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Enhancing the Functionality of a Single Burner Electric Cooker through IoT Automation

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Abstract: *Single-burner electric cookers are frequently utilized in homes and small kitchens because they offer unmatched convenience and portability. However, they often grapple with challenges such as energy inefficiency and limited temperature control, and in some instances, pose potential hazards ranging from fires to electric shocks. Addressing these issues, this research explores the integration of IoT (Internet of Things) automation as a transformative solution to enhance the overall efficiency of single-burner electric cookers. Through the integration of IoT technology, the electric cooker was automated with programmable timer functionality and precise temperature control and connected to a smart device via a wireless connection. This allows users to remotely manage and control the cooker's operations using a dedicated application. The system includes a microcontroller, temperature sensor, timer module, Wi-Fi module, and a mobile application. Users can input the desired cooking parameters on the app, which are then transmitted to the microcontroller through a Wi-Fi network. The temperature sensor continuously monitors the cooking temperature and sends feedback to the microcontroller, which makes necessary adjustments to maintain the desired temperature. The timer function ensures that the cooking process concludes at the specified time, preventing overcooking or burning of food. This system introduces features such as remote monitoring and control, improved cooking precision, enhanced safety measures, and increased energy efficiency*

Keywords: *Electric Stove, IOT, Burner, Wi-Fi, Microcontroller, Temperature, BME 280 Sensors.*

1. INTRODUCTION

Electric cooking stoves can be considered a clean cooking option since they are fuelled by ecologically beneficial renewable energy sources such as solar, wind, or hydro, which are considered environmentally friendly. This made them a suitable cooking device for homes and industries as they help reduce the release of pollutants and particulate matter into the environment and improve indoor and outdoor air [1- 4]. As opposed to the traditional methods that are endangering lives and the environment. The government of Nigeria is doing all in its power to make electricity available and affordable for all citizens, both in urban and rural communities [5] to meet the SDG 7 goal, thereby encouraging clean cooking practices.

Over the years, electric cooking stoves have gained popularity due to their convenience, safety features, and precise temperature control [6] over gas and kerosene stoves. However, most of the available ones are not energy efficient and lack the ability for advanced self-control [7]. Since their mode of operation is analog, they lack the pre-set function, so users are required to constantly monitor and adjust the temperature knob and cooking time for different cooking tasks to prevent overcooking or undercooking. Major components of this stove include a thermostat, which contains a temperature sensor; a heating element made of a resistive material, such as a metal coil or solid plate; a cooktop; and a heat regulator. When the stove is connected to a power supply, the current flow through the heating element is resisted, causing the element to heat due to joule heating [8] the heat generated is then transferred to the cooktop for cooking or heating food. The user regulates the heat via the regulator to adjust the temperature for different cooking needs.

The thermostat continually regulates the internal temperature between high and low levels as long as the cooker is powered without care for the cookware or its content burning. In a situation where the thermostat gets damaged due to excessive heat, particularly when the stove operates at the highest temperature or due to overvoltage, the stove overheats and causes damages, leading to losses ranging from food burning to energy wastage, and, in some cases, human losses [9] via electric shock, etc., Single-burner electric cookers are commonly used in households and small kitchens all round Nigeria for their convenience, portability and affordability. However, the most available ones are the conventional models characterized by restricted control functionalities, such as rudimentary temperature adjustments and manual knobs, which are not particularly efficient. Furthermore, they are deficient in features like programmable timers [10], energy-saving modes, or the capability for remote control and monitoring[11]. This lack of precise control makes it difficult to maximize energy efficiency and can lead to overcooking or undercooking food, consequently contributing to further energy wastage. This necessitates the need to integrate a system on a chip into the electric cooker to automate its operation and optimize energy usage by precisely controlling the heating elements.

This paper delves into the intricacies of the IoT automation system, elucidating how users can set precise cooking parameters in a mobile app, which are then transmitted to the microcontroller via the Wi-Fi module. The continuous monitoring of cooking temperatures by the embedded temperature sensor empowers the microcontroller to make real-time adjustments, ensuring optimal temperature maintenance. Additionally, the inclusion of a timer function prevents overcooking or burning by orchestrating the cooking process to conclude at the designated time.

In the research, a Wi-Fi-based control system, that allows users to remotely monitor and control the operation of a single burner electric cooker was developed, as against the existing traditional model that relies solely on thermostats that are susceptible to damage from high voltage or temperature fluctuations and other modified gas stoves [12], ovens, and similar appliances, which may be automated but lack remote control functionality. The implemented system enables users to set precise cooking time and temperature parameters through a mobile application or web interface, eliminating the need for constant manual intervention. By providing remote access and control, users can conveniently monitor and adjust the cooking process from any location within the Wi-Fi network. In addition, this innovative project can contribute to efficient electricity utilization and conservation and promote sustainable practices in the kitchen.

2. REVIEW OF LITERATURE

Several attempts have been made to automate electric cookers for self-control, encompassing a progression from simple thermostats to advanced microcontroller-based systems [13, 14]. The evolution of automation in electric cookers has led to more precise and convenient cooking experiences for users. Initially, thermostats were employed to regulate the cooker's temperature by turning the heating element on or off based on predefined temperature thresholds. While effective to some extent, this approach lacked flexibility and advanced control options.

With technological advancement, microcontrollers emerged as a pivotal solution for enhancing cooker automation. These miniature computing devices allowed for more intricate control algorithms and versatile features. Microcontroller-based systems could accurately manage temperature, time, and other cooking parameters through programmable logic. This marked a significant step towards achieving consistent and desired cooking outcomes. As technology progressed, integrating wireless communication, such as Wi-Fi connectivity, opened new horizons for cooker automation. This innovation enabled remote control and monitoring, transforming traditional cookers into smart appliances. Users gained the ability to set cooking parameters, monitor progress, and receive notifications through smartphone applications. This level of automation streamlined cooking processes, offering convenience and ensuring that meals were prepared exactly as desired. Caiphas Svosve and Loice Gudukeya [7] in their work identified a lack of self-control and automation abilities in most available electric stoves, with the few existing automation features primarily found in the oven rather than the cooktop heating plate. To address this issue, the duo developed a smart electric cooking stove with enhanced functionality. The main feature of their stove is its ability to automatically power on when it detects the presence of cookware on the cooktop. This feature helps prevent accidental activation of the stove when no cookware is present, reducing the risk of kitchen fires. Moreover, the stove is designed to automatically power off if no cookware is detected after five (5) minutes, thereby conserving power and improving energy efficiency. Another significant aspect of their design is the stove's capability to detect food burning. This is accomplished by observing the fluctuations in temperature on the heating plate. By analyzing the temperature patterns, the stove can determine if the pot has sufficient water during cooking or if the water has completely evaporated. This feature serves to prevent food from burning and ensures better cooking outcomes. However, the stove lacks a timer, and as a result, the stove continues to operate as long as there is cookware with a considerable amount of water on the plate. This limitation implies that users must manually monitor and control the cooking time, which may not be ideal for recipes requiring precise timing. Mizanur et al [15] proposed the development of a microcontroller-based smart natural gas oven to optimize energy utilization. Their work highlights the significance of meeting energy demands by increasing the gas supply and promoting efficient gas usage. By utilizing advanced control and automation features, the smart oven offers improved energy efficiency and contributes to sustainable energy practices. However, the risk associated with gas is enormous. Michael David et al [9] focused on the development of a microcontroller-based electric cooker or oven with temperature and time control features. The device offers a user-friendly interface through an LCD, allowing users to set and monitor the cooking temperature and time. This research contributes to the advancement of cooking technologies in developing countries, providing a cost-effective solution that enhances cooking precision and convenience. The work does not indicate the specification of the cooker or oven used in the testing or for analysis.

3. METHODOLOGY

The proposed system incorporates essential components such as an ESP32 microcontroller, BME 280 temperature sensor, RTC timer module, Wi-Fi module, and a dedicated mobile app with an electric cooker Users can leverage this connectivity to remotely control and monitor the cooker's functions, allowing for a more streamlined and efficient cooking process. The microcontroller includes built-in support for Wi-Fi connectivity, enhancing security features. This enables remote control of the cooker from a distance of over 100 meters, allowing wireless shutdown and adjustment of settings such as temperature range and timer settings. The system operates primarily in two modes: Temperature Mode and Timer Mode.

In Timer Mode, the cooker is automated based on a predetermined time limit for operation, referred to as the set time. This is particularly useful for time-sensitive cooking tasks. Upon reaching the set time, the cooker goes off triggering an alarm, alerting the user until it is reset from the app or put off via an SPST switch.

In Temperature Mode, the cooker is controlled by a specified temperature range, with operations temporarily put off when the maximum temperature is attained. The system waits until the cooker cools to the minimum temperature before resuming operation, ensuring the cooking temperature remains within a predefined range suitable for the selected food. This cycle repeats until the food is fully cooked. Both modes are responsive and preceded using the Wi-Fi control mode, accessible through a dedicated Wi-Fi network and web page interface/dashboard for cooker settings and control. Through the web page interface on a smartphone, users can set desired cooking times and temperatures. The microcontroller receives these inputs, making necessary adjustments to the cooker. Real-time feedback on the current temperature and elapsed time is displayed on an LCD connected to the system, allowing users precise monitoring and control of the cooking process. Additionally, the system supports the simultaneous use of both temperature and timer functions, providing flexibility in cooking operations. The flowchart and block diagram of the system are shown in Figure 1 and Figure 2 respectively

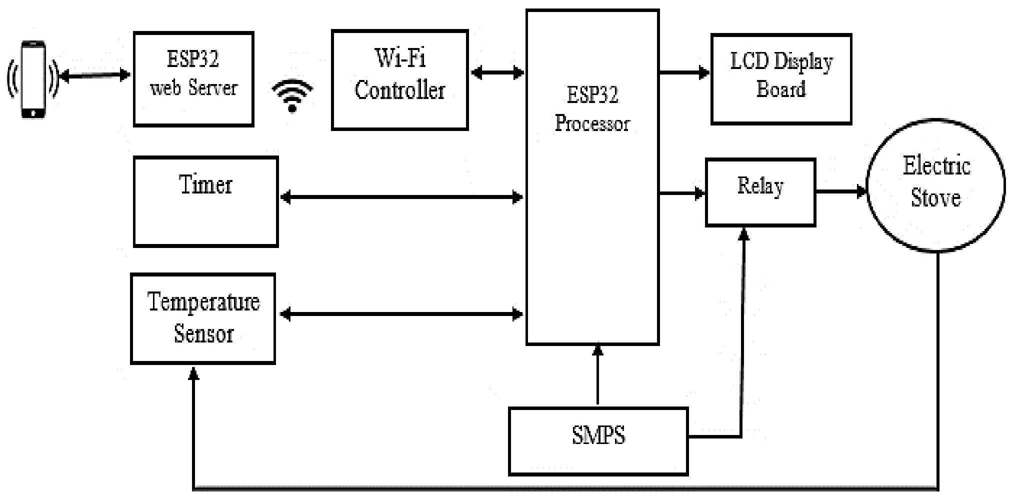

Figure 1: System block diagram

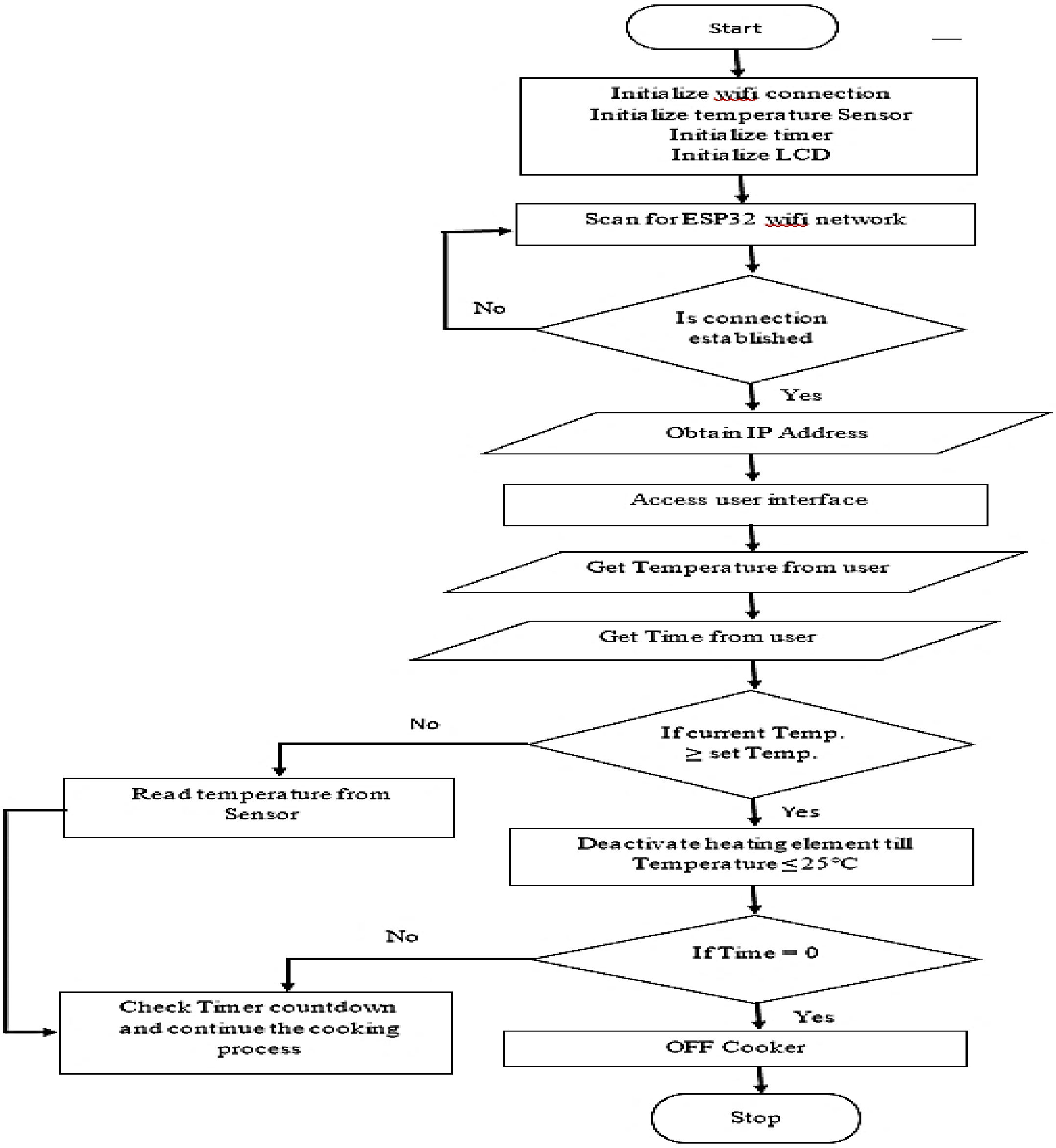

Figure 2: Flowchart of the system

3.1 Hardware Design

The hardware design consists of basically four (4) units: The power supply, control, display, and sensor unit. The units are constructed using the following components.

i. Electric Stove
ii. SMPS Power supply
iii. ESP 32 microcontroller
iv. BME 280 Temperature Sensor
v. LCD Display
vi. RTC Module

3.1.1 Electric Stove

A single-burner glass-top electric cooker was used in this research (Figure 2). The cooker had a ceramic glass surface with an embedded heating element made of radiant coils Underneath the ceramic. When electricity passes through the coils, it is converted to heat, and this heat is transferred to the cookware placed on top of the ceramic surface through direct contact. The ceramic cooktop cooker was chosen because of its energy efficiency and flat surface, which allow for better heat distribution and faster heating, resulting in reduced energy consumption. To automate the cooker, a BME 280 temperature sensor, DS1307 RTC, and ESP32 microcontroller were incorporated into the cooker's system.

Figure 2: Electric cooker heating element

3.1.2 BME 280 Sensor

The BME 280 is a sensor that combines temperature, humidity, and pressure-sensing capabilities in a single package. It can measure temperatures ranging from -40°C to 85°C at ±1.0 to ±1.5 °C. The sensor supports both I2C (Inter-Integrated Circuit) and SPI (Serial Peripheral Interface) communication protocols, making it compatible with a wide range of microcontrollers and development boards. [16, 17]. The sensor was interfaced with the ESP32 (figure 3) via its SCL (clock line) and SDA (data line) pins and placed close to the heating coils to measure the cooker's internal temperature. The measured temperature is then transmitted to the microcontroller to turn on or off the cooker based on the user's predefined temperature limits.

Figure 4: BME interface with microcontroller

3.1.3 Power Supply

The 220V AC power from the main supply is stepped down to 5V DC voltage through a 5V, 5A switching power supply. This 5V output powers the microcontroller, drives the relay, and supplies power to the passive components. The connection to the cooker is established via a relay module connected to the main supply. The negative terminal of the stove connects to the common (COM) terminal of the relay, while the opposite end connects to the normally open (NO) terminal of the relay. A transistor facilitates the connection between the control terminal of the relay and the microcontroller. The transistor amplifies the signal from the microcontroller to activate the relay, enabling it to switch on and off. Upon activation by the microcontroller, the relay closes the circuit between the common and normally open terminals, enabling the flow of current to the cooker.

3.1.4 Timer Unit

The timer unit consists of DS1307, a real-time clock used to keep track of time in microcontroller-based systems and other electronic devices. The module has a built-in battery backup that enables it to continue to keep track of time even when the main power supply is disconnected. The timer in this system served as a countdown timer for the user-specified cooking task. The 12C bus is used to interface it with the microcontroller.

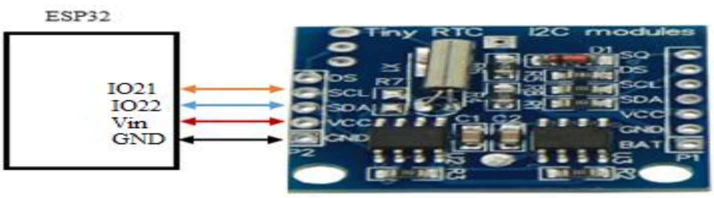

Figure 5: DS1307 interface with the microcontroller

3.1.5 The Control Unit

This unit consists of a low-power, low-cost ESP32 microcontroller. The microcontroller offers various low-power modes that can be utilized to minimize power consumption when the cooker is not in active use. One advantage of using the ESP32 is its built-in Wi-Fi and Bluetooth capabilities, which enable remote control of devices. It has a dual-core processor and several input/output (I/O) pins [18] for connecting various sensors, making it a perfect choice for IOT projects that require wireless communication. The microcontroller interfaced with other units via its UART, SPI, and I/O interface, received inputs from the BME 280 sensors, and control actuators, and communicated with other units to perform the desired operation. The interconnection of the control unit with other units in the system is shown in the circuit diagram in (Figure 5) The circuit was designed in Proteus 8 Professional.

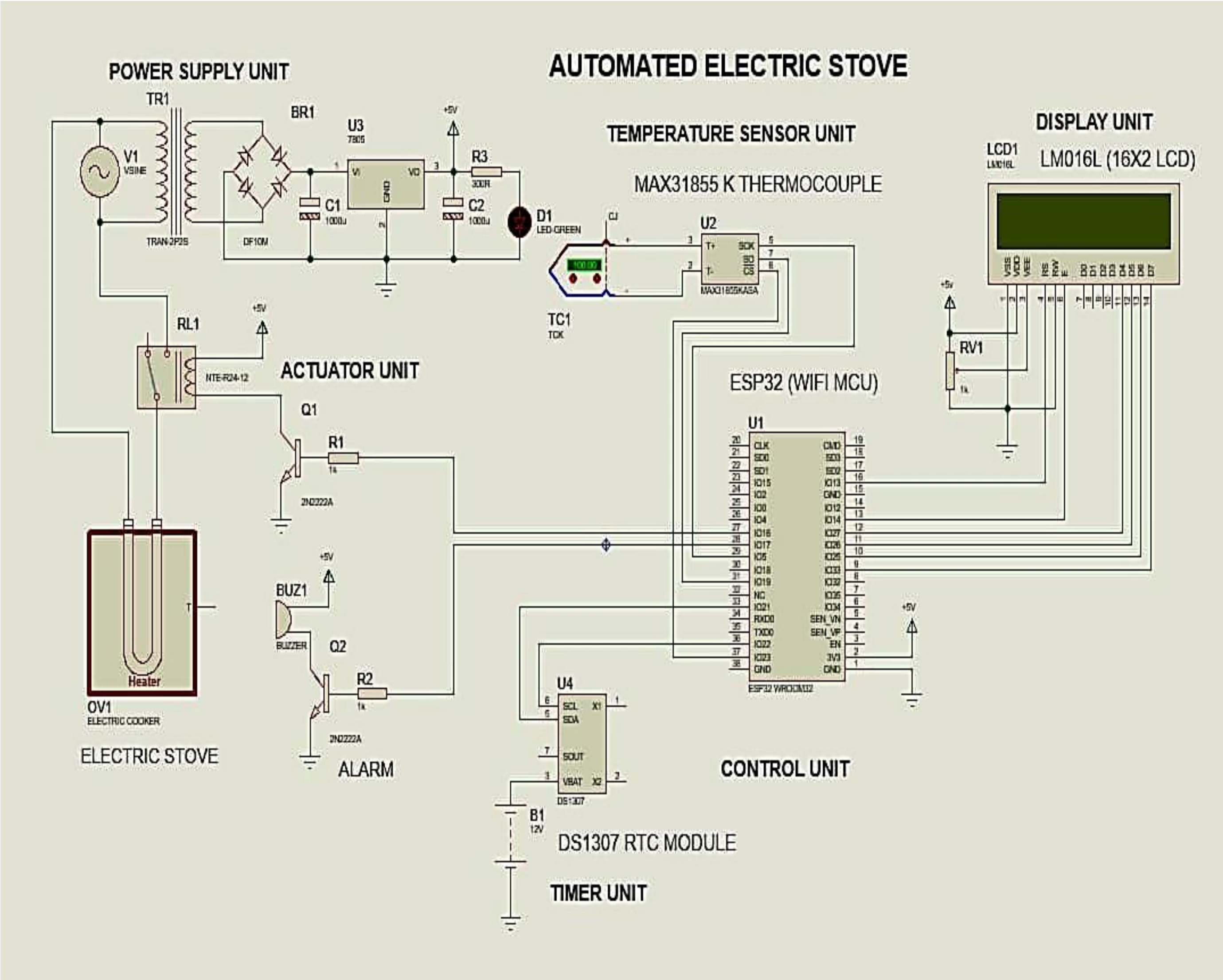

Figure 6: Schematic diagram of the system

3.2 System Implementation and Testing

The Enhanced electric cooker control system utilizes a wireless connection between a smartphone and an ESP32 webserver to facilitate remote monitoring and control of the cooking process. The implementation followed the schematic diagram depicted in Figure 5, designed using the Proteus 8.13 design suite. The microcontroller was programmed on the Arduino IDE platform using C programming with all relevant libraries installed. The ESP32 microcontroller was interfaced with the BME 280 sensor and DS1307 using the SPI and I/O pins. Data from the BME 280 is transmitted to the microcontroller via the SDA pin at the transition of the clock pin (SCL). The sensor measures the cooker's internal temperature and transmits the reading to the microcontroller. The microcontroller compares the reading with the user-defined temperature at every interval of time and trips out the cooker's heating element(s) via a relay if the read is above the specified temperature. To test the system a wireless connection was established between the microcontroller and the smartphone. The smartphone was paired with ESP32 webserver and users accessed the control dashboard/webpage via an IP address in a web browser. Through the webpage application, users set their desired cooking temperature, time, and controlled power access wirelessly. The DS1307 RTC keeps track of the timer count for the cooking task, while the microcontroller maintains the user-preset temperature limit and controls the cooker based on both timer and temperature settings

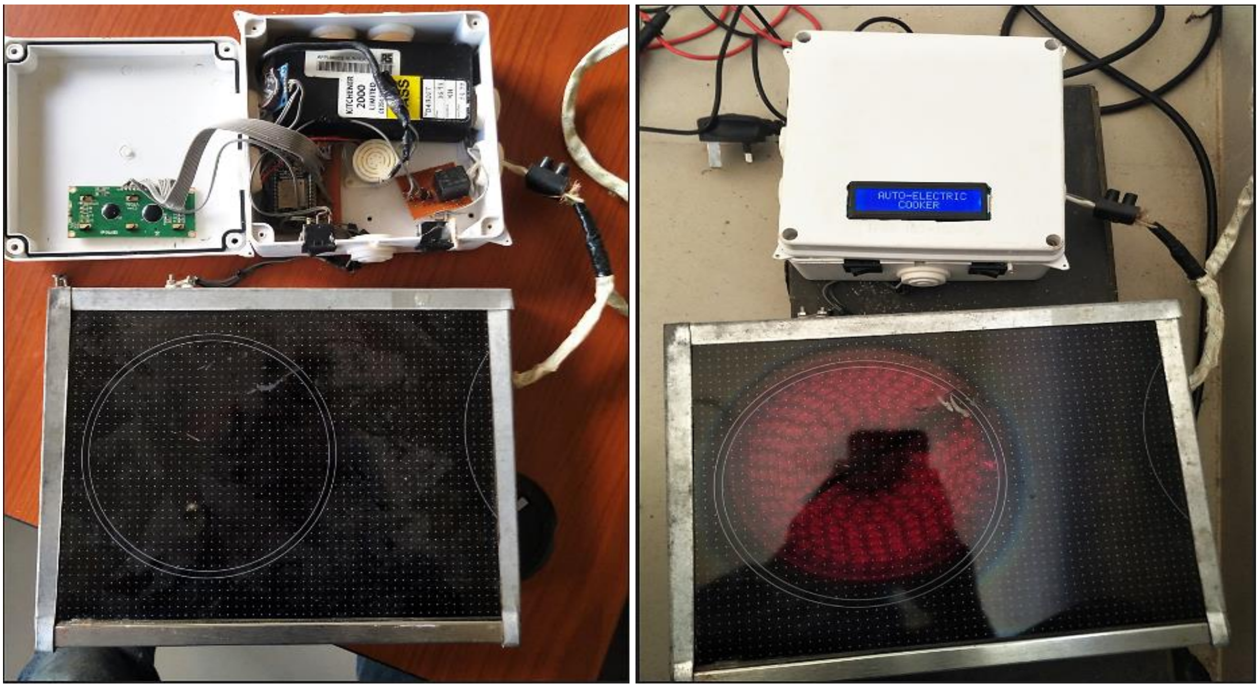

Figure 7: The enhanced electric cooker

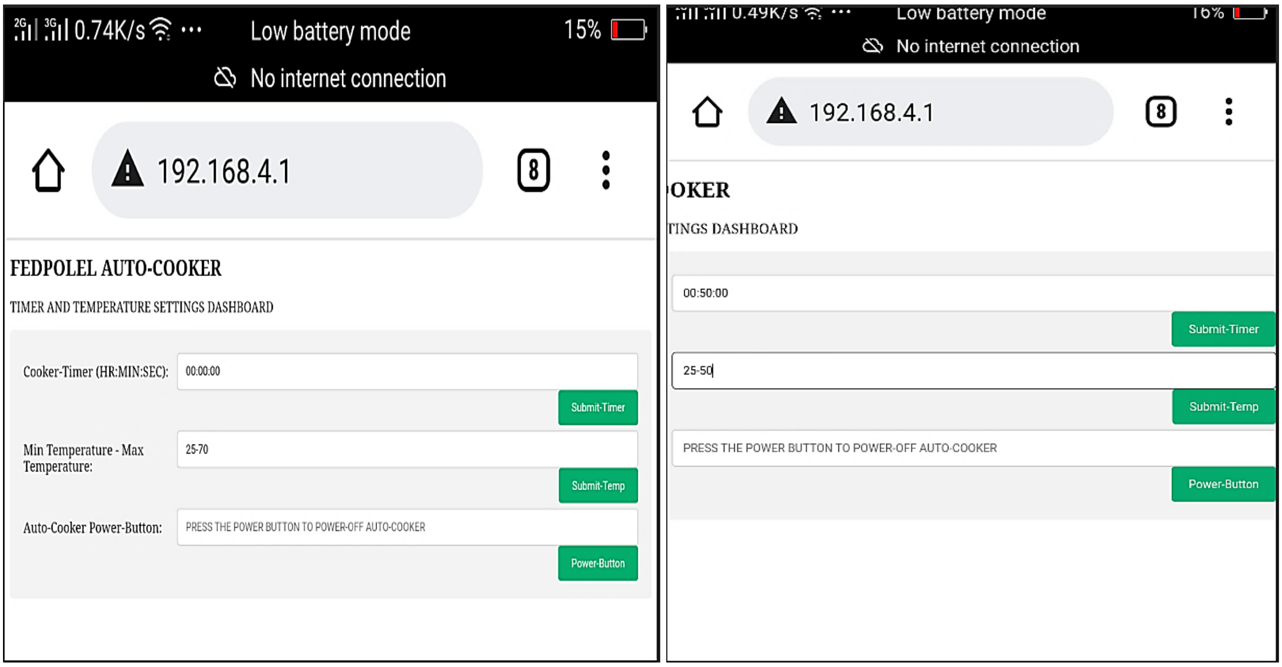

Figure 8: The webpage interface

In temperature control mode, users set a desired temperature range. Upon reaching the maximum temperature, the system produces a beep and automatically deactivates the heating element of the cooker, allowing it to cool to the minimum temperature of 25℃ before resuming operation. Likewise, in the timer mode, users set the cooking duration, and when the timer counts up to the set time, the cooker turns off and triggers an alarm that sounds continuously to signal the completion of the cooking process. The alarm persists until the timer is switched off or reset on the webpage application. Users can switch between modes or use both simultaneously using two SPST switches. The gradation in temperature and the timer count, are displayed on an LCD in real-time, providing users with continuous information about the cooking process.

Figure 9: Testing the cooker in temperature mode

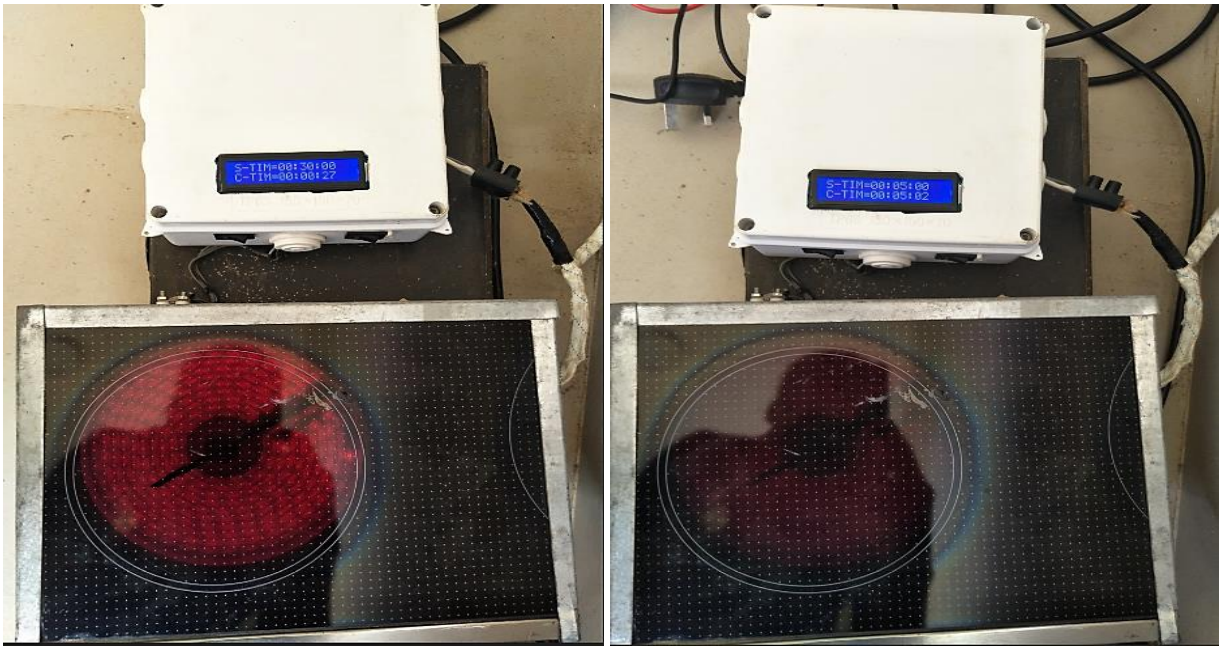

Figure 10: Testing the cooker in timer mode

4. RESULTS AND DISCUSSION

The system was subjected to a series of tests where various temperature ranges and timer settings were evaluated to observe their effects on the behavior of the cooker. The testing provided valuable insights into its performance and functionality and demonstrated the system's capability to achieve and maintain the desired cooking temperature at various time intervals. The experiment encompassed different temperature ranges (from 25°C to higher temperatures) and various timer settings (ranging from 5 minutes to 60 minutes). Each combination of temperature ranges and timer duration resulted in specific effects on the cooker's behavior: The results of these tests are summarized in Table 1

Table 1: The effect of temperature and timer on the electric cooker

S/N	Preset Temp. Range (°C)	Timer Settings (minute)	Measured Temp. (°C)	Variation (°C)	Measured Time (stopwatch) (min/sec/ms)	Accuracy %	Observed Effect on Cooker
1	25 – 40	5	39.5	0.5	5:00:03	98.75	Slight Heating
2	25 – 45	10	44.2	0.8	10:00:01	98.22	Moderating Heating
3	25 – 50	20	49.4	0.6	20:00:01	98.8	High Heating
4	25 – 55	30	54.1	0.9	30:00:02	98.36	Intense Heating
5	25 – 60	45	58.4	1.6	45:00:01	97.33	Very Hot
6	25 – 70	60	68.2	1.8	60:00:02	97.43	Maximum Heat
	Average Accuracy					98.15	

Findings from the test showed that at a temperature range of 25°C–40°C with a 5-minute timer. The cooker exhibited a slight heating effect. This suggests that the cooker started heating up, but the temperature increase was relatively minimal due to the short duration. With a slightly extended timer of 10 minutes at 25°C–45°C, the cooker's heating effect became more noticeable, signifying that it was reaching a moderate level of heat. As the temperature and timer duration increased, the observed effect escalated to significant heating. The cooker reached a temperature range where cooking or heating food would be feasible. At a maximum timer duration of 60 minutes at 25°C–70°C, the cooker exhibited maximum heat, indicating its capacity to reach high temperatures within the specified temperature range.

The results presented in the table demonstrate the system's ability to effectively regulate the cooker's temperature and cooking duration. It reveals the system's performance in controlling the temperature and timer settings. The minimum temperature was kept at 25 °C throughout the test to ensure that the cooker's temperature returned to a comfortable level, establish a consistent starting point for each subsequent test, and isolate the effects of different temperature and timer settings on the cooker's performance without any interference from previous tests. When the difference between the preset temperature and the measured temperature is computed, an average accuracy of 98.2% was derived. This indicates that the system achieved a high level of accuracy of 98% in maintaining the cooker's temperature within the preset ranges. Despite minor discrepancies, between the preset and measured temperature as well as time, during the testing phase, the system consistently upheld the chosen temperature within the designated range, and the timer functionality operated efficiently. It automatically deactivated the cooker once the preset duration elapsed, thereby averting overcooking and promoting energy efficiency.

Overall, the results of the comprehensive tests offer valuable insights into the capabilities of the enhanced electric Cooker under varying conditions. The system's heating effects, as influenced by temperature and timer settings, enable users to make informed decisions when employing the cooker for different culinary tasks. The slight variation in measured temperatures could be attributed to factors such as sensor calibration, the distribution of heat within the cooker, and the sensor's response time to temperature changes. These variations underscore the significance of accurate sensor calibration and a clear understanding of the system's behavior for achieving precise temperature control.

5. CONCLUSION

The transition from a traditional single-burner electric cooker to an IoT-enabled intelligent appliance marks a significant advancement in kitchen technology. The harmonious blend of age-old cooking techniques with contemporary automation not only simplifies daily chores but also establishes a model for the forthcoming era of interconnected households. As technology progresses, the potential for improving efficiency, safety, and user satisfaction in the kitchen is limitless, ushering in a new age of intelligent cooking devices. Through the incorporation of IoT into the electric cooker, users gain the capability to remotely manage and monitor their electric cookers, offering unparalleled convenience and adaptability. The ability to adjust temperature settings, set timers, and receive real-time updates via mobile devices ensures that cooking processes can be precisely tailored to individual preferences. Furthermore, the integration of smart features fosters a safer cooking environment. As the enhanced cooker is equipped with sensors to detect anomalies, such as overheating or unsafe conditions, triggering automatic shutdowns or alerts to prevent potential hazards. This proactive approach to safety enhances the overall user experience, instilling confidence in the use of the appliance. In all this research provides a comprehensive approach to energy conservation, efficiency improvement, and the promotion of clean cooking energy use. By optimizing cooking practices, minimizing energy waste, and enabling remote control, this innovative system contributes to a more sustainable culinary landscape. As technology evolves, these solutions pave the way for a greener future by advocating responsible energy consumption and fostering a culture of efficiency.

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