

3.6.1 Deployment Strategy

- Choose a deployment model based on the system architecture, scalability requirements, and budget constraints.

3.6.2 Deployment Process

- Develop a deployment plan outlining the steps, roles, and responsibilities for each deployment phase.

3.6.3 Post-Deployment Activities

- Conduct post-deployment testing to validate system functionality, performance, and security in the production environment.

3.6.4 Continuous Improvement

- Establish a process for capturing and prioritizing user feedback, feature requests, and bug reports for future system enhancements

3.7 Chapter Summary

Overall, the methodology chapter provides a comprehensive framework for understanding the systematic approach taken in the development of the "Intelligent Energy Control System for Home" and serves as a guiding reference for future research and development endeavors in similar domains.

CHAPTER 4

DESIGN AND IMPLEMENTATION

4.1 Introduction

The design chapter serves as a repository of essential documentation, providing detailed insights into the conceptualization, development, and implementation of our energy control system. It encompasses a series of key drawings, including the Block Diagram, Flowchart, and Sequence Diagram, each offering a unique perspective on the system's architecture, functionality, and interconnections.

4.2 Structure of IECSH system

The structure of IECSH system can be seen in Figure 7. Basically, the system comprises of a NodeMCU controller with the ability to communicate with server via Wi-Fi, NodeMCU controller for power measurement and controlling operations, IECSH interface and server, respectively.

The combination of these units aims to plan for the proposed system which is explained using the following diagram.

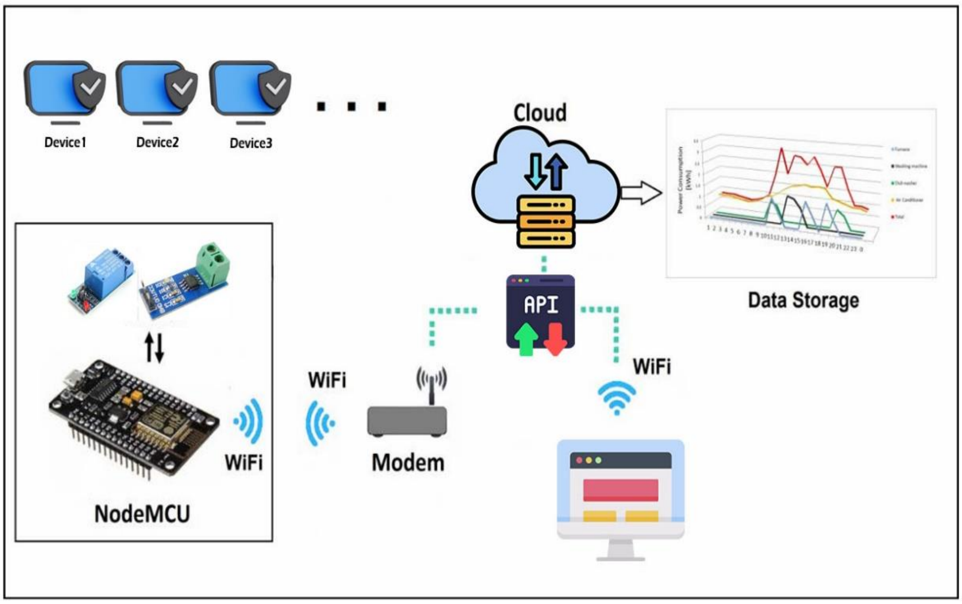

Figure 7 The Structure of IECSH system

4.3 Required Hardware & Software

Effective analysis and gathering of requirements play a pivotal role in the triumph of any project. In software engineering, requirements analysis is a methodical process aimed at identifying the necessary tasks to ascertain the requisites and parameters for crafting a new product or effecting modifications in an existing one. This undertaking entails addressing the diverse demands of stakeholders, examining documentation, and ensuring the validation of the system. It is imperative that these requirements are actionable, measurable, testable, and aligned with the specified needs of the system design.

4.4 Hardware Requirements

The IECSH shall provide minimum hardware requirements. The following hardware configurations are required for a server using IECSH:

- NodeMCU
- Relay Module
- ACS712 Current Sensor
- Wire Kit for Arduino
- Breadboard

4.5 Software Requirement

This section outlines the essential requirements necessary for the efficient operation of the system. It includes specifications such as the required operating system for optimal system performance, the interface required to execute the application, the driver necessary for running Ubidots web applications, the integrated development environment utilized for application development, and the third-party tool utilized for editing purposes.

- Operating System: Linux, Ubuntu, Mac, Windows, Android.

- Environment: Arduino IDE
- Front-End: ubidots

4.6 Microcontroller

The microcontroller's input is linked to the sensors' output. In this setup, an Arduino NodeMCU development board equipped with the ATmega328p microcontroller is utilized. The Arduino board can detect the analog values of the sensors connected to its analog pins and subsequently process them for subsequent actions through a program scripted in the Arduino IDE software. The Arduino code is scripted following an algorithm based on a straightforward analog signal reception and storage mechanism. Additionally, a buzzer is connected to the development system, and the Arduino board dispatches an activation signal to the buzzer when the value surpasses a predefined threshold, In Figure 8 we show an image of the module [10].

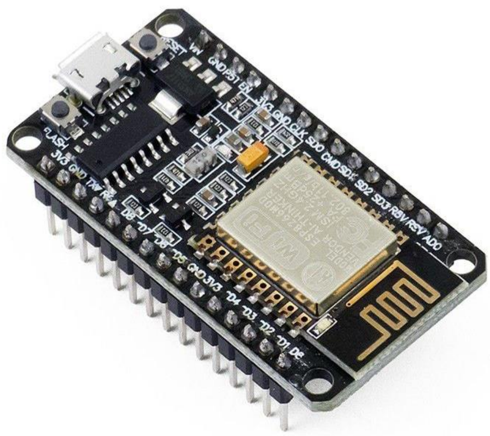

Figure 8 Arduino NodeMCU **[10]**.

4.7 Relay Module

Relay modules are simply circuit boards that house one or more relays. They come in a variety of shapes and sizes, but are most commonly rectangular with 2, 4, or 8 relays mounted on them, sometimes even up to a 16 relays.

Relay modules contain other components than the relay unit. These include indicator LEDs, protection diodes, transistors, resistors, and other parts. But what is the module relay, which makes the bulk of the device? You may ask. Here are facts to note about it:A relay is an electrical switch that can be used to control devices and systems that use higher voltages. In the case of module relay, the mechanism is typically an electromagnet. The relay module input voltage is usually DC. However, the electrical load that a relay will control can be either AC or DC, but essentially within the limit levels that the relay is designed for.

A relay module is available in an array of input voltage ratings: It can be a 3.2V or 5V relay module for low power switching, or it can be a 12 or 24V relay module for heavy-duty systems.

The relay module information is normally printed on the surface of the device for ready reference. This includes the input voltage rating, switch voltage, and current limit, In Figure 9 we show an image of the module [11].

Figure 9 Relay Module **[11]**.

4.8 ACS712 Current Sensor Module

For measuring current in a circuit, a sensor is required. ACS712 Current Sensor is the sensor that can be used to measure and calculate the amount of current applied to the conductor without affecting the performance of the system.

ACS712 Current Sensor is a fully integrated, Hall-effect-based linear sensor IC. This IC has a 2.1kV RMS voltage isolation along with a low resistance current conductor, In Figure 10 we show an image of the module [12].

Figure 10 ACS712 Current Sensor Module **[12]**.

4.9 Wire Kit for Arduino

A wire kit for Arduino is a collection of wires and cables specifically designed for use with Arduino microcontroller boards and related components. These wire kits typically include a variety of wires with different lengths, colors, and connectors to facilitate easy and convenient connections between Arduino boards, sensors, modules, and other electronic components, In Figure 11 we show an image of the module [13].

Figure 11 Wire Kit for Arduino [13]

4.10 Breadboard

"Breadboard Arduino" is a term that generally refers to using an Arduino microcontroller board in conjunction with a breadboard for prototyping and experimenting with electronic circuits.

A breadboard is a rectangular board with a grid of holes and conductive metal strips beneath the surface. It allows you to quickly and easily connect electronic components together without the need for soldering. Components such as resistors, capacitors, LEDs, and integrated circuits (ICs) can be inserted into the holes and connected by inserting jumper wires into the holes, In Figure 12 we show an image of the module [14].

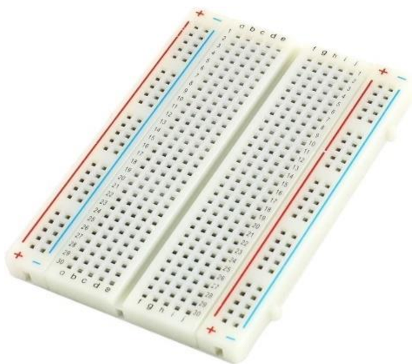

Figure 12 Breadboard **[14]**.

4.11 Block Diagram

The block diagram of the "Intelligent Energy Control System for Home" provides a visual representation of the system's architecture and the interactions between its main components As shown in Figure 13. Here's an explanation of each block in the diagram:

1. **NodeMCU**: This block represents the NodeMCU microcontroller, which serves as the central processing unit of the system. The NodeMCU is responsible for coordinating

the operation of the entire system, including data acquisition, analysis, decision-making, and control of connected devices.

2. **Relay Module**: The Relay Module block represents the component responsible for controlling the electrical appliances or devices connected to the system. The NodeMCU sends signals to the relay module to activate or deactivate specific appliances based on the system's energy optimization decisions.

3. **ACS712 Current Sensor**: This block represents the ACS712 Current Sensor, which is used to measure the electrical current flowing through the system. The sensor provides real-time data on energy consumption, allowing the system to monitor and analyze usage patterns.

4. **Wire Kit for Arduino**: The Wire Kit for Arduino block symbolizes the collection of wires and cables used to establish connections between different components of the system. These wires facilitate communication and power transfer between the NodeMCU, relay module, ACS712 sensor, and other peripheral devices.

5. **Breadboard**: The Breadboard block represents the breadboard used for prototyping and connecting electronic components in the system. It provides a platform for assembling and testing circuitry before final implementation, allowing for easy modifications and troubleshooting.

The interactions between these components enable the Intelligent Energy Control System to effectively monitor, analyze, and optimize energy consumption within a home environment. The NodeMCU acts as the brain of the system, receiving input from the ACS712 sensor, making decisions based on energy usage data, and controlling connected appliances through the relay module. The Wire Kit for Arduino and

Breadboard facilitate the physical connections between these components, ensuring seamless communication and operation of the system.

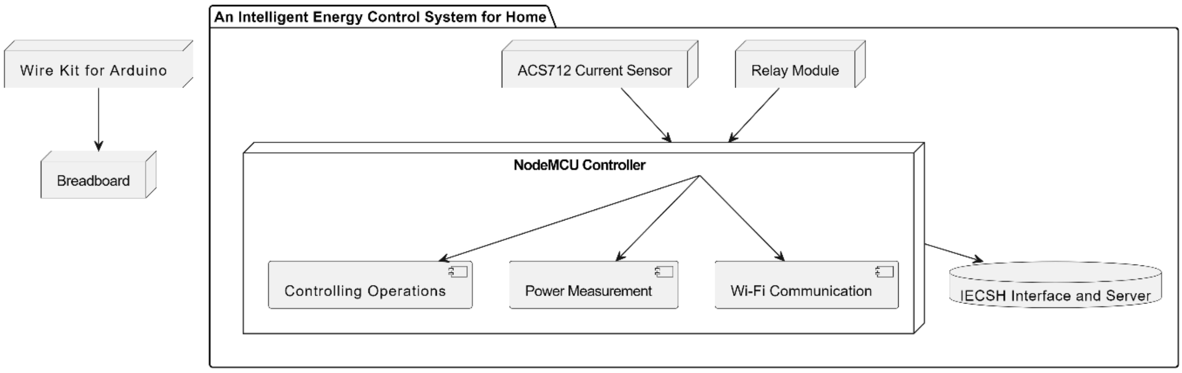

Figure 13 Block Diagram.

4.12 Sequence Diagram

The sequence diagram outlines the interactions within an intelligent energy control system for homes, involving components like NodeMCU, Relay Module, ACS712 Current Sensor, Wire Kit for Arduino, Breadboard, and a server. It begins with user interactions, including appliance control, energy consumption monitoring, and energy-saving schedule configuration. The NodeMCU communicates with the components accordingly, such as the Relay Module for appliance control and the ACS712 Current Sensor for monitoring. Configuration changes are transmitted through the Wire Kit to the Breadboard and then to the Relay Module. Data is also sent to the server for storage and analysis. Overall, the diagram illustrates how these components work together seamlessly to manage energy usage efficiently in a home environment As shown in Figure 14.

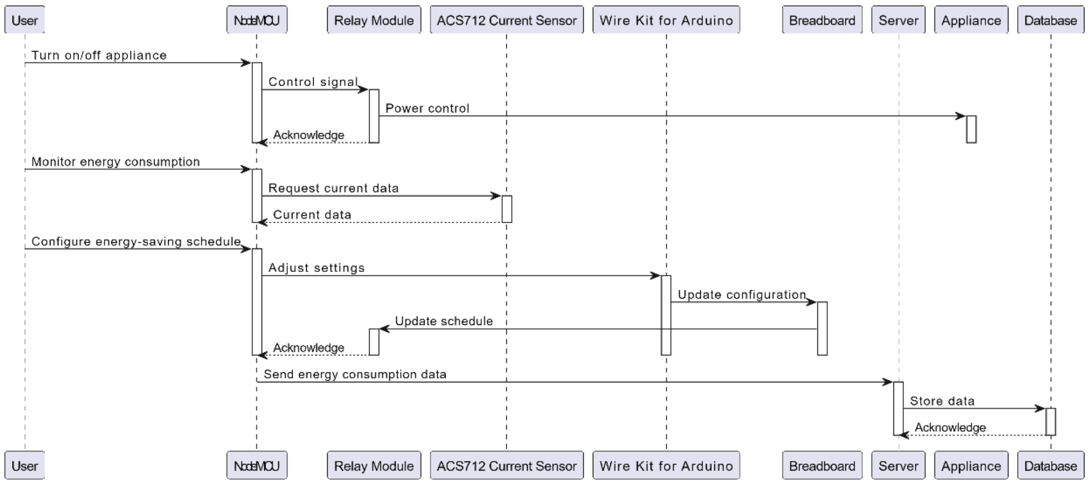

Figure 14 sequence diagram

4.13 Circuit design

Figure 13 depicts the comprehensive electrical circuit layout encompassing all electronic components and sensors, elucidating the intricate interconnections required for seamless functionality. By meticulously outlining the connections between NodeMCU, Relay Module, ACS712 Current Sensor, Wire Kit for Arduino, and Breadboard, this visual representation facilitates a clear understanding of the intricate wiring scheme essential for optimal performance. With detailed annotations and visual cues, Figure 15 empowers users to effectively implement the proposed energy control system, ensuring precision in component placement and connectivity to realize the system's full potential.

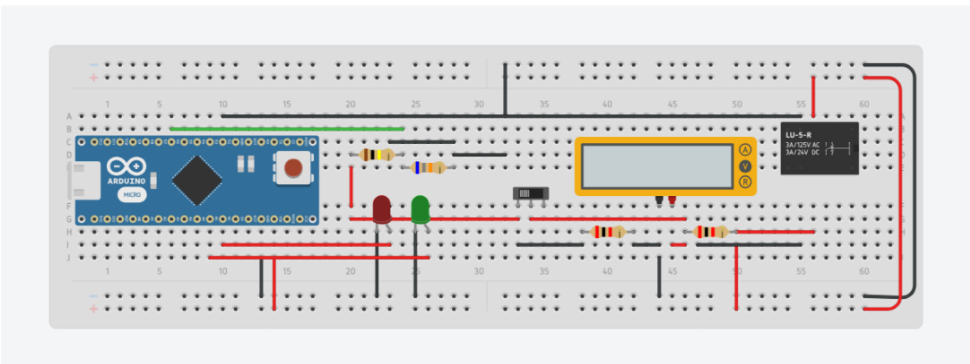
Figure 15 Circuit design.

4.14 Flowchart

The flowchart diagram illustrates the operation of an Intelligent Energy Control System designed for home applications. This system integrates various components such as NodeMCU, Relay Module, ACS712 Current Sensor, Wire Kit for Arduino, and Breadboard to effectively manage and optimize energy consumption within a household setting As shown in Figure 16. Here's an explanation of the flowchart:

1. **Start**: The process begins with the initialization of the system.

2. **Initialize NodeMCU**: The NodeMCU, serving as the central controller, is initialized to prepare it for operation.

3. **Connect to Wi-Fi**: The system establishes a connection to a Wi-Fi network, enabling communication with other devices and the internet.

4. **Read Sensor Data**: Data from sensors, particularly the ACS712 Current Sensor, is acquired to monitor energy consumption levels in real-time.

5. **Process Sensor Data**: The collected sensor data undergoes processing to extract relevant information and perform necessary calculations.

6. **Analyze Data**: The processed data is then analyzed to identify patterns, trends, or anomalies in energy usage.

7. **Energy Optimization Decision**: Based on the analysis results, the system makes decisions regarding energy optimization strategies, such as adjusting appliance usage schedules or activating/deactivating specific devices.

8. **Control Relay Module**: If energy-saving conditions are detected, the system controls the Relay Module accordingly to implement the recommended optimization measures.

9. **Send Data to Server**: The processed and analyzed data is transmitted to a remote server for storage, further analysis, or visualization.

10. **Data Transmission Status Check**: The system verifies the successful transmission of data to the server. If successful, it proceeds to the "Data Sent Successfully" step; otherwise, it handles any transmission errors.

11. **Data Sent Successfully**: If the data transmission is successful, the system acknowledges it with a success message. Otherwise, it logs and reports any errors encountered during the transmission process.

12. **Stop**: The process concludes here, indicating the completion of the system's operation.

This flowchart provides a structured representation of the key steps involved in the Intelligent Energy Control System's operation, illustrating how various components collaborate to monitor, analyze, and optimize energy usage in a home environment.

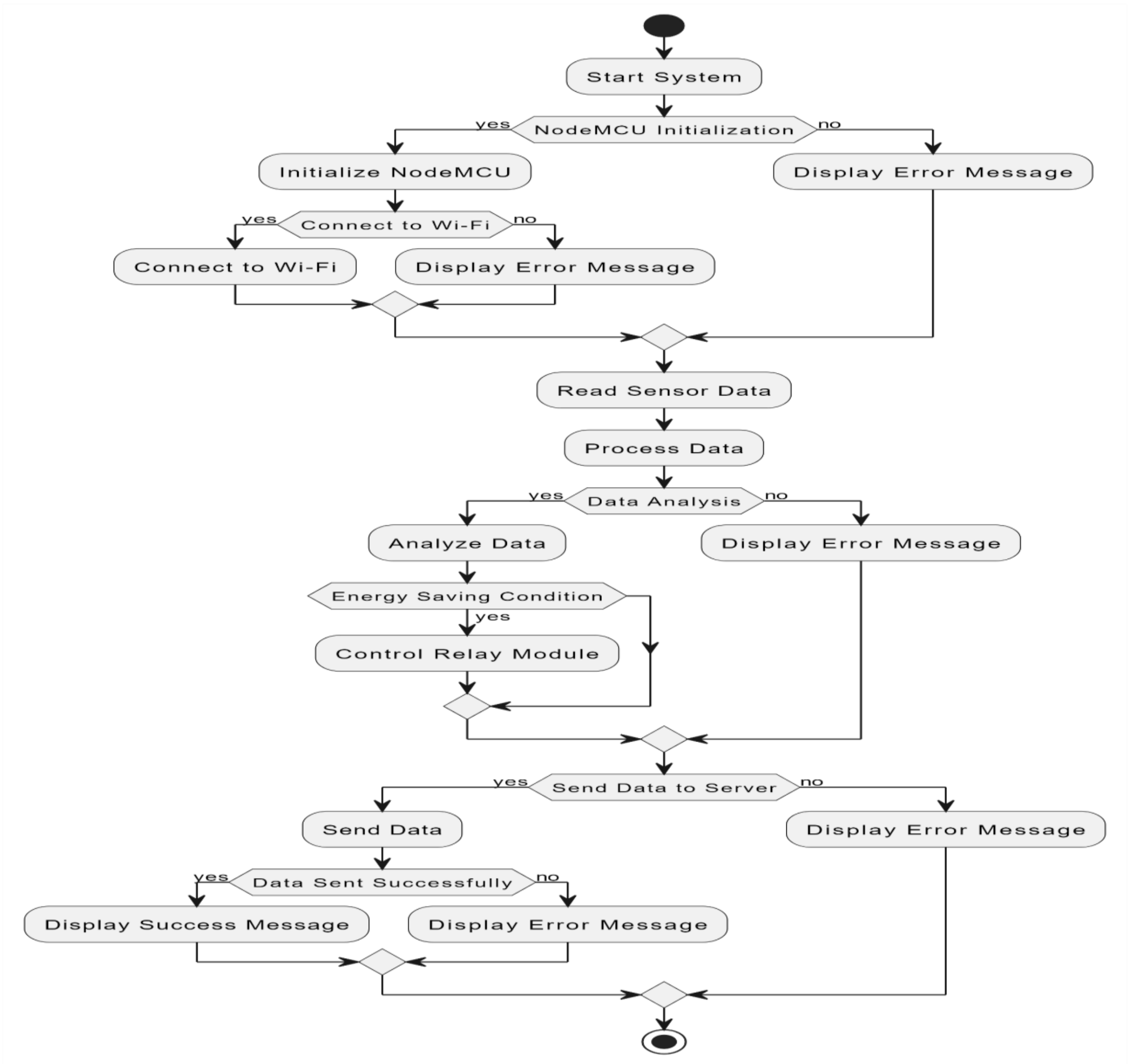

Figure 16 Flowchart.

The Dashboard provides detailed statistics on current energy consumption. It displays real-time electricity usage, along with an in-depth analysis of daily, monthly, and yearly consumption. The dashboard includes illustrative graphs that help users understand consumption patterns over time. Additionally, it features a button that allows users to easily turn the device on or off with a single click. This button is user-friendly and clearly indicates the current status of the device, whether it is on or off, offering complete control in a smooth and secure manner.

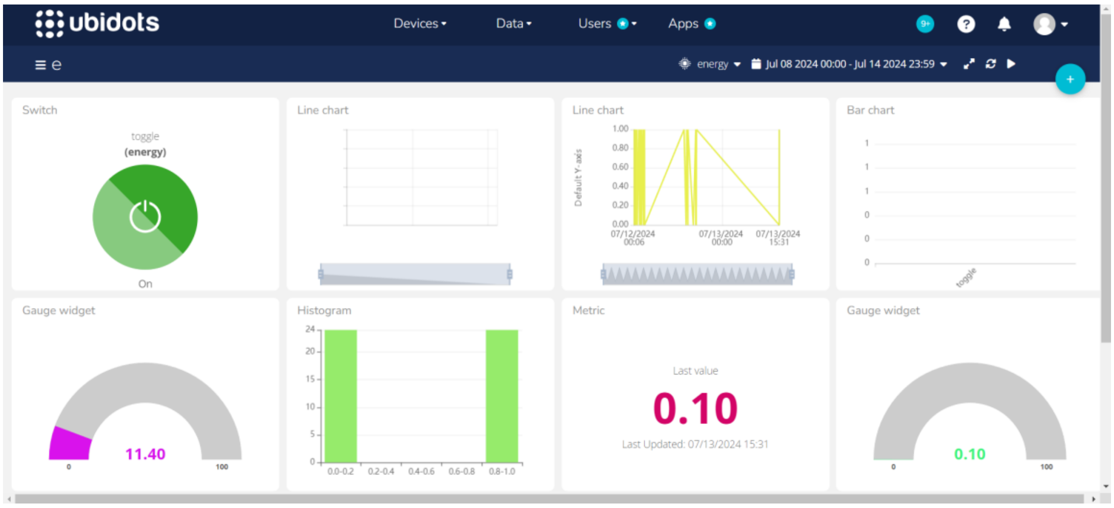

Figure 17 Dashboard

The Add Device page allows users to seamlessly integrate new devices into the system. It provides a straightforward interface where users can input device details, such as name. This section ensures that all newly added devices are correctly configured to communicate with the central system. It includes step-by-step instructions to guide users through the setup process, ensuring that each device is properly connected and operational. The section also offers troubleshooting tips and support options to assist users in resolving any issues that may arise during the device addition process. This feature ensures a hassle-free experience, enabling users to expand their system effortlessly and maintain optimal functionality.

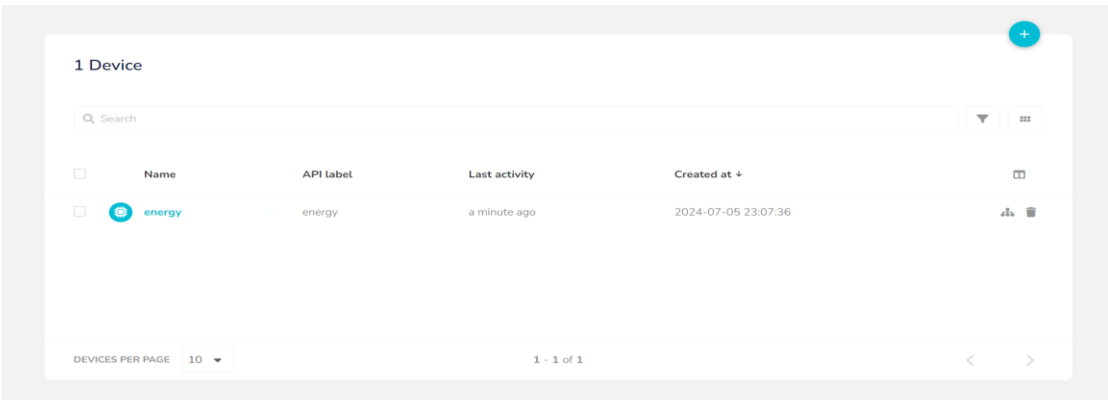

Figure 18 Add Device.

The events page is a comprehensive tool for managing device operations based on power consumption thresholds. Here, users can specify detailed settings to automatically shut down specific devices when their power consumption exceeds a predefined limit. This feature allows for precise scheduling, enabling users to set specific times and conditions under which the shutdown should occur. For instance, users can configure the system to monitor a device's power usage and initiate a shutdown if the consumption surpasses a certain amount during peak hours. The events page offers a user-friendly interface to input these parameters, ensuring that the rules are clear and easy to adjust as needed. Additionally, it provides visual aids and real-time updates to help users track the effectiveness of their settings and make informed adjustments. This functionality not only enhances energy efficiency but also contributes to overall system management by preventing overuse and potential damage to devices.

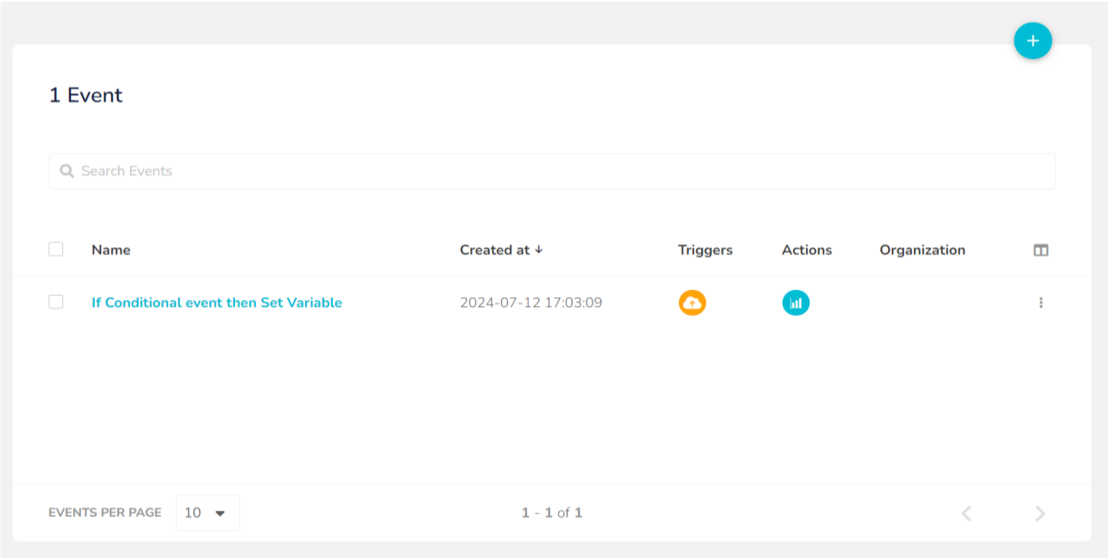

Figure 19 Create events.

The Data Analysis page is an essential feature designed to provide in-depth insights into device performance and energy consumption patterns. Here, users can access a comprehensive set of tools and visualizations that help them analyze and interpret data collected from their devices. This page includes detailed graphs and charts that display historical data, trends, and anomalies in power usage over specified periods. Users can filter data by device, time frame, and other parameters to gain a clear understanding of how their devices are operating and where improvements can be made.

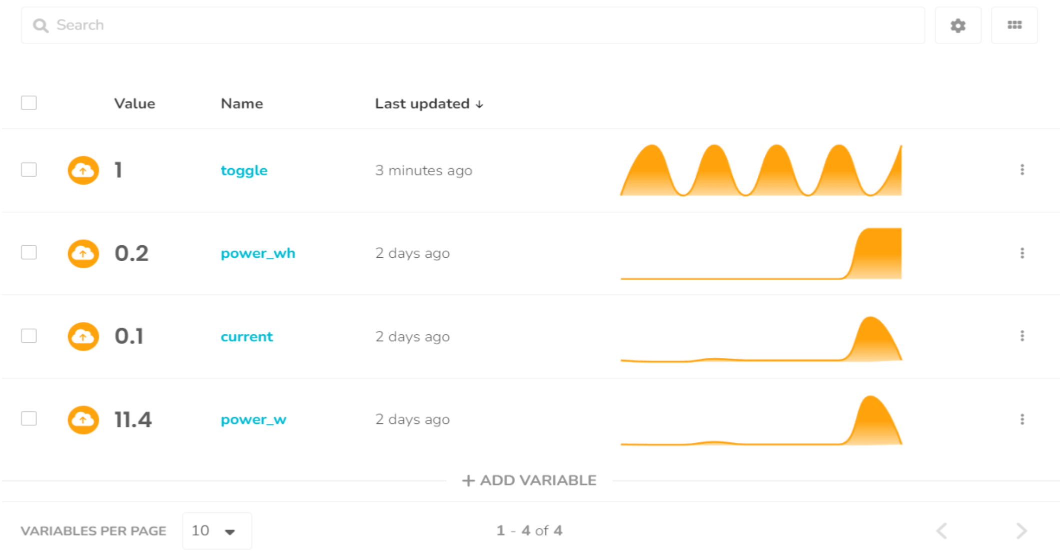

Figure 20 Data Analysis.

The final device image showcases the completed system of the IECSH project. The image displays a neatly organized assembly of integrated components, including the main control unit, sensors, and electrical connections. The device is designed to provide an easy-to-use interface, allowing users to efficiently manage and control household appliances and energy consumption. It is securely mounted on a wall to provide a practical and real-life installation, ensuring high performance and easy access for users. This setup reflects the successful achievement of the project’s goal by delivering an effective and reliable home energy management system.

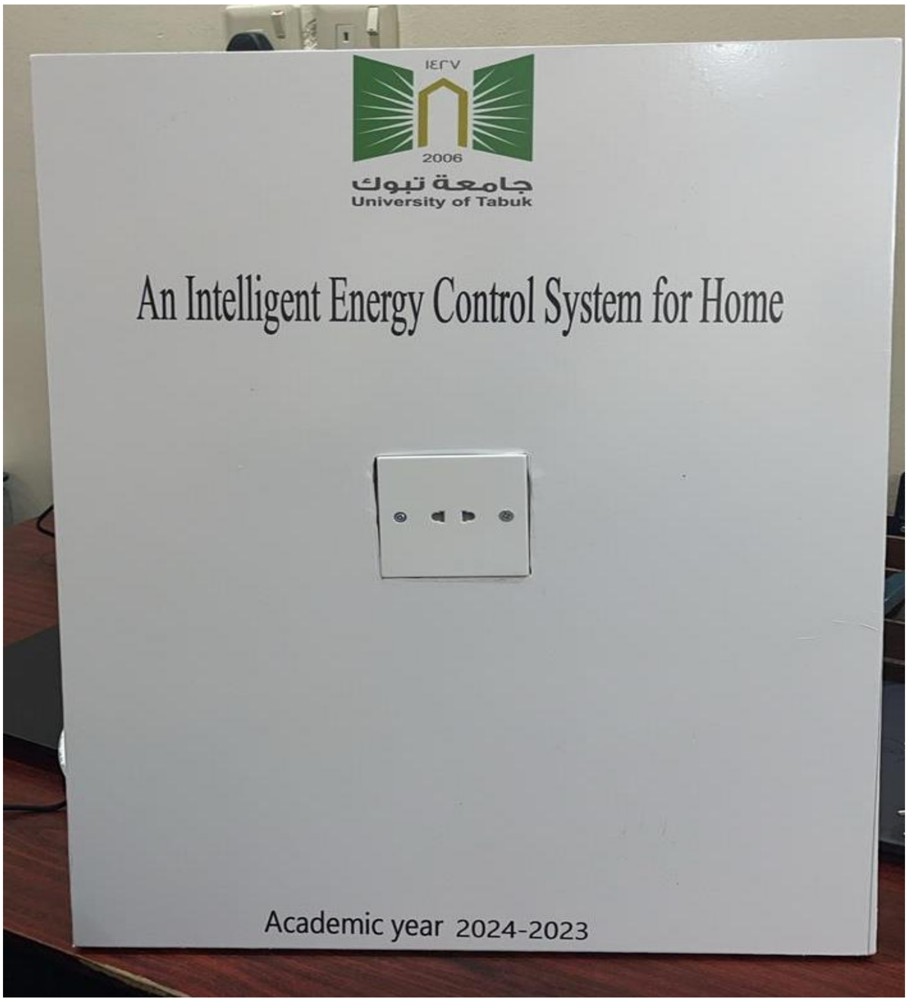

Figure 21 Final Device Image

4.15 Chapter Summary

In essence, the design chapter encapsulates our commitment to innovation, sustainability, and technological advancement, showcasing the transformative potential of intelligent energy control systems in shaping more efficient and environmentally conscious homes.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the development and implementation of "An Intelligent Energy Control System for Home" represent a significant step forward in addressing the growing demand for energy efficiency, sustainability, and smart home automation. Throughout the project lifecycle, we have leveraged advanced technologies such as artificial intelligence, the Internet of Things (IoT), and data analytics to create a sophisticated yet user-friendly system. This system empowers homeowners to optimize their energy usage, reduce utility bills, and minimize environmental impact. Notably, the system's response time does not exceed three seconds, ensuring prompt and efficient performance. The comprehensive integration of these technologies ensures that the energy control system is not only efficient but also intuitive and accessible to a broad range of users. By promoting smarter energy consumption habits and providing detailed insights into energy usage patterns, the system significantly contributes to the global efforts towards sustainable living. As we continue to refine and expand upon this foundation, the potential for further innovations in home energy management remains vast, promising even greater advancements in the pursuit of a greener, more efficient future.

Achieved Objectives:

1. The system's response time does not exceed three seconds, ensuring prompt and efficient performance.

2. The comprehensive integration of AI, IoT, and data analytics has resulted in an efficient yet intuitive system accessible to a broad range of users.

3. The system promotes smarter energy consumption habits and provides detailed insights into energy usage patterns.

4. It significantly contributes to global efforts towards sustainable living by reducing energy waste and promoting efficient energy use.

As we continue to refine and expand upon this foundation, the potential for further innovations in home energy management remains vast, promising even greater advancements in the pursuit of a greener, more efficient future.

5.2 Recommendations

The development of "An Intelligent Energy Control System for Home" has paved the way for significant advancements in energy efficiency and smart home technology. As we look to the future, it is crucial for researchers to build on this foundation, exploring new possibilities and addressing emerging challenges. The following recommendations aim to guide future researchers in enhancing and expanding the capabilities of intelligent energy control systems.

Explore Advanced AI Algorithms:

- Investigate the use of more advanced artificial intelligence and machine learning algorithms to enhance the system's predictive capabilities and decision-making processes.
- Focus on developing adaptive algorithms that can learn from user behavior and environmental changes to optimize energy usage further.

Expand IoT Integration:

- Research ways to integrate the energy control system with a wider array of IoT devices and sensors.

- Explore interoperability with different smart home platforms to create a more seamless and comprehensive energy management solution.

Focus on User Experience:

- Conduct user studies to gather detailed feedback on the system's interface and functionality.
- Develop and test new features that enhance user experience and make the system more intuitive and user-friendly.

Enhance Data Security and Privacy:

- Investigate advanced encryption methods and secure data handling practices to protect user information.
- Explore privacy-preserving techniques such as differential privacy to ensure user data is used responsibly without compromising security.

Implement Renewable Energy Integration:

- Research ways to integrate the energy control system with renewable energy sources like solar and wind.
- Develop algorithms that optimize the use of renewable energy to reduce reliance on non-renewable sources.

Study Environmental Impact:

- Conduct studies to measure the environmental impact of the energy control system, focusing on its ability to reduce carbon footprints.

- Explore ways to enhance the system’s contributions to sustainability and energy conservation.

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