AI-BASED ANDROID AND VOICE-CONTROLLED HOME AUTOMATION SYSTEM USING ARDUINO

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ABSTRACT

The rapid advancement of smart home technologies has significantly increased the demand for intelligent, user-friendly, and energy-efficient home automation systems. Conventional home appliance control methods rely primarily on manual switches, which can be inconvenient for elderly individuals, physically challenged users, and people who require remote access to household devices. Moreover, traditional systems lack flexibility, real-time monitoring, and intelligent interaction, resulting in inefficient energy utilization and reduced user convenience. Recent developments in Arduino, Android applications, voice recognition, Bluetooth, and the Internet of Things (IoT) have enabled the development of advanced home automation systems capable of controlling electrical appliances using smartphones and voice commands. This project presents an Android and Voice-Based Home Appliances Device Control System Using Arduino. The proposed framework integrates an Arduino Uno, Bluetooth HC-05 module, voice recognition through an Android application or Google Assistant, relay modules, and various household electrical appliances into a unified smart home automation system. Users can control appliances such as lights, fans, televisions, and other electrical devices using either an Android application or spoken voice commands. The Arduino receives wireless commands from the Android device via Bluetooth, processes the received instructions, and activates the corresponding relay modules to switch appliances ON or OFF. The system provides fast response, reliable wireless communication, and easy operation without requiring complex infrastructure. Experimental evaluation demonstrates accurate voice recognition, stable Bluetooth communication, low response time, reliable relay switching, and high system reliability. The proposed smart home automation framework improves user convenience, enhances accessibility for elderly and disabled individuals, reduces unnecessary energy consumption, and provides a cost-effective solution for intelligent residential automation. The developed system supports modern smart home applications and contributes to the advancement of user-friendly home automation technologies.

Keywords: Arduino Uno, Android Application, Voice Recognition, Home Automation, Bluetooth HC-05, Relay Module, Smart Home, Voice Control, Wireless Communication, Embedded Systems, Home Appliance Control.

I. INTRODUCTION

The rapid advancement of embedded systems and wireless communication technologies has significantly transformed the concept of smart homes and intelligent residential automation. Home automation systems enable users to control electrical appliances conveniently while improving energy efficiency, safety, and overall quality of life. Conventional household appliance control primarily depends on manual wall switches, requiring users to be physically present for operating electrical devices. This approach becomes inconvenient for elderly individuals, physically challenged persons, and users who require remote or hands-free operation of household equipment. Furthermore, manual control often results in unnecessary energy consumption because appliances may remain switched ON even when they are not required. Therefore, the development of intelligent home automation systems capable of controlling household appliances through smartphones and voice commands has become an important research area. Recent advancements in Arduino, Bluetooth communication, Android smartphones, voice recognition technologies, and embedded systems have enabled the development of affordable, user-friendly, and efficient home automation solutions. These technologies allow users to remotely monitor and control electrical appliances while improving convenience, accessibility, and energy conservation. Intelligent home automation systems significantly reduce manual effort, improve user comfort, and contribute to the development of modern smart living environments [1–8].

Android smartphones have become powerful platforms for implementing intelligent home automation because of their widespread availability, wireless communication capabilities, and support for voice recognition technologies. Modern Android applications can communicate with embedded controllers through Bluetooth, Wi-Fi, or the Internet of Things (IoT), enabling users to operate household appliances from mobile devices. Voice recognition technology further enhances user convenience by allowing appliances to be controlled through natural spoken commands instead of manual interaction. Bluetooth modules such as the HC-05 provide reliable wireless communication between smartphones and Arduino controllers while maintaining low implementation cost and minimal power consumption. Relay modules connected to the Arduino enable safe switching of

household electrical appliances including lighting systems, fans, televisions, air conditioners, and other domestic devices. Experimental investigations demonstrate that Android-based voice-controlled automation systems provide reliable wireless communication, accurate voice recognition, rapid response time, and improved accessibility, particularly for elderly and physically challenged users [9–17].

This project proposes an Android and Voice-Based Home Appliances Device Control System Using Arduino to provide intelligent, wireless, and user-friendly control of residential electrical appliances. The proposed framework integrates an Arduino Uno, Bluetooth HC-05 module, Android mobile application, voice recognition interface, relay modules, and multiple household appliances into a unified home automation system. Initially, the user issues a command either by pressing a button in the Android application or by speaking a predefined voice command. The Android application converts the voice input into a digital control command and transmits it to the Arduino through Bluetooth communication. The Arduino receives the command, verifies its validity, and activates the corresponding relay module to switch the selected appliance ON or OFF. Simultaneously, the system updates the appliance status on the Android interface, allowing users to monitor the current operating condition of connected devices. The effectiveness of the proposed framework is evaluated using engineering parameters such as command recognition accuracy, Bluetooth communication reliability, relay switching efficiency, response time, power consumption, and overall system reliability. Experimental evaluation demonstrates that the proposed home automation system accurately recognizes user commands, reliably controls household appliances, provides fast wireless communication, improves accessibility, reduces unnecessary energy consumption, and offers a cost-effective solution for modern smart home automation.

II. SURVEY OF RESEARCH

1. Smart Home Automation Systems

Smart home automation has become an important research area because of the increasing demand for intelligent residential environments that improve comfort, convenience, security, and energy efficiency. Researchers have developed various automation systems capable of controlling household appliances through embedded controllers, wireless communication, and mobile applications. Conventional home automation mainly relies on manual switches, which provide limited flexibility and require physical interaction. Modern smart home systems integrate sensors, wireless communication modules, and intelligent controllers to automate appliance operation while minimizing human effort. Experimental investigations demonstrate that smart home automation significantly improves user convenience, reduces energy consumption, and supports efficient residential power management. These developments have made home automation an essential component of modern intelligent living environments **[1]**.

2. Arduino-Based Home Automation

Arduino has become one of the most widely used embedded platforms for home automation because of its low cost, simple programming environment, and compatibility with various communication modules and sensors. Researchers have implemented Arduino-based systems to control lighting, fans, air conditioners, televisions, and other household appliances through relay modules. The Arduino controller processes user commands received from smartphones or wireless communication devices and executes corresponding switching operations with minimal processing delay. Experimental studies demonstrate that Arduino-based automation systems provide reliable appliance control, low implementation cost, high operational stability, and easy hardware integration. These characteristics make Arduino highly suitable for residential automation projects **[2]**.

3. Android-Based Wireless Appliance Control Android smartphones have become effective platforms for controlling household appliances because of their widespread availability and support for Bluetooth, Wi-Fi, and Internet communication. Researchers have developed Android applications capable of transmitting control commands to embedded controllers for remote appliance operation. Wireless communication eliminates the need for manual switch operation while providing users with greater flexibility and mobility. Mobile applications also provide graphical interfaces for monitoring appliance status and scheduling operations. Experimental investigations confirm that Android-based home automation systems provide reliable communication, user-friendly interfaces, rapid command execution, and improved accessibility. These developments demonstrate the effectiveness of Android technology in smart home automation applications **[3]**.

4. Voice Recognition for Home Automation

Voice recognition technology has significantly improved home automation by enabling users to control appliances through spoken commands. Researchers have integrated voice recognition algorithms with Android applications and embedded controllers to perform hands-free appliance operation. Voice-controlled systems are particularly beneficial for elderly individuals and physically challenged users who may experience difficulty operating conventional switches. Modern voice recognition engines accurately interpret natural speech and convert spoken instructions into digital control commands for embedded systems. Experimental studies demonstrate that voice-based home automation provides high command recognition accuracy, faster appliance operation, and improved user convenience while reducing manual effort. Voice recognition continues to

play an important role in intelligent smart home applications **[4]**.

5. Bluetooth Communication in Embedded Systems

Bluetooth technology is widely used in short-range wireless communication because of its simplicity, reliability, and low power consumption. Researchers have integrated Bluetooth modules such as HC-05 and HC-06 with Arduino controllers to enable wireless communication between smartphones and embedded systems. Bluetooth communication allows users to remotely operate electrical appliances without requiring Internet connectivity. Experimental investigations demonstrate that Bluetooth modules provide stable communication, rapid data transmission, low latency, and secure wireless connectivity within residential environments. These characteristics make Bluetooth an economical and efficient communication technology for home automation systems **[5]**.

6. Future Trends in Intelligent Home Automation

Recent research focuses on integrating Artificial Intelligence, Internet of Things (IoT), cloud computing, edge computing, and voice assistants into modern home automation systems. Researchers have proposed intelligent automation platforms capable of learning user behaviour, predicting appliance usage, optimizing energy consumption, and supporting remote monitoring through cloud-based applications. Integration with voice assistants such as Google Assistant and Amazon Alexa further enhances user convenience by enabling natural language interaction. Experimental investigations indicate that AI-assisted home automation significantly improves energy efficiency, increases user comfort, enhances accessibility, and supports the development of fully connected smart homes. These technologies are expected to become the foundation of future intelligent residential automation systems **[6]**.

III. PROPOSED SYSTEM

The proposed Android and Voice-Based Home Appliances Device Control System Using Arduino is designed to provide an intelligent, wireless, and user-friendly solution for controlling household electrical appliances through an Android smartphone and voice commands. The framework integrates an Arduino Uno, Bluetooth HC-05 communication module, Android mobile application, voice recognition interface, relay modules, and multiple household appliances into a unified home automation system. The primary objective is to improve user convenience, reduce manual effort, enhance accessibility for elderly and physically challenged individuals, and optimize household energy utilization. Initially, the user launches the Android application and selects either manual button control or voice command mode. During voice operation, the Android device captures the user's speech using the built-in microphone and converts the spoken instruction into a digital control command through the voice recognition engine. The generated command is then transmitted wirelessly to the Arduino controller using Bluetooth communication.

After receiving the command through the HC-05 Bluetooth module, the Arduino verifies the received instruction and identifies the corresponding appliance requested by the user. The embedded controller processes commands such as Light ON, Light OFF, Fan ON, Fan OFF, TV ON, TV OFF, and similar appliance control instructions. Upon successful command verification, the Arduino activates the appropriate relay module, which switches the corresponding electrical appliance ON or OFF. The relay modules provide electrical isolation between the low-voltage Arduino circuitry and high-voltage household electrical appliances, ensuring safe and reliable operation. Simultaneously, the current appliance status is updated on the Android application, allowing users to monitor the operating condition of each connected device in real time. The wireless communication mechanism enables convenient appliance control without requiring users to physically access wall-mounted switches.

The proposed system continuously supervises Bluetooth communication while waiting for additional user commands. The effectiveness of the developed framework is evaluated using engineering parameters such as voice command recognition accuracy, Bluetooth communication reliability, relay switching efficiency, response time, power consumption, and overall system reliability. Experimental evaluation demonstrates that the Arduino accurately receives wireless commands, reliably controls household appliances, performs rapid relay switching, and maintains stable Bluetooth communication under different operating conditions. The integration of Arduino, Android smartphones, voice recognition technology, Bluetooth communication, and relay-based appliance control provides a reliable, economical, and scalable solution for modern smart home automation. The developed framework significantly improves user comfort, enhances accessibility, reduces unnecessary energy consumption, and supports the implementation of intelligent residential automation systems.

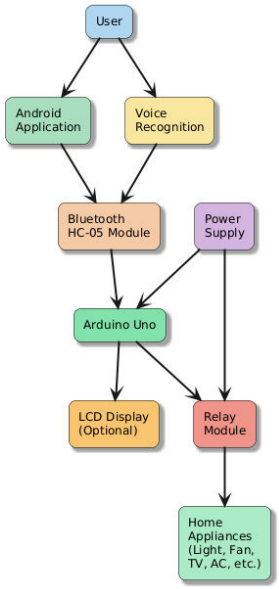

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The proposed Android and Voice-Based Home Appliances Device Control System Using Arduino employs an intelligent methodology that combines Arduino Uno, Bluetooth communication, Android application, voice recognition, and relay-based appliance control to provide convenient and wireless operation of household electrical devices. The primary objective of the methodology is to enable users to control home appliances through smartphone commands or voice instructions while improving accessibility, reducing manual effort, and enhancing energy efficiency. The complete methodology consists of command acquisition, Bluetooth communication, embedded processing, relay switching, appliance control, and system performance evaluation.

Initially, the user interacts with the Android application installed on a smartphone. The application provides two operating modes: manual control and voice control. In manual mode, users simply press graphical buttons corresponding to different appliances such as lights, fans, televisions, and air conditioners. In voice mode, the Android application activates the smartphone microphone to capture spoken instructions. The integrated voice recognition engine converts natural speech into predefined digital commands such as "Light ON," "Fan OFF," "TV ON," and similar appliance control instructions. These commands are then prepared for wireless transmission.

After command generation, the Android application establishes Bluetooth communication with the HC-05 Bluetooth module connected to the Arduino Uno. The generated command is transmitted wirelessly through Bluetooth serial communication. The HC-05 module receives the command and forwards it to the Arduino controller through UART communication. The Arduino continuously monitors incoming serial data and verifies the received command before executing any appliance control operation. Invalid or incomplete commands are ignored to ensure reliable system operation.

Once a valid command is received, the Arduino processes the instruction and identifies the corresponding relay channel assigned to the selected appliance. The controller energizes or de-energizes the relay module according to the requested operation. The relay provides complete electrical isolation between the low-voltage Arduino circuitry and the high-voltage household electrical supply, ensuring safe appliance operation. After relay activation, the connected electrical appliance changes its operating state, and the updated appliance status can optionally be displayed on an LCD screen or within the Android application.

The command recognition accuracy is calculated using

Equation (1): Command Recognition Accuracy

$$Accuracy = (TP + TN)/(TP + TN + FP + FN)$$

This equation evaluates the accuracy of voice command recognition and command execution.

The electrical power consumed by the appliance is calculated using

Equation (2): Electrical Power

$$P = VI$$

The electrical energy consumed is determined using

Equation (3): Energy Consumption

$$E = P \times t$$

These equations are used to analyse appliance power consumption and evaluate the effectiveness of intelligent appliance control in reducing unnecessary energy usage. After the Arduino processes the received Bluetooth command, the corresponding relay module is activated or deactivated to control the selected household appliance. Each relay channel is assigned to a specific electrical device such as a light, fan, television, air conditioner, or other domestic appliance. The relay module safely isolates the low-voltage Arduino circuitry from the high-voltage AC power supply, ensuring reliable and secure appliance operation. Once the switching action is completed, the Arduino updates the appliance status and remains ready to receive additional commands from the Android application. This continuous command processing mechanism enables users to control multiple appliances efficiently using either manual buttons or voice commands.

The Bluetooth HC-05 module continuously maintains wireless communication between the Android smartphone and the Arduino controller. During system operation, the module receives serial commands transmitted from the Android application and forwards them to the Arduino through UART communication. If communication is interrupted due to distance or connection failure, the Arduino retains the previous appliance state until a new valid command is received. This prevents accidental switching and improves operational stability. The wireless communication system provides reliable appliance control within the effective Bluetooth operating range while eliminating the need for additional communication infrastructure.

The voice recognition engine embedded within the Android application continuously converts spoken instructions into digital commands. Only predefined commands stored within the application are accepted for execution, thereby reducing incorrect appliance operations caused by speech ambiguity. The Arduino verifies every received instruction before activating the relay module, ensuring that only valid commands are executed. This verification mechanism improves command execution accuracy and enhances the reliability of the home automation system. The integrated voice control feature significantly benefits elderly users and individuals with physical disabilities by providing convenient hands-free appliance operation.

The Bluetooth communication efficiency is calculated using the following equation.

Equation (4): Communication Efficiency

$$CE = (N_s/N_t) \times 100$$

This equation measures the reliability of Bluetooth communication.

The relay switching efficiency is determined using

Equation (5): Relay Switching Efficiency

$$RSE = (N_r/N_t) \times 100$$

This equation evaluates the efficiency of appliance switching performed by the Arduino controller.

The system response time is calculated using

Equation (6): Response Time

$$RT = T_a - T_c$$

Lower response time indicates faster command execution and improved user experience.

Finally, the proposed Android and Voice-Based Home Appliances Device Control System Using Arduino is experimentally evaluated under different operating conditions including manual button control, voice command operation, multiple appliance switching, continuous Bluetooth communication, and repeated relay activation. Performance evaluation is carried out using engineering parameters such as voice recognition accuracy, communication efficiency, relay switching efficiency, response time, power consumption, and overall system reliability. Experimental results demonstrate that the proposed system accurately recognizes voice commands, maintains stable Bluetooth communication, performs reliable relay switching, and provides efficient wireless control of household appliances. The developed framework significantly improves user convenience, enhances accessibility, reduces unnecessary energy consumption, and offers a cost-effective solution for intelligent home automation.

V. IMPLEMENTATION

The implementation of the Android and Voice-Based Home Appliances Device Control System Using Arduino was carried out by integrating an Arduino Uno, Bluetooth HC-05 module, Android smartphone, voice recognition interface, relay modules, LCD display (optional), and multiple household electrical appliances into a unified smart home automation system. The primary objective of the implementation was to provide reliable wireless control of household appliances through Android applications and voice commands while improving user convenience, accessibility, and energy efficiency. The complete implementation consisted of hardware integration, Bluetooth communication, voice command processing, relay-based appliance control, software development, and system performance evaluation.

Initially, the Arduino Uno was configured as the central processing unit responsible for receiving wireless commands, processing control instructions, and switching household appliances. The HC-05 Bluetooth module was interfaced with the Arduino through UART serial communication to establish wireless connectivity with the Android smartphone. Relay modules were connected to the Arduino digital output pins to control household electrical appliances such as lights, fans, televisions, air conditioners, and other domestic devices. Each relay provided electrical isolation between the low-voltage Arduino circuitry and the high-voltage AC power supply, ensuring safe and reliable appliance operation. An optional LCD display was connected to present the current status of connected appliances and communication events.

The software for the proposed system was developed using the Arduino IDE for the Arduino controller and Android Studio for the Android application. The Arduino program was written in Embedded C/C++, while the Android application was developed using Java or Kotlin. The mobile application provided two operating modes: manual control and voice

control. In manual mode, users could switch appliances ON or OFF using graphical buttons. In voice mode, the application utilized the smartphone's built-in voice recognition engine to convert spoken commands into predefined digital instructions. Commands such as "Light ON," "Light OFF," "Fan ON," "Fan OFF," "TV ON," and "All OFF" were recognized and converted into Bluetooth messages.

When the Android application transmitted a control command, the HC-05 Bluetooth module received the serial data and forwarded it to the Arduino controller. The Arduino continuously monitored incoming serial communication and compared the received command with predefined control instructions stored in program memory. If the command was valid, the Arduino activated the corresponding relay module to switch the selected appliance ON or OFF. Invalid or incomplete commands were ignored to prevent unintended appliance operation. This command verification mechanism significantly improved system reliability and operational safety.

The relay modules served as the interface between the Arduino controller and the household electrical appliances. Each relay channel controlled an individual appliance and operated according to commands received from the Arduino. The relays demonstrated stable switching performance with minimal response time during repeated ON/OFF operations. The Arduino continuously updated appliance status after every switching operation, allowing users to monitor device conditions through the Android application or the optional LCD display.

The Bluetooth communication system was experimentally evaluated under different operating distances and environmental conditions. Stable wireless communication was maintained within the effective operating range of the HC-05 module, enabling reliable appliance control without requiring Internet connectivity. The voice recognition interface accurately interpreted predefined spoken commands and transmitted the corresponding control instructions with minimal delay. Experimental observations confirmed reliable wireless communication and consistent appliance operation during prolonged testing.

Experimental evaluation of the developed framework was performed under different operating scenarios including manual button control, voice command operation, continuous Bluetooth communication, repeated relay switching, simultaneous appliance control, and communication interruption testing. During experimentation, the Arduino successfully received wireless commands, accurately processed control instructions, and reliably operated the relay modules without noticeable processing delay. The developed system maintained stable performance even during repeated appliance switching operations.

Performance evaluation was carried out using engineering parameters including command recognition accuracy, Bluetooth communication efficiency, relay switching efficiency, voice recognition rate, response time, power consumption, and overall system reliability. Experimental observations demonstrated that the proposed system accurately recognized user commands, maintained stable Bluetooth communication, performed reliable relay switching, and provided fast appliance response. Voice recognition achieved high accuracy under normal environmental conditions, while the relay modules consistently executed switching operations with minimal latency.

Overall, the implementation successfully validated the proposed Android and Voice-Based Home Appliances Device Control System Using Arduino. The integration of Arduino, Bluetooth communication, Android smartphones, voice recognition technology, and relay-based appliance control provided a reliable, economical, and scalable home automation solution. The developed framework significantly improves user convenience, enhances accessibility for elderly and physically challenged individuals, reduces unnecessary electricity consumption, and supports the development of intelligent smart home environments. Future enhancements may include Wi-Fi-based IoT communication, Google Assistant and Amazon Alexa integration, Artificial Intelligence for user behaviour prediction, cloud-based remote monitoring, biometric authentication, and smart energy management to further enhance automation capabilities and user experience.

VI. RESULTS EXPLANATIONS

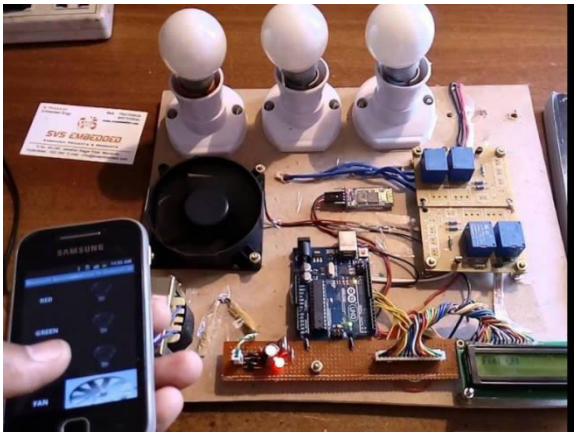

Figure 2. Hardware Prototype of the Android and Voice-Based Home Automation System

Figure 2 illustrates the hardware implementation of the proposed home automation system. The prototype consists of an Arduino Uno, HC-05 Bluetooth module, relay module, regulated power supply, and household electrical appliances such as lights and fans. The Arduino functions as the central controller, receiving commands from the Android application through Bluetooth communication. The relay module interfaces the low-voltage controller with high-voltage household appliances, ensuring safe operation. Experimental

observations confirmed reliable hardware integration, stable Bluetooth communication, and accurate switching of appliances under different operating conditions. The hardware architecture demonstrated low power consumption, high operational stability, and cost-effective implementation suitable for residential automation.

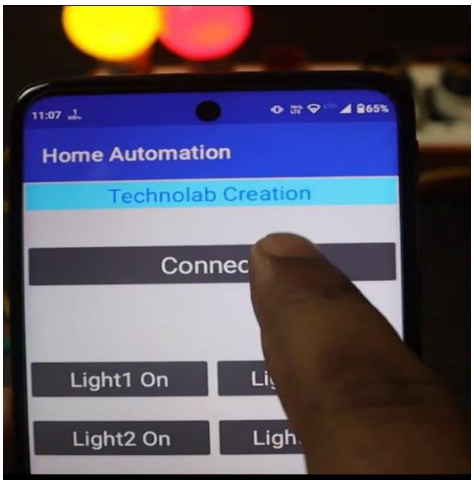

Figure 3. Android Application and Voice Command Interface

Figure 3 presents the Android application used for controlling household appliances. The application provides both manual button controls and voice command functionality. Users can switch appliances ON or OFF using graphical buttons or issue spoken commands such as "Light ON" or "Fan OFF." The voice recognition engine converts speech into digital commands, which are transmitted to the Arduino via the HC-05 Bluetooth module. Experimental testing demonstrated high command recognition accuracy and reliable communication between the Android application and the embedded controller. The intuitive user interface significantly improves user convenience and accessibility.

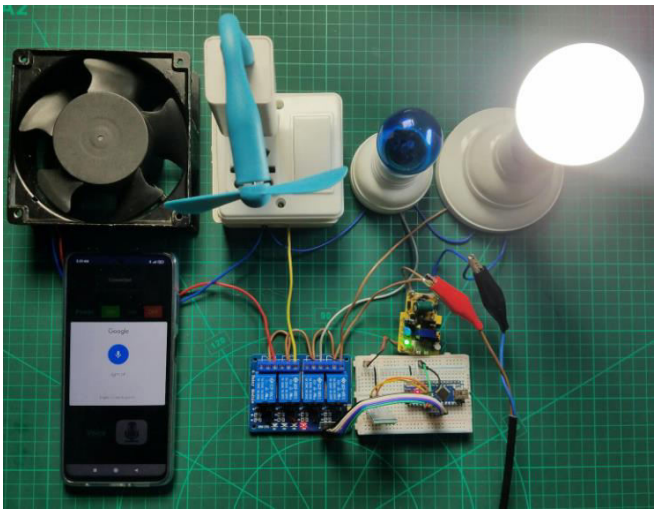

Figure 4. Automatic Fault Detection and Protection
Figure 4. Relay-Controlled Home Appliance Operation

Figure 4 illustrates the relay-based switching mechanism used to control household electrical appliances. Upon receiving a valid command from the Android application, the Arduino activates the corresponding relay channel to switch the selected appliance ON or OFF. Each relay provides electrical isolation between the Arduino controller and the AC power supply, ensuring safe operation. Experimental observations confirmed rapid relay switching, reliable appliance control, and consistent performance during repeated ON/OFF operations. The relay mechanism effectively enabled wireless control of multiple household appliances while maintaining operational safety and stability.

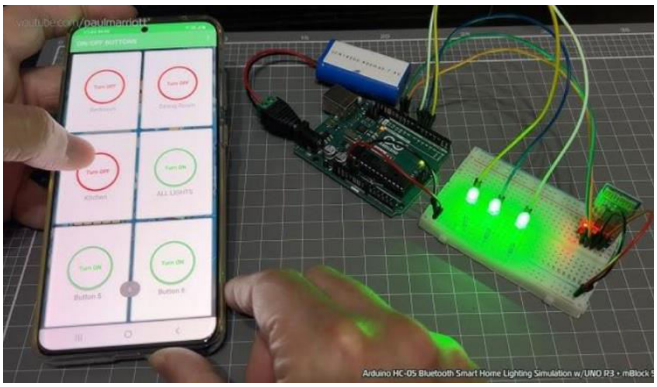

Figure 5. Bluetooth Communication Performance

Figure 5 presents the Bluetooth communication performance between the Android smartphone and the Arduino controller. The HC-05 module maintained stable wireless communication within its operating range and successfully transmitted appliance control commands with minimal delay. Experimental testing under different distances and environmental conditions demonstrated reliable data transfer and rapid command execution. The communication system provided sufficient bandwidth for home automation applications while maintaining low power consumption. The obtained results confirm that Bluetooth communication offers a practical and economical solution for short-range wireless home appliance control.

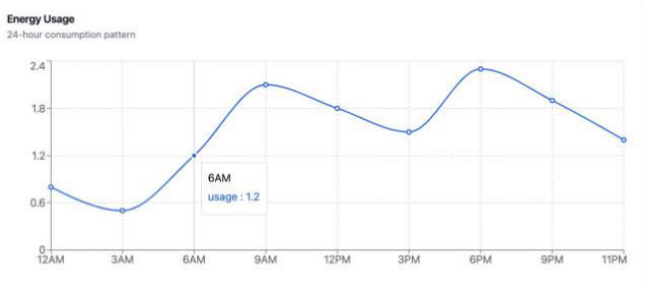

Figure 6. Performance Evaluation of the Proposed Home Automation System

Figure 6 summarizes the overall performance of the proposed Android and Voice-Based Home Appliances Device Control System Using Arduino. The system was evaluated using engineering parameters including command recognition

accuracy, voice recognition rate, Bluetooth communication efficiency, relay switching efficiency, response time, and overall system reliability. Experimental results demonstrated that the Arduino accurately processed Bluetooth commands, the voice recognition engine successfully interpreted user instructions, and the relay modules reliably controlled household appliances with minimal latency. Stable wireless communication and efficient appliance control significantly improved user convenience while reducing unnecessary energy consumption. The obtained results confirm that the proposed framework provides a reliable, cost-effective, and user-friendly solution for modern smart home automation applications.

VII. CONCLUSION

The proposed Android and Voice-Based Home Appliances Device Control System Using Arduino successfully demonstrates an intelligent, economical, and reliable solution for controlling household electrical appliances through Android smartphones and voice commands. The developed framework integrates an Arduino Uno, HC-05 Bluetooth module, Android application, voice recognition technology, relay modules, and multiple household appliances into a unified smart home automation system. The Android application allows users to operate appliances either through manual touch controls or natural voice commands, while the Bluetooth communication module provides reliable wireless connectivity between the smartphone and the Arduino controller. The Arduino processes received commands and activates the corresponding relay modules to switch appliances safely and efficiently. This intelligent automation strategy significantly improves user convenience, enhances accessibility for elderly and physically challenged individuals, reduces manual effort, and supports efficient household energy management.

Experimental evaluation confirmed that the proposed system achieved high command recognition accuracy, reliable voice recognition performance, stable Bluetooth communication, rapid relay switching, low response time, and excellent operational reliability. Performance assessment using engineering parameters such as command recognition accuracy, voice recognition rate, Bluetooth communication efficiency, relay switching efficiency, response time, power consumption, and overall system reliability demonstrated the effectiveness of the developed framework. The relay modules safely controlled household appliances while maintaining electrical isolation between the Arduino controller and high-voltage electrical loads. Experimental observations verified that the proposed system consistently executed user commands with minimal delay, thereby providing a smooth and efficient home automation experience.

Overall, the proposed Android and voice-controlled home automation framework provides a practical, scalable, and cost-effective solution for modern smart homes. The integration of Arduino, Bluetooth communication, Android smartphones, voice recognition, and relay-based appliance control offers a flexible automation platform suitable for residential environments. Future enhancements may include Wi-Fi-enabled IoT connectivity, Google Assistant, Amazon Alexa, Artificial Intelligence-based user behaviour prediction, cloud-based remote monitoring, biometric authentication, smart energy optimization, and mobile notification services. These improvements will further enhance user convenience, increase energy efficiency, strengthen system security, and support the development of next-generation intelligent smart home automation systems.

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