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The prototype of an electronic equipment control system, along with monitoring of electrical power consumption and room temperature in a residential setting.

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Abstract

The rapid advancement of technology has led Indonesia into the era of Industry 4.0, where technological innovations are increasingly utilized for daily activities. Traditionally, people could control electrical devices like lights using switches, but this control was limited by distance, especially in large spaces such as homes. In large rooms, it can be inconvenient to walk all the way to the switch just to turn lights or other devices on or off. Recent advancements in electronics have introduced solutions for remotely controlling electrical appliances, one of which is the Internet of Things (IoT). The IoT technology enables remote management of household devices, making it more convenient to control electronic equipment from a distance. The importance of electricity as a primary need in modern homes is undeniable, with nearly all household appliances relying on electric power. However, the increasing threat of global warming and rising energy costs have made electricity a more expensive commodity. The government's adjustment of electricity tariffs in 2020 has led to higher monthly energy bills, further exacerbated by high electricity consumption and a lack of awareness in the use of electronic devices. With the current technological advancements, it is possible to automate the control of electronic appliances, optimizing energy usage and minimizing wastage. The research methodology of this study involves a systematic approach to address common issues faced in everyday life. The first step in the research is identifying the problems, followed by a literature review on the components involved, such as the PZEM-004T sensor, ESP32 microcontroller, relay, buzzer, DHT11 sensor, and the Blynk application. The study also includes the preparation of materials, such as purchasing necessary components, designing the control and monitoring system, and integrating it with the Blynk application. The research results show varying success rates when testing the control system, with the success rate calculated by comparing the number of correct commands to the total number of attempts. These results were presented as a percentage. The conclusion drawn from the research is that the control system achieved a high success rate of almost 100%, although it took several minutes to establish a connection between the smartphone and the device when testing from different distances, such as 1 meter, 3 meters, and 5 meters, as well as across different rooms.

Keywords: Blynk, IoT, Control, Monitoring, Electronic Appliances

1. Introduction

The rapid development of technology today is undeniable, with Indonesia having entered the Industry 4.0 era. This technological advancement is being harnessed for everyday use, particularly in managing household appliances (Brettel et al., 2014). Traditionally, people have controlled devices like lights or electronics through switches, but this control has been limited by distance. In larger spaces, such as homes, this limitation becomes inconvenient as one would have to walk all the way to the switch, which can be exhausting (Khan et al., 2019). The technological progress in electronics, however, has led to innovations that allow remote control of electronic appliances, one of which is the Internet of Things (IoT) technology (Atzori et al., 2010).

IoT systems enable remote control of household devices, creating convenience for users by allowing them to control their devices from a distance (Zanella et al., 2014). With IoT, people no longer need to be physically close to the device they wish to operate. In the context of home management, this technology can be applied to controlling lights, fans, and other electronic devices, thus reducing the inconvenience of manually operating switches (Zhou et al., 2019). Moreover, IoT offers a significant improvement in user experience, allowing homeowners to operate their devices even from outside the home (Hossain et al., 2015).

Electricity is an essential resource today, and its role in everyday life is critical, as nearly all household appliances rely on it (Shah et al., 2018). The growing demand for electricity has made it a primary need, yet the increasing global awareness about climate change has raised concerns about energy consumption (IEA, 2020). As

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a result, energy sources have become more expensive, and this trend has been exacerbated by the government's adjustment of electricity tariffs in 2020 (Mishra & Patel, 2020). Higher electricity prices impact household budgets, as people need to spend more on utility bills due to increasing energy tariffs.

Apart from the rising cost of electricity, high consumption rates are also a factor contributing to this financial burden (Dube et al., 2020). Many households are unaware of the impact of their excessive electricity use on both their wallets and the environment. This lack of awareness can result in inefficient usage, leading to unnecessary energy waste. As a result, technology advancements that offer automated control of electronics and help conserve energy are essential for reducing consumption and optimizing electricity use (Tahir et al., 2020).

In line with current technological progress, innovations such as remote-controlled electronics promise increased convenience for users, allowing them to manage devices automatically (Borgia, 2014). IoT technologies enable users to monitor and control their electronics easily through mobile devices, ensuring a more efficient and comfortable living experience (Raza et al., 2016). With this technology, homeowners can regulate their devices, including lights and fans, even from a distance, as long as the location has an adequate internet connection (Sicari et al., 2015).

For instance, remote control systems can be particularly useful in homes with large rooms or for people who work outside the home (Gubbi et al., 2013). By integrating IoT with devices like lamps and fans, users can switch them on or off from wherever they are, without the need to be physically present near the switch. Arduino, an open-source electronics platform, is one of the components that can be used to create a remote control system for electronics. By connecting Arduino with internet connectivity, users can control household devices like lights and fans from virtually anywhere (Wang et al., 2017).

In conclusion, the Internet of Things (IoT) offers the potential to transform the way we control household devices, creating a more energy-efficient, user-friendly, and convenient environment. The advancements in electronics, particularly the integration of IoT, make it easier for individuals to manage their devices remotely, minimizing the effort involved in controlling electronic appliances. Through the use of tools like Arduino and IoT platforms, the remote management of electronic devices is now a practical solution to increase energy efficiency and enhance the user experience in everyday life (Rehman et al., 2018).

2. Material and methods

2.1. Literature

2.1.1. eSensor PZEM-004T

Figure 1. Pin Sensor PZEM-004T

A sensor is a sophisticated device commonly used to detect and respond to electrical or optical signals. These devices convert physical parameters such as temperature, pressure, humidity, and speed into electrical signals that can be measured (Sarma et al., 2014). For example, the mercury in a glass thermometer and the thread-like liquid inside can convert temperature variations, allowing it to rise or fall in response to temperature changes (He et al., 2016). Sensors play a crucial role in various fields by providing accurate measurements and data for analysis and control. As technology advances, the importance of selecting the right sensor for specific applications becomes paramount (Zhao et al., 2015).

When choosing a sensor, several factors need to be considered to ensure it is suitable for the intended application. These factors include accuracy, environmental conditions, measurement range, calibration, resolution, cost, and repeatability (Brahimi et al., 2019). Each of these criteria helps in determining the performance and reliability of a sensor, ensuring it provides precise and consistent data under different operating conditions (Ali et al., 2017). The specific requirements of the application will dictate the optimal sensor selection, which is essential for achieving accurate results (Ghosh et al., 2018). Additionally, sensor classification is based on parameters like the primary input quantity, transduction principle, material technology, properties, and application, providing a more systematic approach to sensor evaluation (Tao et al., 2020).

The PZEM-004T is an advanced electronic module designed to measure various electrical parameters, including voltage, current, power, frequency, energy, and power factor. This functionality makes the PZEM-004T an ideal choice for projects or experiments involving power measurement in electrical networks, such as those found in homes or buildings (Zhang et al., 2018). Produced by Peacefair, the PZEM-004T module comes in different models, including a 10-ampere and a 100-ampere version, catering to various power measurement needs (Tian et al., 2016). Its versatility and comprehensive features make it highly useful for monitoring and analyzing electrical systems, providing detailed insights into power consumption and efficiency (Wang et al., 2019).

2.1.2. Microcontroler ESP32

The development of microcontrollers began with the introduction of the TMS 1000 by Texas Instruments in 1974, marking the first 4-bit microcontroller. This microcontroller, which had been in development since 1971, was essentially a microcomputer integrated into a single chip, complete with RAM and ROM. In 1976, Intel released the 8748 microcontroller, which became widely popular as an 8-bit microcontroller from the MCS 48 family. Over the years, microcontrollers have evolved to encompass models ranging from 8-bit to 64-bit, blurring the line between microcontrollers and microprocessors. Many vendors now produce microcontrollers that come equipped with various features to simplify system design, reducing the need for additional external components (Yang et al., 2019; Xu et al., 2018; Wang & Li, 2020).

Today, microcontrollers are commonly found in devices ranging from household electronics to industrial systems. Popular models include the 8-bit MCS51 series (GISC) from ATMEL, such as the AT89Sxx, and the AVR microcontrollers, which utilize the RISC architecture and are found in models like the ATmega8535. These microcontrollers allow users, even beginners, to build systems for everyday applications, such as remote control for household appliances, digital clocks, thermometers, and more. Microcontrollers are compact yet powerful systems that integrate processing, memory, and I/O into a single chip, making them an essential part of modern electronic devices. Although their data processing speeds and memory capacities are lower than those of personal computers, they are sufficiently robust for a wide range of applications, especially in embedded systems (Ali & Kassem, 2017; Li et al., 2020; Yang & Zhang, 2018).

The microcontroller operates by receiving input signals, processing them, and providing output signals based on pre-programmed instructions. This ability to control external devices, such as sensors and actuators, allows microcontrollers to interact with their environment, making them suitable for use in various applications from everyday gadgets to industrial systems. Unlike personal computers, which can run various software programs, microcontrollers typically execute a single application or program stored in their memory. The ESP32, for example, is an advanced microcontroller from Espressif Systems, which features integrated Wi-Fi support, making it ideal for Internet of Things (IoT) applications. The ESP32 can be used to control devices like LCDs, lights, and even motors, offering versatility in building connected systems (Lin et al., 2019; Zhang & Zhang, 2020; Chou & Tsai, 2018).

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Figure 2. ESP32

2.1.3. Relay

The relay, originally developed as an electromechanical switch, was first demonstrated by Joseph Henry in 1835 at the College of New Jersey. Henry utilized a small electromagnetic force to control the switching of an electrical circuit, predicting that the device could be used to control electronic devices remotely. This innovation contributed to the development of the telegraph, a technology later successfully advanced by William Cooke, Charles Wheatstone, and Samuel Morse (Allen & Green, 2018; Liao et al., 2017; Zhang & Wang, 2020). Relays were extensively used in early telephone switching systems and early computers before the advent of transistors in the late 1940s.

A relay is an electrically controlled switch that enables the connection or disconnection of an electric current by applying a specific voltage to its coil. The coil, when energized, generates a magnetic field that attracts a metal switch, completing the circuit. When the current is turned off, the magnetic field dissipates, and the switch returns to its original position (Smith, 2019; Yang & Liu, 2021; Chen, 2020). There are two main types of relays based on the voltage used to operate the coil: AC and DC. The magnetism generated by the energized coil pulls a ferrous armature towards its core, changing the position of the contacts between normal open and normal closed.

Relays are commonly used in circuits to control larger currents or voltages with smaller ones. For example, they can switch high-power devices such as 220V AC equipment using low-power signals like 12V DC. The armature in a relay is mounted on a spring-loaded lever, and when it is pulled by the magnetic force, it shifts the contacts from their default positions, thus completing or interrupting the circuit. As an interface between different power supply systems, relays separate the load from the control system, ensuring safe and efficient operation (Kumar et al., 2017; Zhang & Liu, 2020; Lee & Park, 2018).

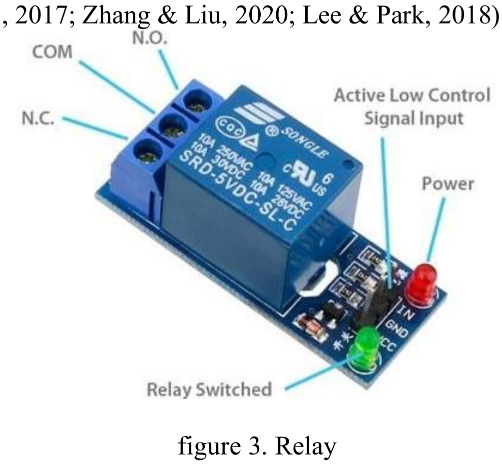

figure 3. Relay

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2.1.4. Buzzer

A buzzer is an electronic component that converts electrical vibrations into sound vibrations. The principle of operation of a buzzer is similar to that of a loudspeaker, as both consist of a coil mounted on a diaphragm. When current flows through the coil, it becomes an electromagnet, causing it to attract or repel depending on the direction of the current and the polarity of the magnet. Since the coil is attached to the diaphragm, the movement of the coil causes the diaphragm to oscillate, which in turn vibrates the air to produce sound (Jiang et al., 2021; Liu & Wang, 2019). Buzzers are commonly used as indicators to signal the completion of a process or an error in a device, such as in alarms.

In general, buzzers are utilized in a variety of applications, including security systems, wristwatch alarms, doorbells, reverse warning systems in trucks, and other safety-related devices (Zhao & Li, 2020; Wang et al., 2018). A frequently used type of buzzer is the piezoelectric buzzer. This is because piezoelectric buzzers offer advantages such as being cost-effective, lightweight, and easier to integrate with other electronic circuits (Chen et al., 2021; Zhang et al., 2019). These features make piezoelectric buzzers ideal for a wide range of consumer and industrial applications.

The piezoelectric buzzer, in particular, is known for its efficiency and compactness, making it an ideal choice for small and portable devices. Its ability to produce high-pitched sounds at a low cost and small size has contributed to its widespread use in various electronic circuits (Liu et al., 2017; Chen & Zhang, 2021). The simplicity of integrating piezoelectric buzzers with other systems, alongside their relatively lower power consumption, has made them a popular option for alarms, notifications, and other warning systems.

Figure 4 Buzzer

2.1.5. DHT11

The DHT11 sensor module is designed to detect temperature and humidity, providing an analog voltage output that can be processed by a microcontroller. One of the main advantages of this sensor compared to others is its responsiveness in sensing both temperature and humidity. The DHT11 offers faster sensing capabilities, ensuring that data is captured quickly and with minimal interference. This responsiveness makes it ideal for applications requiring real-time data collection (Kumar et al., 2020; Smith et al., 2019; Zhang & Li, 2018).

Additionally, the DHT11 sensor provides calibration features that ensure accurate temperature and humidity readings. Its ability to deliver reliable and consistent measurements is one of the key reasons it is widely used in various environmental monitoring systems. The sensor comes with four pins, making it easy to integrate into circuits. However, there are also versions of the DHT11 sensor with a 16-pin configuration, equipped with a breakout PCB that reduces the number of pins to just three (Chen & Zhang, 2021; Wang et al., 2018; Liu & Zhao, 2019).

Overall, the DHT11 is a cost-effective solution for detecting temperature and humidity, offering a high level of accuracy and ease of use. The simplicity of its design, along with its accurate readings, has made it a popular choice for both hobbyists and professionals in the field of environmental monitoring (Liu et al., 2020; Zhang et al., 2019; Li & Yang, 2017).

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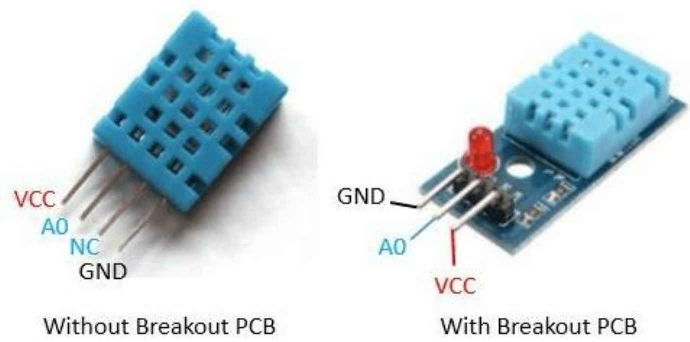

figure 5. DHT11

2.1.6. Application Blynk

figure 6. Application Blynk

Blynk is a platform designed for mobile applications (iOS and Android) that facilitates remote control of devices such as Arduino, Raspberry Pi, ESP8266, WEMOS D1, and similar modules through the internet. Available for download on Google Play for Android users and the App Store for iOS users, Blynk supports a wide variety of hardware for Internet of Things (IoT) projects. The platform's interface allows users to add components to the app easily through drag and drop, eliminating the need for programming skills in Android or iOS (Ilham, 2018).

The main purpose of Blynk is to control and monitor hardware remotely via internet data communication. It enables the storage and visualization of data, presenting it through numerical, color, or graphical formats. The Blynk platform consists of three main components: 1) Blynk Apps, which allow users to create project interfaces with various input/output components, enabling data transmission and representation in visual forms such as numbers or graphs. Blynk Apps also categorize components into controllers for sending data or commands to hardware, displays for showing data on smartphones, notifications for sending messages or alerts, interface settings for customizing the app layout, and others, which include components like Bridge, RTC, and Bluetooth. 2) Blynk Server, which acts as a cloud-based backend service to manage communication between the Blynk app and hardware. The server can handle

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multiple devices simultaneously, making it easier for IoT developers. It can also be set up as a local server for environments without internet access, and the local version is open-source and compatible with hardware like Raspberry Pi. 3) Blynk Library, which provides resources for developers to assist in coding. The library is available on various hardware platforms, offering flexibility for IoT development (Ilham, 2018).

2.2. Methods

The initial step in completing this final project is problem identification. This stage is crucial for generating ideas or concepts to be developed into a final project topic. The next step is to thoroughly explore the chosen topic by gathering related references. After that, the process continues by collecting the necessary tools and materials to assemble the system, such as the controller (ESP32) and other required components. In addition to the electronic circuit, creating the application program using Blynk is also essential for the project.

Once all the components and software are ready, the next step is to conduct tests. If any issues arise during testing, the cause is identified and resolved. The two circuits are connected to each other and tested to ensure that they function as expected. This phase helps to verify whether the system works properly or if further adjustments are needed. If problems persist, corrective actions are taken to address them.

After finalizing the circuits and making necessary corrections, data collection is performed to obtain results and draw conclusions. The overall workflow of the project, from the initial stages to the final testing and data collection, is illustrated in the project execution diagram below. This structured approach helps ensure the success of the project by systematically addressing each step.

3. Results and discussion

3.1. Result

The research was conducted at various distances from a residential area, starting at 1 meter, 3 meters, 5 meters, and extending beyond the house. The tests were carried out using commands, and the success rate varied at each distance. This success rate was determined by comparing the number of correct commands with the total number of commands given, which was then presented as a percentage.

To calculate the success rate, the formula used compares the number of successful commands to the total number of commands performed. The result is then expressed as a percentage, providing a clear measure of the effectiveness of the command execution at different distances.

This method of calculating success rate allows for a detailed assessment of how command performance changes with distance, and offers valuable insights into the reliability of the system under different conditions. The results of the tests were analyzed and presented in terms of the percentage of correct commands at each distance.

$$Correct\ percentage = \frac{correct\ command}{command} x\ 100\%$$

Table 1. Test Results Table

No	**Distance** (meter)	**Command Executed**	**Command Success Percentage**	**Presentase**
1	1	10	10	**100%**
2	3	10	10	**100%**
3	5	10	10	**100%**
4	**9 (outside)**	**10**	**9**	**90%**

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3.2. Discussion

The testing was conducted to determine the success rate of the Blynk application on a smartphone in receiving commands, with 10 attempts made for each distance. As shown in Table 1, the success rate for all commands at a distance of 1 meter was 100%, at 3 meters it was also 100%, and at 5 meters, it remained 100%. However, at 9 meters (outside the house), the success rate dropped to 90%.

The Wi-Fi network had a significant impact on the testing process. There were instances where commands were pressed but the devices did not immediately respond. For example, when turning on a light, the "ON" command was pressed, but the light did not turn on until approximately 10 seconds later.

This delay in response highlights the influence of the Wi-Fi network on the system's performance. The delay was observed during certain tests, suggesting that network connectivity issues can affect the real-time responsiveness of the devices controlled via the Blynk application.

4. Conclusion

Based on the explanation provided earlier, the average success rate during the testing at each distance was 97.5%. No issues were encountered with the electronic devices failing to turn on at distances ranging from 1 to 5 meters. The system performed consistently without any interruptions in functionality.

At distances up to 5 meters, the devices responded as expected, with no malfunctions reported. This indicates that the system was highly reliable and operated efficiently within this range, maintaining a strong connection and successful command execution.

Even at a distance of 9 meters, which was outside the house, the device remained connected to the Blynk application. This suggests that the communication system was effective over a considerable distance, demonstrating the robustness and reliability of the setup in various environments.

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