



An-Najah National University

College of Engineering and Information Technology

Department of Electrical Engineering

Development of an Intelligent Smart Distribution Board for Advanced Power
Monitoring and Control in Residential Settings

Group, supervisor: Dr. Moien Omar

Duha Daghlas 11717815

Mohammed Zakarneh 11926552

Hamzah Yaseen 11924430

Fayez Nasasreh 11924432

Nablus, 2023/2024

اهداء

قال تعالى "قُرْأَ وَرَبُّكَ الْأَكْرَمُ الَّذِي عَلَّمَ بِالْقَلَمِ عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ."

الحمد لله من قبل ومن بعد ... الصلاة والسلام على معلمنا الاول سينا محمد.

نتقدم بالشكر والامتنان الى جامعة النجاح الوطنية والى دكاترة كلية الهندسة عامة وقسم الكهرباء خاصة نخص بالذكر الدكتور رئيس القسم والمشرف على هذا العمل د.معين عمر.

نهدي هذا المشروع تحية اكار واحترام الى الوطن فلسطين ,وارواح الشهداء الابرار.

كما نتقدم باسمى ايات المحبه والعرفان بالفضل الى اهلنا الكرام ,شكرا لزملائنا الاعزاءالذين شرفوا حياتنا الاكاديمية بروح التعاون والصداقة.

نامل ان يكون هذا الانجاز بداية رحلة جديدة للنجاح والتفوق

ACKNOWLEDGEMENT

In the **name of Allah**, the most gracious, the most merciful. First and foremost, we thank God for His grace to complete our study journey.

Our endless gratitude to our wonderful supervisor, **Dr. Moin Omar**, for bringing the weight of his great experience and knowledge to this project. His high standards have made us better at what we do.

Special thanks to the team members who did their best to complete this project.

Many thanks to our **family** and **friends** for their constant encouragement and support throughout the project.

Table of contact

ACKNOWLEDGEMENT	3
Table of contact	4
List of Figures:	5
CHAPTER 1:	6
Abstract:	6
1.1 Introduction:	6
1.2 Literature review	8
1.3 Objectives:	9
1.4 Expected Outcomes:	9
1.5 Significance of the Project:	9
1.6 Expectations of success	12
Chapter 2:	14
Methodology:	14
Chapter 3	15
Design Constraints and standards	15
Engineering Standards	16
Chapter 4:	19
Project implementation	19
Part1: Hardware	20
Part 2: Software	38
Chapter5:	43
5.1 Implementation stage and finding solutions	43
5.2 Technical Implementation Details	44
5.3 Possible developments on the project	48
Chapter6:	49
6.1 The challenges	50
6.2 Future aspirations and recommendations	51
Chapter7:	52
Conclusion:	53
References:	55

List of Figures:

<u>Fig.1 Board description</u>	<u>10</u>
<u>Fig.2 Detailed board components</u>	<u>19</u>
<u>Fig.3 Microcontroller chip</u>	<u>20</u>
<u>Fig.4 Microcontroller table GPIO</u>	<u>23</u>
<u>Fig.5 Measurements board</u>	<u>24</u>
<u>Fig.6 The relay used in the project</u>	<u>28</u>
<u>Fig.7 Relay connections</u>	<u>28</u>
<u>Fig.8 Relays modules</u>	<u>29</u>
<u>Fig.9 connect of display</u>	<u>30</u>
<u>Fig.10 display tables</u>	<u>31</u>
<u>Fig.11displays</u>	<u>32</u>
<u>Fig. 12 Mobile phone charger</u>	<u>33</u>
<u>Fig.13 Residual current circuit breaker</u>	<u>35</u>
<u>Fig.14 resistors and capacitors</u>	<u>37</u>
<u>Fig. 15: The contactor used in the project</u>	<u>38</u>
<u>Fig.16 block diagram</u>	<u>38</u>
<u>Fig. 17: Programming code explaining setupLCD</u>	<u>39</u>
<u>Fig. 18: Programming code explaining Setup</u>	<u>39</u>
<u>Fig. 19: Programming code explaining readAndDisplayVoltage</u>	<u>40</u>
<u>Fig.20: Programming code explaining sendToBlynk</u>	<u>40</u>
<u>Fig.21: Programming code explaining Loop</u>	<u>41</u>
<u>Fig.22: ESP8266 User in the project</u>	<u>45</u>
<u>Fig.23: Mobile Application</u>	<u>47</u>
<u>Fig.24: A final image of the project in operation</u>	<u>54</u>

CHAPTER 1:

Abstract:

The proposed project aims to design and develop a smart distribution board with advanced monitoring and control capabilities for residential power management. The system will be equipped to measure key electrical parameters, provide real-time data via Wi-Fi connectivity, and offer intelligent control of energy distribution across circuit breakers.

1.1 Introduction:

Smart power distribution project using Wi-Fi using ESP8266 board is a project to monitor and control the electricity distribution in your home or office intelligently via the Internet. You can use this for a project to improve the efficiency of electricity consumption and track consumption accurately.

The proposed project aims to design and develop an innovative Smart Distribution Board with advanced monitoring and control capabilities for residential power management. The system will be equipped to measure key electrical parameters, provide real-time data via Wi-Fi connectivity, and offer intelligent control of energy across circuit break.

The distribution of digital power is increasing greatly day by day. The existing power grids are converted into smart grids so as to meet the growing power requirements. Information is accumulated from sensors, smart meters and several other devices for the sake of analysis and understanding. For the purpose of implementing IoT in smart grids, mobility support, location awareness, distributed coordination and latency sensitivity are to be considered. Smart Grid systems in combination with IoT can assist the consumption, distribution, transmission and generation of energy. IoT allows smart monitoring and control of smart grid.

The consumers can obtain information regarding consumption of energy and price on a real-time basis thereby moderate the energy consumption.

Electric load management through continuous monitoring and intelligent controlling has become a pressing requirement, particularly in light of rising electrical energy costs.

The main purpose of this work is to realize a low-voltage electrical distribution panelboard that allows for real-time load monitoring and that provides a load forecasting feature at the household level.

In this regard, we demonstrate the design and the implementation details of an IoT-enabled panelboard with smart features.

An IoT dashboard was used to display the most significant information in terms of voltage, current, real power, reactive power, apparent power, power factor, and energy consumption.

We have used the ESP8266 microcontroller for demonstration purposes. The console is capable of this Communicate with the computer in time. When we turn on the power for our prototype,

All sensors start sensing the current and sending real-time information to and from the server the offer, it compares all the values in real time with the pre-set values and sends a signal for the trip the relay feeder as well as the screen update show the same notification for our application, if any the values override the preset values. By following up on user requests, relays will be triggered. At the same time there will be no power outages. If we want to run any feeder, we can also run the feeder through it Send the command from the application.

1.2 Literature review

Development of distribution boards The journey towards smart panel distribution boards (SPDBs) has been influenced by advances in power distribution technologies. Traditional distribution panels, while effective, lacked the intelligence and real-time monitoring capabilities that modern electrical systems require. Previous solutions focused primarily on incremental improvements, such as more efficient circuit breakers and enhanced safety features. The integration of IoT into smart grids offers significant advancements in power management, emphasizing consumption, distribution, transmission, and generation of energy [1]. This aligns with the overarching goal of our project, the Smart Electrical Distribution Board, to intelligently monitor and control electricity distribution. Leveraging the ESP8266 microcontroller [2] ensures seamless communication, as demonstrated in the real-time load monitoring capabilities discussed in [3]. The project's choice of low-voltage distribution panelboards is informed by authors insights into advancements in smart home electrical distribution systems [4]. Additionally, the project draws inspiration from Kim and Park's work on energy consumption tracking and forecasting [5] and authors exploration of efficiency improvements in electrical distribution through IoT [6]. The role of relay control systems, as discussed in [7], is crucial in preventing power outages and aligns with our project's emphasis on uninterrupted electricity distribution. Moreover, considerations from authors review of wireless communication protocols for IoT in smart grids [8] ensure the reliability of the Wi-Fi-enabled Smart Electrical Distribution Board. authors insights into user-friendly interfaces for IoT-based power management systems [9] influence our project's commitment to providing a seamless application interface for users. In essence, the outcomes from these references collectively contribute to the theoretical foundation of our project, shaping its core principles and technological choices. Intelligent distribution

box controller for customer-based operations the design of a smart distribution box controller is proposed in this study in order to allow consumers to control or regulate their energy use during off-peak and peak hours. during Peak times, the smart system allocates different loads to them Different priorities and removes non-priority loads. It is too Monitors voltage and frequency. Automation integration A notable precursor to SPDBs involved the integration of automation systems within distribution boards.

1.3 Objectives:

- a. To design and implement a Smart Distribution Board capable of measuring: Current, Voltage, Power Factor, Power and Energy Consumption
- b. To integrate Wi-Fi connectivity for remote access and control.
- c. To enable live power monitoring and real-time data visualization.
- d. To implement energy management for saving power consumption.
- e. To generate and plot daily load curves for insightful energy consumption patterns.

1.4 Expected Outcomes:

- a. A functional Smart Distribution Board prototype capable of measuring and displaying power parameters accurately.
- b. Real-time access to power data via a user-friendly interface.
- c. Efficient energy management capabilities for optimized power distribution.
- d. Daily load curves for insightful analysis of energy consumption patterns.

1.5 Significance of the Project:

The Smart Distribution Board will provide homeowners with real-time insights into their power consumption habits, enabling them to make informed decisions about energy usage. The system's ability to control energy across circuit breakers will help optimize power usage and reduce wastage. The integration of

Wi-Fi connectivity will enable remote monitoring and control, enhancing convenience and accessibility.

Our project can be realized through cooperation with experts in the fields of electrical engineering, communications technologies and artificial intelligence. We hope that this project will make an important contribution to the development of smart energy management solutions and contribute to building a more sustainable future.

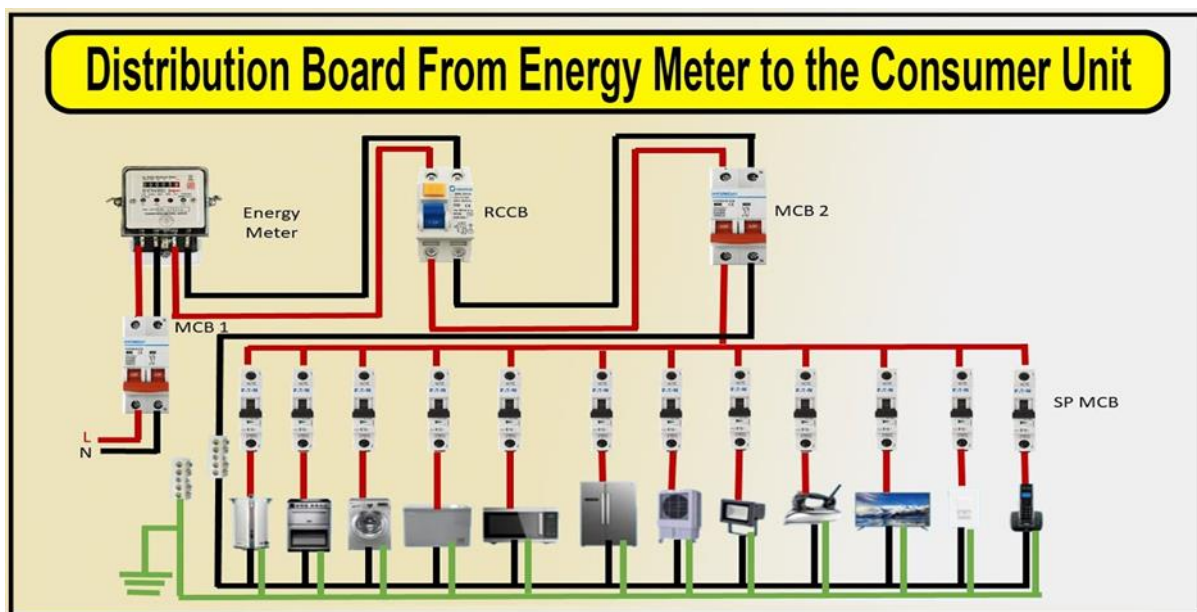


Fig.1: Board description

The project idea to develop an intelligent system for managing electricity consumption in smart buildings could come from multiple sources and be the result of the need for more efficient and sustainable solutions in the field of energy management. Here are some inspirational sources for the project idea

Personal need:

The project idea may arise when a person or group of people faces special challenges in managing electricity consumption in their homes. For example, there may be a desire to reduce high electricity bills or to monitor and improve Use of electricity

Personal need is one of the most important drivers that can push individuals and innovators to develop new projects, including the smart energy management system project. A personal need arises when an individual faces a personal challenge or suffers from a problem that affects his daily life and needs a solution.

Here is how to interpret personal need in the context of an intelligent energy management system project:

- a. **High Electricity Bills:** A personal need can arise when an individual faces a challenge in affording high electricity bills in his or her home. These bills may be expensive due to inefficient energy consumption or operating electrical appliances without supervision.
- b. **Desire for sustainability:** Some individuals can be determined to reduce their environmental impact and improve the sustainability of energy consumption. They are looking for a solution that will help them use electricity more efficiently and save energy.
- c. **Save time and effort:** Some people want to simplify their lives and save time and effort by being able to control electrical appliances in their homes remotely. This can include turning appliances on and off and adjusting lighting and heating easily.
- d. **Maintaining security:** The need to maintain security can contribute to pushing individuals towards developing a system that can detect any unauthorized activities or suspicious behavior such as electrical thefts and others.
- e. **Reduce excess consumption:** Some people want to reduce excess electricity consumption in their homes to achieve economy and reduce bills.
- f. **Improving the quality of life:** The need to improve the quality of life can push individuals towards developing a system that increases their comfort and provides them with a more comfortable and intelligent environment. In short, personal need plays an important role in guiding individuals towards developing innovative projects such as intelligent energy management system. If they have personal challenges related to electricity or personal aspirations for efficiency and comfort, these needs can be the impetus for starting a project and developing innovative solutions.

Technological innovation:

Technology is considered one of the most important factors that contribute to the development of the smart energy management project, the idea of which was the " smart distribution board with WIFI lot Arduino project." Indeed, modern technologies such as intelligent Internet (IoT) and artificial intelligence (AI) can be used to improve electricity use efficiency and provide multiple benefits. Here's how technology can contribute to this project:

- a. **Accurate monitoring and measurement:** Using sensors and Internet-connected (IoT) systems, the project can collect accurate data on electricity consumption in real time. This allows the user to monitor electricity consumption throughout the home or factory and understand which activities consume electricity the most.
- b. **Data analysis and forecasting:** Thanks to artificial intelligence (AI), the collected data can be intelligently analyzed to understand patterns and trends in electricity consumption. The system can predict future needs and improve energy planning.
- c. **Intelligent control:** Using the smart Internet and Arduino, the project can implement an intelligent control system that allows electricity sources and devices to be controlled automatically. Devices can be set to operate at specific times or based on need.
- d. **Security and Protection Management:** Technology can be used to enhance security and protection in a project. For example, a monitoring system can be implemented that allows any unauthorized intrusion to be detected and instant notifications sent.
- e. **Remote communication and control:** By connecting the systems to the Internet, users can control and monitor electricity distribution remotely. They can change settings or turn off devices remotely to save energy.

1.6 Expectations of success

This project is expected to be a model for smart solutions that improve the efficiency of electricity consumption in smart buildings. By introducing advanced technologies and effective methods for energy management and optimization, we expect to make a positive contribution to the environment and economy and can used to solve additional problems like:

Overloading Prevention:

Explanation: Overloading occurs when electrical circuits carry more current than they are designed to handle, which can lead to overheating and potentially cause fires. The smart distribution board should continuously monitor the current flow in circuits and disconnect or redistribute loads if it detects that a circuit is at risk of overloading.

Energy Consumption Awareness:

Explanation: Providing residents with real-time and historical data on their energy consumption helps them become more aware of their electricity usage patterns. This data can be presented through a user-friendly interface, enabling homeowners to make informed decisions about energy-saving measures.

Remote Monitoring and Control:

Explanation: Remote monitoring and control allow homeowners to access and control their smart distribution board from a distance, typically through a smartphone app or a web interface. This feature enhances convenience and flexibility by enabling users to manage their home's power usage even when they are not physically present [1].

Demand Response :

Explanation: Demand response involves adjusting power consumption during peak hours or in response to grid signals to reduce strain on the electrical grid. The smart distribution board can participate in demand response programs by automatically adjusting energy usage or notifying homeowners to make manual adjustments.

Chapter 2:

Methodology:

Software Development:

- Creation of firmware to interface with sensors and microcontrollers. Implementation of communication protocols for Wi-Fi connectivity.
- Development of a user-friendly interface for data visualization and control .

Energy Management Algorithms:

Design algorithms for intelligent energy distribution based on real-time data. Incorporate safety features to prevent overload or short circuits.

Data Logging and Analysis :

- Setup a database to log and store historical data
- Implement algorithms for daily load curve generation.

Hardware Design and Development:

- Selection of appropriate sensors and microcontrollers for accurate measurement and data processing
- Integration of Wi-Fi module for wireless connectivity.
- Development of circuitry for monitoring and control .

Chapter 3

Design Constraints and standards

Design Constraints In this chapter, we will discuss the various design constraints and available option for implementing the various stages of the smart energy metering and remote controlling of the appliances. The Arduino programming was used for the design of this project. This chapter focuses on the design steps of the energy meter implementation. Moreover, the embedded system is an essential and digital system having a dedicated operation within a massive electrical system or mechanical system, usually having real-time computing limitations. It is incorporated as one of the complete devices, which usually include mechanical and hardware parts. On the contrary, a personal computer or the general-purpose computer is made flexible to satisfy the different needs of the end-users. Most of the devices used nowadays are controlled by the embedded systems.

The modern embedded systems' operations are on the basis of microcontrollers alongside peripheral interfaces and/or the integrated memory, while the ordinary microprocessors (with the use of external chips for the peripheral interface circuits and memory) remain popular, particularly in complex systems. In any of these cases, there are different types of the processor(s) applied, which include the general purpose ones and the extremely specialized ones in specific computation categories, or including the custom designed for the underworking application.

Generally, an energy or electric meter measures the quantity of consumed electric energy by an entity (electrically powered device, residence or business). Typically, energy meters have calibration in billing units – kilowatt-hour (kWh). The energy consumed and billing cycles are set up by the periodic readings of the electricity meters amid a cycle. For the choice of energy savings

for a particular time, the settings of the meters can be used for the demand Public Information 16 measurement, including the maximum power used for a particular interval. Electric rates are allowed by “time of day” metering to change during the day, for usage recording amid the off peak lower-cost intervals or the peak high cost intervals. Additionally, other types of meters are designed with demand response load, which shed amid peak load intervals. Since the 1880s when electric energy spread commercially, it turned out extremely essential that an electric energy meter, just like the gas meters around, was necessitated to appropriately get customers billed for the energy costs, rather than being billed for a particular fixed lamp number each month. The majority of the research kinds of meter were created. A DC electromechanical meter was first operated by Edison alongside a straightforward reading register, but rather got the electrochemical metering system designed, which made use of an electrolytic cell to sum up the existing consumption. [10].

Design Constraint: Cost

Most of the smart energy metering solutions provided are with high cost. The cost of equipment and implementation made it difficult for consumers to adopt the solution. The electricity providing companies have a rising concern of using such high-cost solution. For our proposed work, it is very economical and can be easily implemented in residential as well as commercial sites. The total cost of such device is less than 500 USD which make it more appropriate solution to be utilized. The electricity providing companies are in need to use such sophisticated system to implement for commercial and residential areas.

Engineering Standards

Design constraints are conditions that are needed to be utilized to execute the project successfully. Design constraints helped in narrowing down the available choices and its standardization. Design constraints are sometimes challenging to be addressed but they are helpful to meet the demand and operate the devices safely. For the proposed design, engineering constraints are summarized in this section. [11]

- a. The device should be capable to withstand the temperature of 45° C in summer because of severe weather conditions in Palestine.
- b. The current rating determines the number of appliances to be connected to the given energy metering. It is required to design such an energy metering system for household load or should be capable to withstand the commercial energy usage.
- c. The device should be capable to give accurate reading in severe summer weather.
- d. The devices should withstand with the environmental conditions including sand storms as well as rainy conditions.

Infrastructure Constraints :

Internet Connectivity: The system relies on internet connectivity for remote monitoring and control. In areas with poor or unreliable internet access, providing a seamless user experience can be a limitation .

User Experience:

Usability: Designing an intuitive user interface and user experience that caters to a wide range of users with varying technical abilities is a significant challenge. User feedback and iterative design processes are often required to create a user-friendly system.

Energy Transition:

Adaptation to Changing Energy Sources: As the energy landscape evolves with a greater emphasis on renewable energy sources and changes in grid configurations, the system must be adaptable and capable of accommodating new energy sources and policies .

Successfully addressing these challenges requires a multidisciplinary approach, collaboration with various stakeholders, rigorous testing, adherence to standards and regulations, and ongoing monitoring and improvement. It also requires a commitment to user-centric design and a thorough understanding of the specific needs and expectations of residential users.

Chapter 4:

Project implementation

Our project consists of two parts the first part is the software, which consists of the programming for the project .

the second part is the hardware, which is the part that represents the components that make up the smart distribution panel project.

The block diagram of our project is shown in Fig.1. In this diagram we can see various part of our board. They are ESP8266, LCD display, pzem-004t, power supply, relay module, WIFI router, android app etc. When demands exceed the predetermined value the Relay module is activated according to the instruction given to the ESP8266 microcontroller. So, mode is tripped quickly microcontroller send the notification that the particular demand is overloaded and tripped and the status will be shown on the app and the LCD display .

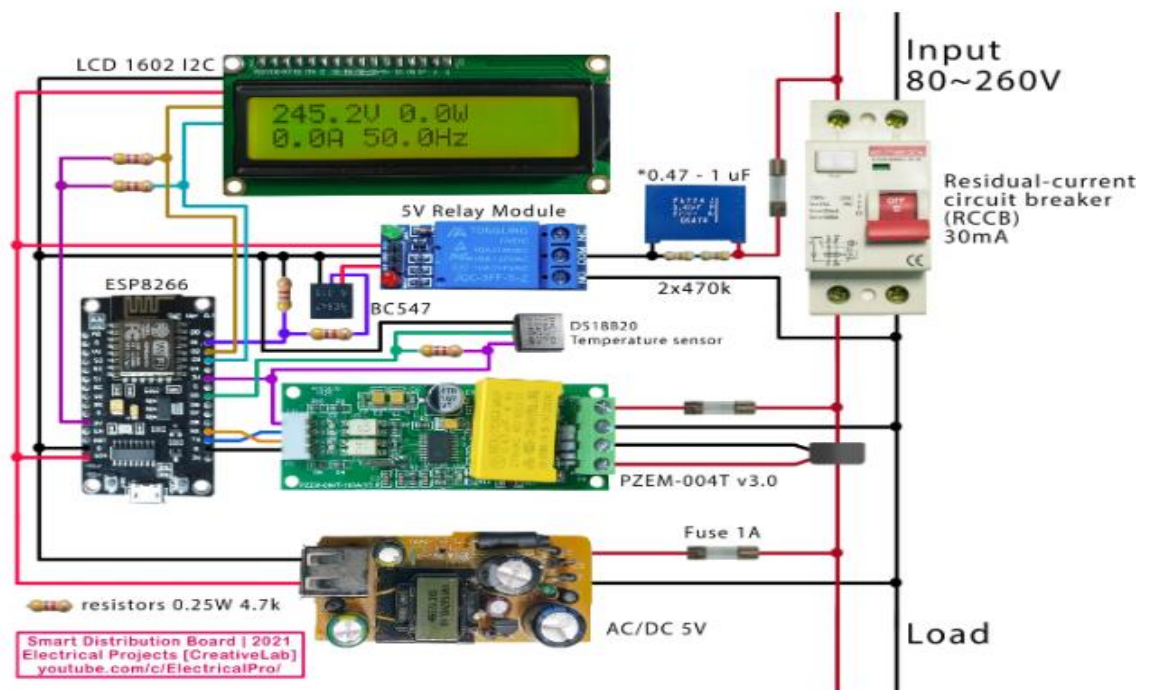


Fig. 2: Detailed board components

Part1: Hardware

The smart distribution panel which shown in Fig.1 consists of a group of electronic parts, each of which performs a specific task.

1. Microcontroller and Architecture: (ESP8266)

Is a low-cost Wi-Fi microchip, with built-in TCP/IP networking software, and microcontroller capability, produced by Express if Systems in Shanghai, China

This piece is considered the project's processor, which receives the information and readings coming from the sensors and processes them in order to output the data that is supposed to be shown on the screen. This is done by networking the electronic parts in it, taking into account writing the code for each cat in order for it to perform its required tasks. As shown in Fig (8)

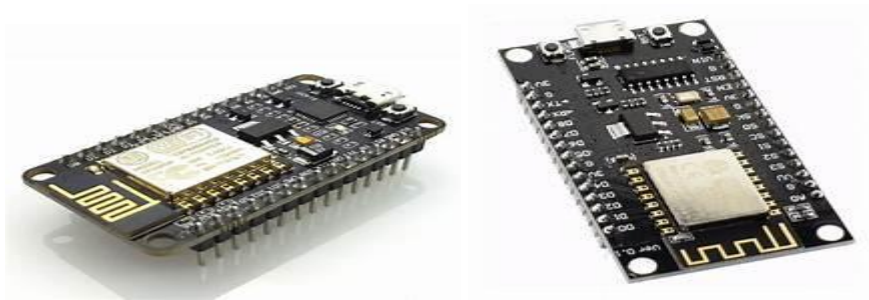


Fig.3: Microcontroller chip

The ESP8266, As shown in (Fig.3) a versatile and widely used Wi-Fi microcontroller developed by Espresso Systems. The ESP8266 is known for its affordability, built-in TCP/IP stack, and microcontroller capabilities. It's commonly used in Internet of Things (IoT) projects where it connects to Wi-Fi networks, gathers data from sensors, and can communicate with other devices or servers.

the ESP8266 is the central processing unit for a project. It receives information and sensor readings, processes them, and then outputs the relevant data to be displayed on a screen. This involves networking the electronic components

within the project and writing the necessary code to enable the ESP8266 to perform its designated tasks.

The ESP8266 can be programmed using various development environments and languages, with Arduino and the Arduino IDE being a popular choice for many developers due to its ease of use. The programming code typically involves configuring the Wi-Fi connection, reading sensor data, and implementing logic for processing and displaying the information.

The ESP8266 is a microcontroller with integrated Wi-Fi capabilities .

It's designed for embedded applications, especially those involving wireless communication. Here are some key points about the ESP8266:

The ESP8266 integrates a Ten silica L106 32-bit microcontroller with a clock speed of 80 MHz (can be overclocked to 160 MHz).

It supports both 32-bit and 16-bit instructions, providing flexibility for different types of applications.

Wi-Fi Connectivity: One of the main features of the ESP8266 is its built-in Wi-Fi connectivity, which allows it to connect to Wi-Fi networks.

It supports 802.11 b/g/n protocols, making it compatible with a wide range of Wi-Fi networks.

The Wi-Fi capabilities enable the ESP8266 to communicate with other devices on the same network or with remote servers.

Memory: The ESP8266 typically comes with different amounts of Flash memory (often 1MB or 4MB) for program storage.

It also has onboard RAM for data storage and program execution.

GPIO Pins: The ESP8266 features General Purpose Input/Output (GPIO) pins that can be used to interface with external devices, such as sensors, displays, or actuators.

Programming: The ESP8266 can be programmed using various development environments and languages, including the Arduino IDE, Platform IO, and the native Espresso SDK.

The programming language is typically a variant of C or C++.

Applications: Common applications of the ESP8266 include IoT projects, home automation, sensor networks, and projects requiring wireless communication.

Power Consumption: The ESP8266 is designed to be power-efficient, making it suitable for battery-powered applications.

Community and Documentation: The ESP8266 has a large and active community, and there are plenty of online resources, tutorials, and forums where developers share their experiences and solutions.

ESP8266 Functions:

Configure Wi-Fi settings to connect to a network.

Read data from sensors or other peripherals connected to GPIO pins.

Implement logic to process the data.

Communicate with other devices or servers over Wi-Fi, sending or receiving data as needed.

Type of processor: Ten Silica L106:

Ten Silica L106 represents the central processing unit (CPU) inside the ESP8266.

It features 32-bit operating technology.

Clock speed:

ix. GPIO Overview:

GPIO	Function	State	Restrictions
0	Boot mode select	3.3V	No Hi-Z
1	TX0	-	Not usable during Serial transmission
2	Boot mode select TX1	3.3V (boot only)	Don't connect to ground at boot time Sends debug data at boot time
3	RX0	-	Not usable during Serial transmission
4	SDA (I ² C)	-	-
5	SCL (I ² C)	-	-
6 - 11	Flash connection	x	Not usable, and not broken out
12	MISO (SPI)	-	-
13	MOSI (SPI)	-	-
14	SCK (SPI)	-	-
15	SS (SPI)	0V	Pull-up resistor not usable
16	Wake up from sleep	-	No pull-up resistor, but pull-down instead Should be connected to RST to wake up

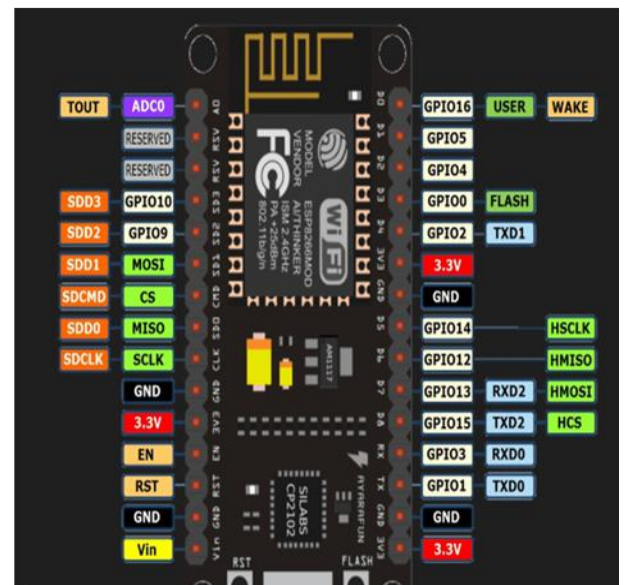


Fig.4: Microcontroller table GPIO

The average clock speed or timing speed of the processor.

It comes with a default clock speed of 80MHz.

The clock speed can be increased to 160MHz when firing (this process is called overclocking or overlocking).

Simply put, this means that the ESP8266 uses a Ten Silica L106 processor that runs at 80MHz, and this speed can be increased to 160MHz when needed.

These are the important specifications of the registry and its capabilities .

2. Measurement board (PZEM-004T)

This measurement board is shown in Fig. consists sensors to measure, current, voltage, phase shift, power factor, and energy.

The PZEM-004T is a versatile electrical parameter measuring module commonly used in various applications. Here are ten key points about the PZEM-004T:

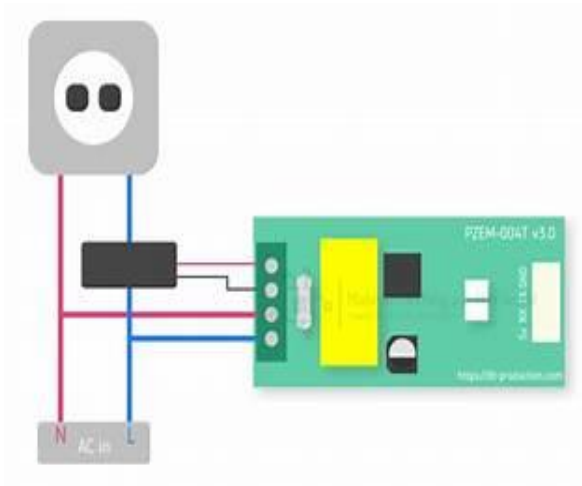


Fig. 5: Measurements board

Functionality: The PZEM-004T is designed to measure and display electrical parameters such as voltage, current, power, energy, and frequency.

Voltage: The electric potential difference across a circuit.

Current: The flow of electric charge in the circuit.

Power: The rate at which electrical energy is transferred or consumed.

Energy: The total electrical power consumed over time.

Frequency: The number of cycles per second in an alternating current .

Measurement Accuracy: It offers high accuracy in measuring electrical parameters, making it suitable for both professional and DIY projects.

The PZEM-004T is known for its high accuracy in measuring electrical parameters. This accuracy is crucial for reliable data, especially in applications where precision is important, such as industrial monitoring or energy management systems.

Communication Interface: The module typically comes with a communication interface, such as RS485 or TTL, allowing for easy integration with microcontrollers like Arduino.

The module typically comes with a communication interface, such as RS485 or TTL (serial communication protocols). This allows easy integration with microcontrollers like Arduino, Raspberry Pi, or other devices, enabling data exchange and control.

LCD Display: Many PZEM-004T modules feature an LCD display that provides real-time readings of the measured electrical parameters. The display provides a convenient way for users to monitor the measured electrical parameters without the need for additional external displays or equipment.

Wide Voltage Range: It supports a wide voltage input range, making it compatible with various electrical systems. The module supports a wide voltage

input range, making it versatile and compatible with various electrical systems. This flexibility allows it to be used in environments with different voltage specifications.

Current Sensing: The module incorporates a current sensor, enabling precise measurement of current flow in the circuit. The PZEM-004T incorporates a current sensor, which is a key component for precise measurement of the current flow in the circuit. This feature is essential for understanding power consumption and for applications where monitoring and controlling current are critical.

Energy Accumulation: It can accumulate energy consumption over time, providing insights into power usage trends. The module has the capability to accumulate energy consumption over time. This means it can provide insights into power usage trends, helping users analyze and optimize energy consumption in a given system.

Modularity: The PZEM-004T is often used as part of larger energy monitoring and management systems due to its modular design. The modular design of the PZEM-004T makes it suitable for integration into larger energy monitoring and management systems. Multiple modules can be used together to monitor different aspects of an electrical system comprehensively.

Applications: Common applications include energy monitoring in smart homes, industrial automation, and renewable energy systems. The PZEM-004T finds applications in various domains, including:

Smart Homes: Monitoring and managing energy consumption.

Industrial Automation: Ensuring efficient use of electrical resources.

Renewable Energy Systems: Monitoring power generation and consumption in renewable energy setups .

3. Relay module 5V:

a 5V relay module as shown in (**Fig. 7**) is a device that controls electrical loads remotely using a 5-volt signal. It is commonly used in hobbyist projects and home automation. The module connects to a control unit, such as Arduino or Raspberry Pi, and switches the electrical current to the load based on a control signal. It operates with a 5-volt control voltage and can handle high currents. The module finds applications in home automation, hobbyist projects, and security systems. Users should be cautious about the maximum current the module can handle and use a suitable power source. A 5V relay module is a versatile component widely used in electronic projects and automation systems.

In our project, we have added additional relays, so that each one of them is responsible for controlling two different types of loads. For example, the lighting breaker is controlled by a limiter that is connected to the relay directly, and the other breaker is responsible for the loads, the other is connected to a contactor, and the contactor is connected to another relay, because the loads here can be high and the relay is alone. It cannot withstand high current

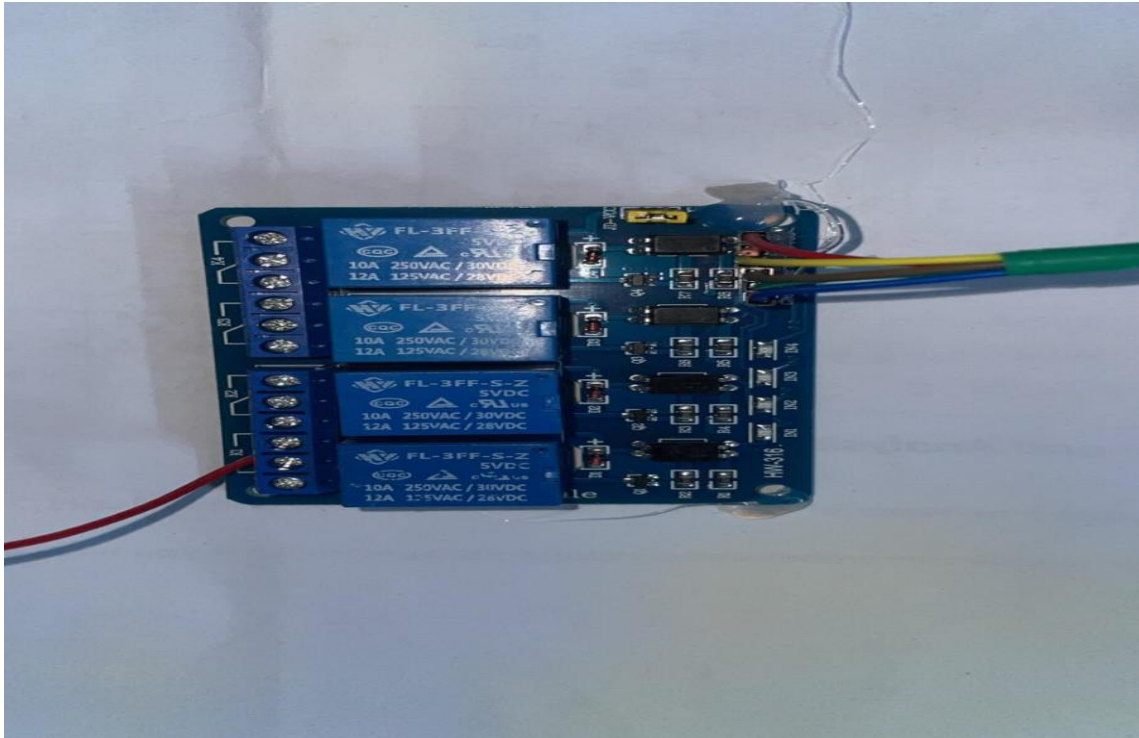


Fig 6. The relay used in the project

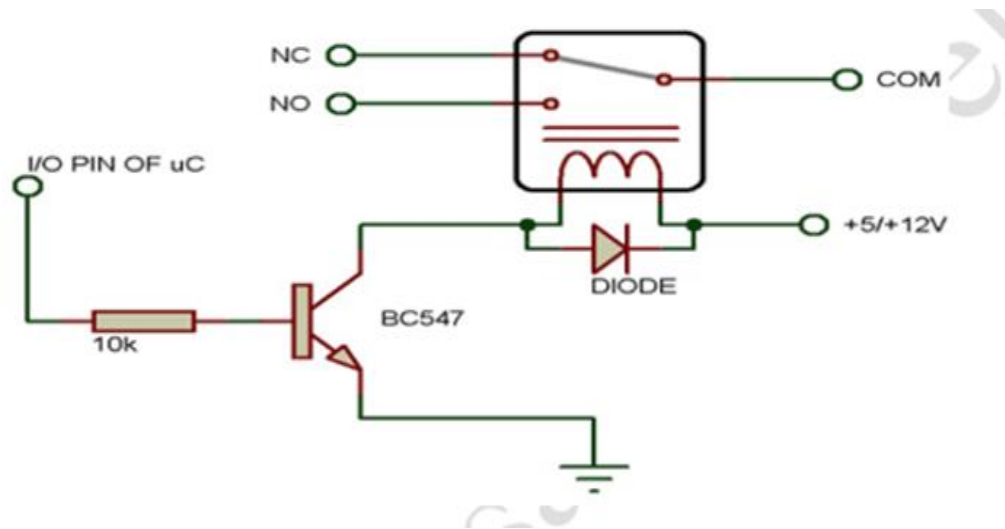


Fig7. Relay connections

Here are some key points about its features and applications:

Control Voltage: The relay module operates with a 5-volt control voltage, making it compatible with microcontrollers like Arduino and Raspberry Pi

Remote Load Control: Its primary function is to control electrical loads remotely. This means you can use a low-voltage signal from a microcontroller to switch on or off a higher voltage circuit, such as turning on/off lights, appliances, or other devices

Switching Capacity: The relay module can handle high currents and is suitable for controlling a variety of loads, including those with higher power requirements

Compatibility: Due to its widespread use in hobbyist projects, the module is compatible with various development boards and platforms, providing flexibility for different applications

Documentation: Always refer to the manufacturer's documentation for specific connection instructions, usage guidelines, and any safety precautions. Understanding the specifications provided by the manufacturer is crucial for proper integration into your project

Proper Wiring: Ensure proper wiring to avoid short circuits or incorrect connections. This includes connecting the control unit (Arduino, Raspberry Pi) appropriately and making sure the load is within the relay's specified limits

In summary, the 5V relay module is a valuable tool for electronics enthusiasts, providing a convenient way to control higher voltage devices in various applications, including home automation, hobbyist projects, and security systems.



Fig.8: Relays modules

4. 1602 I2C Display:

The 1602 I2C display as shown in (Fig. 8) is a 16x2 character LCD with an I2C interface, commonly used in electronics projects. Its I2C interface simplifies wiring, and it often includes an LED backlight. With the popular HD44780 controller, it's compatible with microcontrollers like Arduino and Raspberry Pi. The display is versatile, cost-effective, and widely used for showing sensor data. Users can adjust contrast using a potentiometer, and

documentation should be consulted for proper integration and programming.

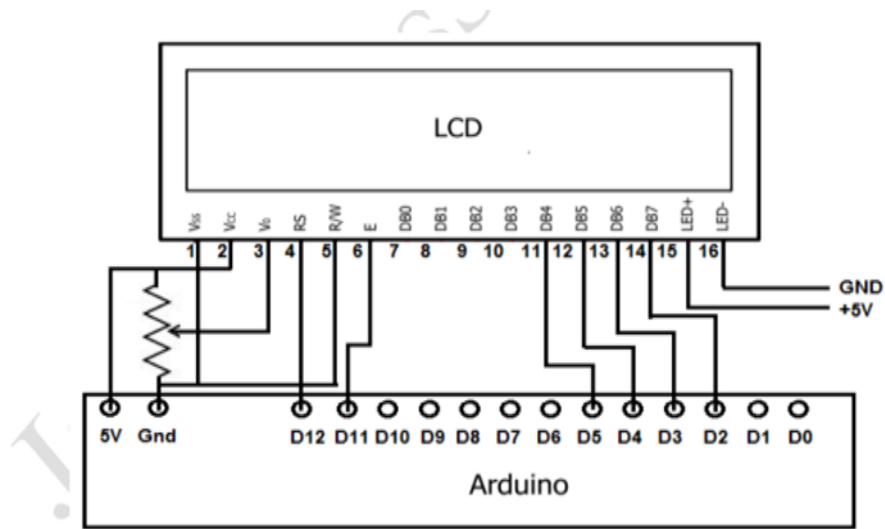


Fig.9: connect of display

Pin Function of LCD

Pin#1	It denoted as Vss	It is ground pinout potential at this pinout is zero.
Pin#2	It denoted as Vdd	At this pinout, five volts are provided.
Pin#3	This pinout denoted as Vo	This pinout is used to set the contrast of the screen.
Pin#4	This pin denoted as RS	It used to H/L register select signal.
Pin#5	It denoted as RW	It used for H/L read/write signal.
Pin#6	This pinout denoted as E	It used for H/L enable signal.
Pin#7-14	The pinouts from seven to fourteen denoted as DB0 – DB7.	It used for H/L data bus for 4 bit or 8-bit mode.
Pin#15	It identified as A (LED+)	It used to set backlight anode.
Pin#16	It recognized as K (LED-).	It used to set backlight cathode.

Parameters	Symbol	Conditions
Input Voltage	It denoted as VDD	The value of VDD is plus five volts.
Supply Current	It denoted as IDD	Its value is ten milliamperes.
LC Driving Voltage for Normal Temperature Version Module	Its symbol is VDD to V0.	Its value is 5.2 volts
LED Forward Voltage	It is denoted as VF.	Its value is 4.3V
LED Forward Current	It denoted as IF.	Its value is 4.6V.
EL Supply Current	This pinout denoted as EL	VEL = 110 VAC, and four hundred frequency.

Fig.10: display tables

The 1602 I2C Display is a widely used component in electronics projects, offering simplicity and versatility. Here are some key features and considerations:

Type: It is a 16x2 character LCD (Liquid Crystal Display), meaning it can display 16 characters in each of its two rows.

Interface: The I2C interface simplifies the wiring and reduces the number of pins required for connection. This is particularly beneficial in projects with limited available pins on microcontrollers like Arduino or Raspberry Pi.

Controller Compatibility: The display typically features the HD44780 controller, a popular controller in the industry. This makes it compatible with a variety of microcontrollers and simplifies the programming process.

Backlight: Many 1602 I2C displays come with an LED backlight, enhancing visibility in various lighting conditions.

Versatility: The display is versatile and commonly used for displaying sensor data, messages, or any other information in projects where a simple character-based display is sufficient.

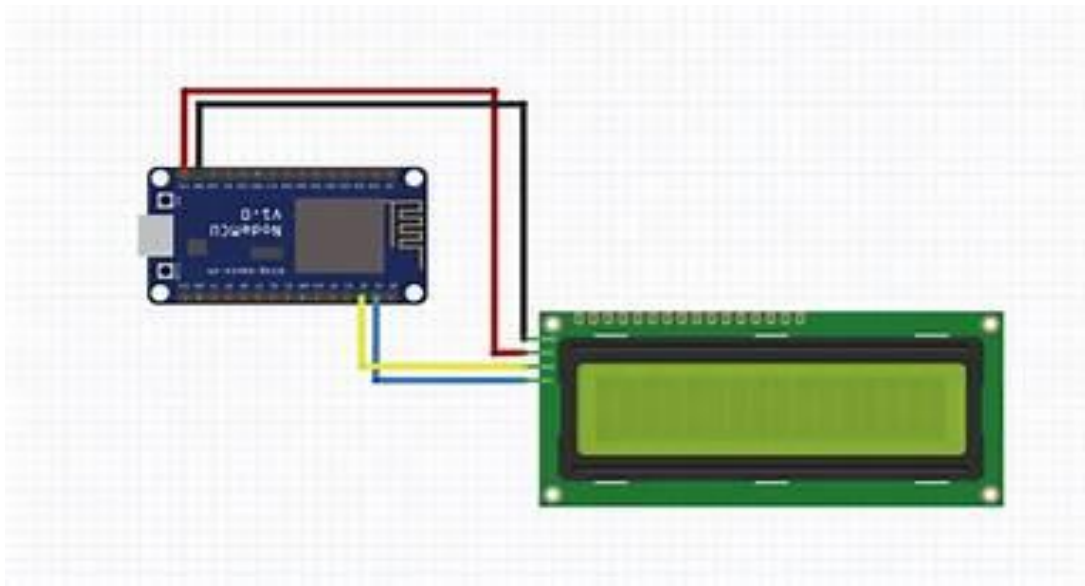


Fig. 11: displays

5. Mobile phone charger:

We need to convert voltage from 220V AC to 5V DC, so we will use a mobile phone charger as shown in (Fig. 11) to power the circuit components with 5V DC.

A mobile phone charger is a common device used to convert household electrical power to a lower voltage suitable for charging mobile devices. Here are some key points about using a mobile phone charger to power a circuit with 5V DC.

Voltage Conversion: The primary function of a mobile phone charger is to convert the standard household alternating current (AC), typically at 220V, to a lower direct current (DC) voltage suitable for charging electronic devices, usually around 5V.

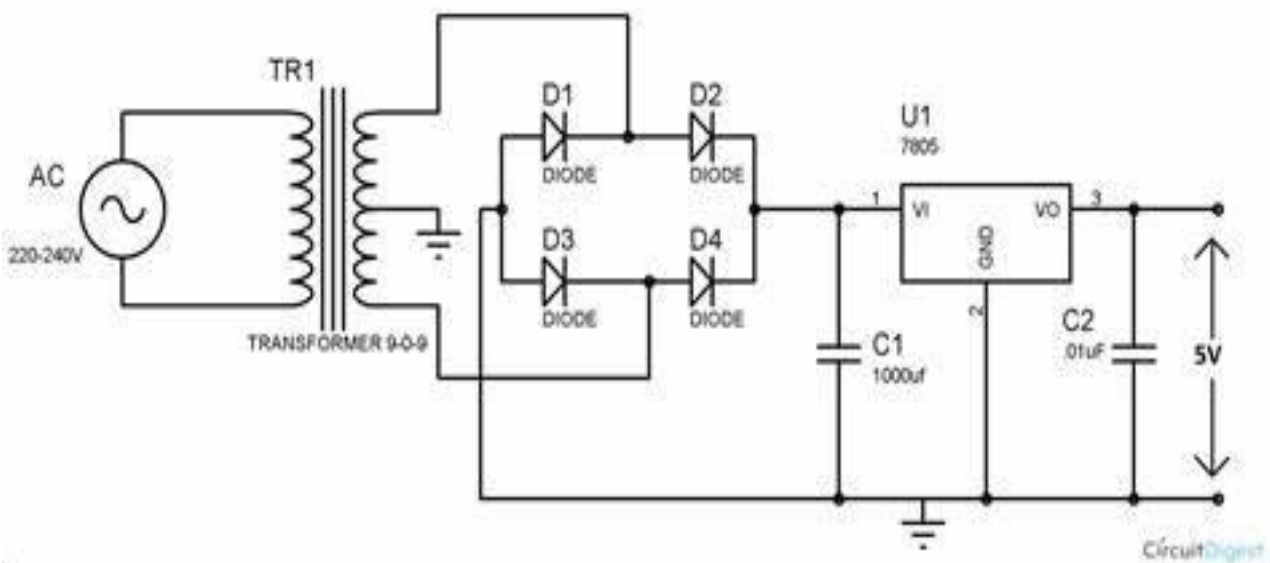
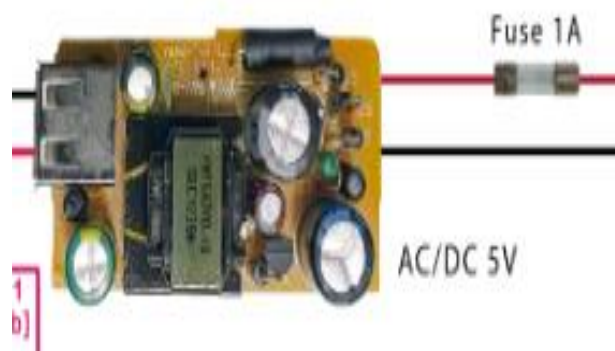


Fig. 12: Mobile phone charger

6. Residual current circuit breaker:

A Residual Current Circuit Breaker (RCCB) is a safety device that detects and rapidly disconnects a circuit in the event of a current imbalance, preventing electric shock and fire hazards. It comes in different sensitivity ratings, is commonly used in various settings, and is installed in electrical distribution panels. Regular testing is recommended for proper functionality, and compliance with local electrical codes is essential. RCCBs are often used alongside Miniature Circuit Breakers (MCBs) for comprehensive electrical protection.

A Residual Current Circuit Breaker (RCCB) is a crucial safety device designed to enhance electrical safety in various settings. Here are key points about RCCBs:

Safety Function: The primary purpose of an RCCB is to rapidly disconnect a circuit if it detects a current imbalance between the live and neutral conductors. This helps prevent electric shock and reduces the risk of fire hazards caused by faulty appliances or wiring.

Current Imbalance Detection: RCCBs continuously monitor the current flowing in both the live and neutral conductors. Any difference in the current levels indicates a leakage, which might be due to a fault, and triggers the RCCB to disconnect the circuit.

Sensitivity Ratings: RCCBs come in different sensitivity ratings, typically expressed in milliamperes (mA). Common sensitivity levels include 30mA and 100mA. The chosen sensitivity depends on the application and the level of protection required.

Installation: RCCBs as shown in (Fig. 12) are commonly installed in electrical distribution panels. They are positioned to cover specific circuits or the entire distribution board, depending on the installation requirements and the desired level of protection.

Complementary Protection: RCCBs are often used in conjunction with Miniature Circuit Breakers (MCBs) for comprehensive electrical protection. MCBs primarily protect against overcurrent's and short circuits, while RCCBs focus on detecting current imbalances.

Regular Testing: Periodic testing of RCCBs is recommended to ensure their proper functionality. This involves using the built-in test button to simulate a fault and verify that the RCCB disconnects the circuit as intended. Regular testing is crucial for maintaining the reliability of the safety device.

Compliance with Codes: Installation and use of RCCBs should comply with local electrical codes and regulations. Following these standards ensures that the safety devices are appropriately integrated and meet the necessary requirements for electrical safety.

Wide Application: RCCBs find applications in various settings, including residential, commercial, and industrial environments. They are a fundamental component of electrical safety systems.



Fig. 13: Residual current circuit breaker

7. Other Hardware components

Resistors and capacitors are basic passive components commonly used in electronic circuits. Here is a brief overview of each:

Resistors:

Function: Resistors limit the flow of electrical current in a circuit. They are used to control voltage levels, protect components, set bias points, and perform various other functions.

Color Code: Resistors are often color coded to indicate their resistance value. The color bands on a resistor can be decoded to determine its resistance in ohms.

Types: Resistors come in different types, including fixed resistors (with a fixed resistance) and variable resistors (such as potentiometers or rheostats, allowing adjustable resistance).

Capacitors:

Function: Capacitors store and release electrical energy. They are used to smooth voltage, filter signals and timing circuits. Capacitors resist changes in voltage and can store energy in an electric field.

Types: Capacitors come in different types, such as electrolytic capacitors, ceramic capacitors, and tantalum capacitors. Each type has specific characteristics suitable for different applications.

Polarity: Electrolytic capacitors are polarized and must be connected with the correct polarity. Other types, such as ceramic capacitors, are non-polarized and can be connected in any direction.

When designing an electrical circuit, the selection of resistors and capacitors as shown in (Fig. 13) depends on the specific requirements of the circuit. Factors to consider include resistance values, capacitance values, power ratings, and the type of signal or function the circuit is intended to perform.

Before finalizing your circuit design, it is necessary to calculate the appropriate resistor and capacitor values based on the needs of your circuit.

Additionally, make sure you have the correct types of resistors and capacitors for your intended applications.

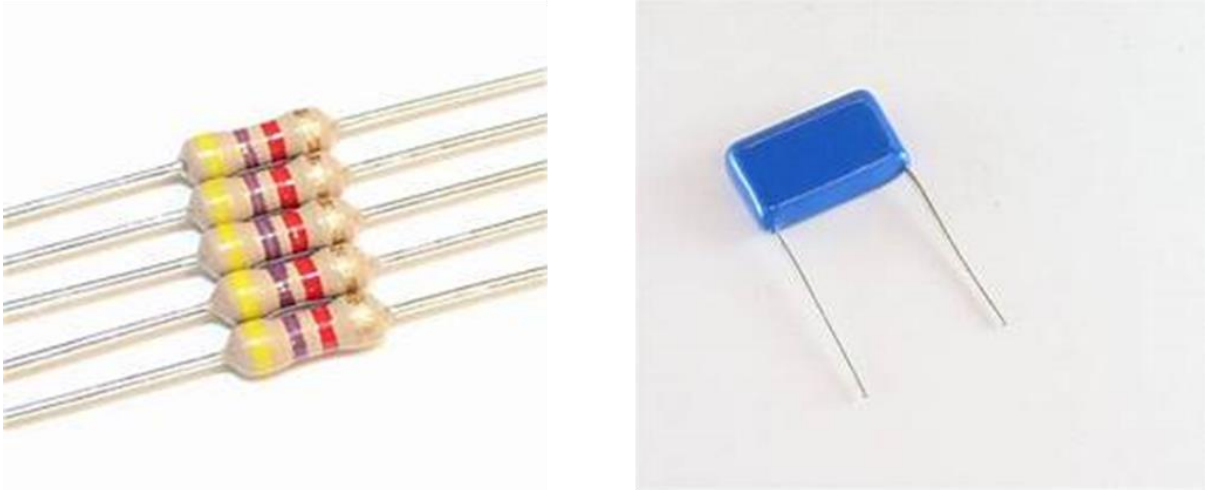


Fig. 14: resistors and capacitors

8 . Contactor

Contactors are electrical switches used to control the connection and disconnection of electrical circuits, and are characterized by the ability to control large loads such as motors and lighting systems. They consist of a coil that generates a magnetic field that attracts a moving arm that closes or opens the contact points. They feature easy automation and remote control, and are used in industrial applications to ensure efficiency and safety in electrical systems.

The contactor can be connected to a processor (such as a microcontroller or PLC) to automatically control electrical circuits. The processor is used to send an on or off signal to the contactor coil, allowing the contactor to control large electrical loads based on digital commands from the processor.

The processor output is connected to the contactor coil via a transistor or small relay. This transistor or relay can act as an intermediary to carry the current required to operate the contactor coil.

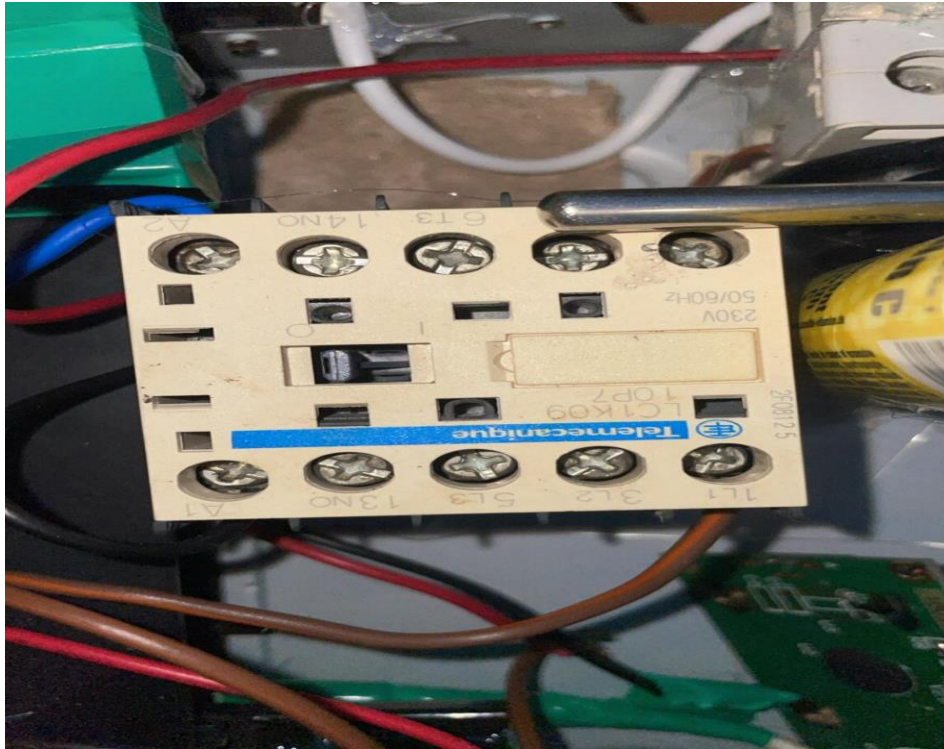


Fig. 15: The contactor used in the project

Part 2: Software: In this section, we will add the code for each component to the ESP8266 to act as the processor for the project. It will receive information from the sensors, process it, and output the required data on the display.

The code is too long to add to this file, so we will either put a link to the

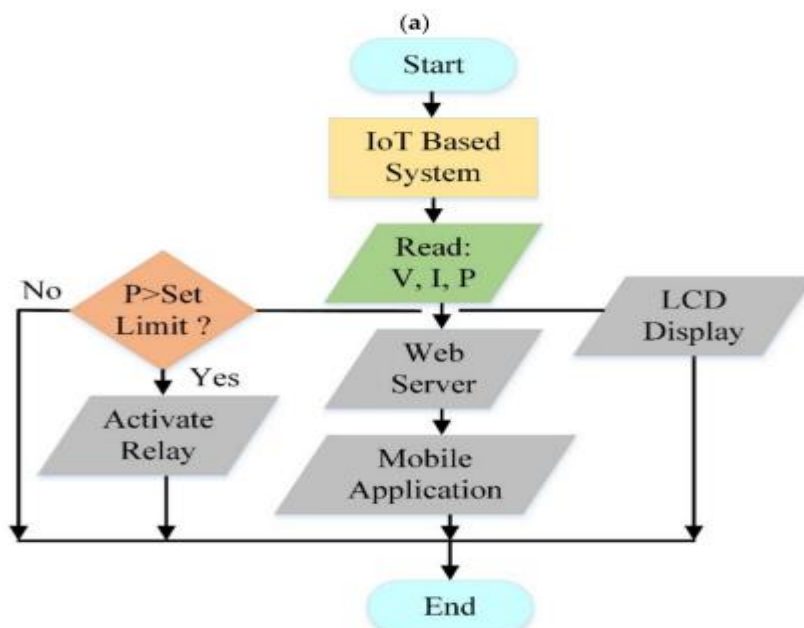


Fig. 16: block diagram

The code is organized in binary form, where each function performs a specific function:

setupLCD

```
void setupLCD() {
  lcd.begin(); // تهيئة شاشة LCD
  lcd.backlight(); // تشغيل الإضاءة الخلفية للشاشة

  lcd.setCursor(0, 0);
  lcd.print("    Energy meter    ");
  delay(1000);

  lcd.setCursor(0, 1);
  lcd.print("    Monitor by IOT    ");
  delay(1000);

  lcd.setCursor(0, 2);
  lcd.print("    Designed by    ");
  delay(1000);

  lcd.setCursor(0, 3);
  lcd.print("HRB Embedded & Craft");
  delay(3000);
}
```

Fig. 17: Programming code explaining setupLCD

Its function: This function initializes the LCD screen and displays introductory messages when the system starts. This provides the user with information about the project and confirms that the device is working properly and communicating.

Setup

```
void setup() {
  Serial.begin(9600); // بدء تشغيل الاتصال التسلسلي بسرعة 9600 بت/ثانية
  setupLCD(); // عرض الرسائل التمهيدية LCD تهيئة شاشة
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80); // بدء الاتصال بمنصة Blynk
  lcd.clear(); // بعد إتمام الإعدادات LCD مسح شاشة
}
```

Fig. 18: Programming code explaining Setup

Its function: This function prepares the system at startup. It includes configuring the serial connection, configuring the LCD display, and connecting to the Blynk platform using the information provided (authentication code, network name and password).

readAndDisplayVoltage

```

void readAndDisplayVoltage() {
    float voltage = pzem.voltage();
    if (!isnan(voltage)) {
        Serial.print("Voltage: ");
        Serial.print(voltage, 1);
        Serial.println("V");
        lcd.setCursor(0, 0);
        lcd.print("Voltage: ");
        lcd.print(voltage, 1);
        lcd.print("V");
    } else {
        Serial.println("Error reading voltage");
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Voltage = 0.00V");
    }
}

```

Fig. 19: Programming code explaining readAndDisplayVoltage

Function: This function reads the voltage using the PZEM004T module and displays the value on both the serial monitor and LCD. If there is a read error, an appropriate error message is displayed.

The process is repeated to read the current, power, power, frequency, and power factor

sendToBlynk

```

void sendToBlynk() {
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float frequency = pzem.frequency();
    float pf = pzem.pf();

    Blynk.virtualWrite(V1, voltage);
    Blynk.virtualWrite(V2, current);
    Blynk.virtualWrite(V3, power);
    Blynk.virtualWrite(V4, energy);
    Blynk.virtualWrite(V5, frequency);
    Blynk.virtualWrite(V6, pf);
}

```

Fig.20: Programming code explaining sendToBlynk

Its function: This function sends the values read from the PZEM004T module to the Blynk platform to display on the user interface.

Loop

```
void loop() {
  Blynk.run(); // الأساسية تشغيل حلقة Blynk

  readAndDisplayVoltage();
  readAndDisplayCurrent();
  readAndDisplayPower();
  readAndDisplayEnergy();
  readAndDisplayFrequency();
  readAndDisplayPowerFactor();

  Serial.println();
  delay(2000); // تأخير لمدة 2 ثانية بين القراءات

  // نشر البيانات كل 5 ثوانٍ
  if (millis() - lastMillis > 5000) {
    lastMillis = millis();
    sendToBlynk();
  }
}
```

Fig.21: Programming code explaining Loop

Its function: This function repeatedly runs basic system tasks. Includes running Blynk, reading and displaying values from the PZEM004T module, and sending the values to the Blynk platform periodically

Elements used in the circuit	Output	Operations	inputs
5V relay module	A screen to display the readings	esp8266	pzem-004t (current reading sensor)
mobile phone charger	Application interface	pzem-004t	pzem-004t (voltage reading sensor)
residual current circuit breaker	-----	-----	-----
resistors and capacitors	-----	-----	-----
Contacter	-----	-----	-----

```
{const uint32_t ThingSpkPostInt = 60000; // set MS intervals between posts to Thing Speak }
```

Time sample: 1 minute

Chapter5:

5.1 Implementation stage and finding solutions

In the second phase of our project, we enhanced the functionality of our smart distribution board by integrating a series of relays connected to an ESP8266 microcontroller.

we added a group of relays connected to the ESP8266 to provide us with the ability to control the load separately through the application on the phone, with the ability to control each load separately without the need to cut off the current from the entire circuit. To solve the problem of loads that consume high current, we connected its relay to the contactor, and thus we have provided the control feature in our project for all types of loads, and through the feature of controlling each load separately, the user, if he notices high consumption, can disconnect unnecessary loads to save energy without affecting the rest of the loads

This setup allows us to independently control multiple electrical loads via a smartphone application. Here's a detailed explanation of the advancements and their benefits

1. Individual Load Control

Relays and ESP8266 Integration: Each relay is connected to an ESP8266 microcontroller. The ESP8266, a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability, enables wireless control of the relays.

Mobile Application Interface: The smartphone application communicates with the ESP8266, allowing users to switch each relay on or off. This setup facilitates individual control of each electrical load connected to the relays.

Selective Load Management: Users can turn off specific loads without disrupting the entire circuit. For example, they can switch off high-power-consuming devices when not needed, thereby optimizing energy usage and reducing costs.

Remote Control: The integration with the mobile app means users can manage their home's power consumption from anywhere, enhancing convenience and control.

2. Handling High Current Loads

Contactor Integration: For loads that draw high current, relays alone might not suffice due to their limited current handling capacity. To address this, the relays are connected to contactors. A contactor is a switch used for switching an electrical power circuit, similar to a relay but capable of handling higher currents.

Current Load Management: By controlling the contactor via the relay, we ensure that high-current devices can be managed effectively without risking damage to the relays.

Safety and Reliability: This setup ensures the system can safely control high-power appliances, preventing overloads and potential damage.

Extended Control: Users can manage both low and high-power devices, providing comprehensive control over the household's energy consumption.

3. Energy Efficiency and Cost Savings

Real-Time Monitoring: The system can monitor energy consumption in real-time and provide data to the user via the mobile application. If a device or a set of devices is using excessive power, the user can take immediate action.

Intelligent Load Shedding: When high consumption is detected, users can selectively turn off non-essential loads to save energy without affecting critical appliances.

Optimized Energy Use: By disconnecting unnecessary loads during peak consumption times, users can significantly reduce their energy bills.

5.2 Technical Implementation Details

Components Used

ESP8266 Microcontroller: Provides the wireless communication backbone for controlling the relays.

Relays: Serve as the switches that control individual loads.

Contactors: Used for managing high-current loads to ensure system stability and safety.

Smartphone Application: Acts as the user interface for monitoring and controlling the system.

System Architecture

ESP8266 Configuration:

Connected to a Wi-Fi network.

Programmed to receive control signals from the mobile app.

Sends signals to the relays to control the loads.

Relay and Contactor Setup:

Relays are connected to the ESP8266 and control the switching of electrical circuits.

For high-current loads, relays control contactors, which handle the actual switching of high-power circuits.

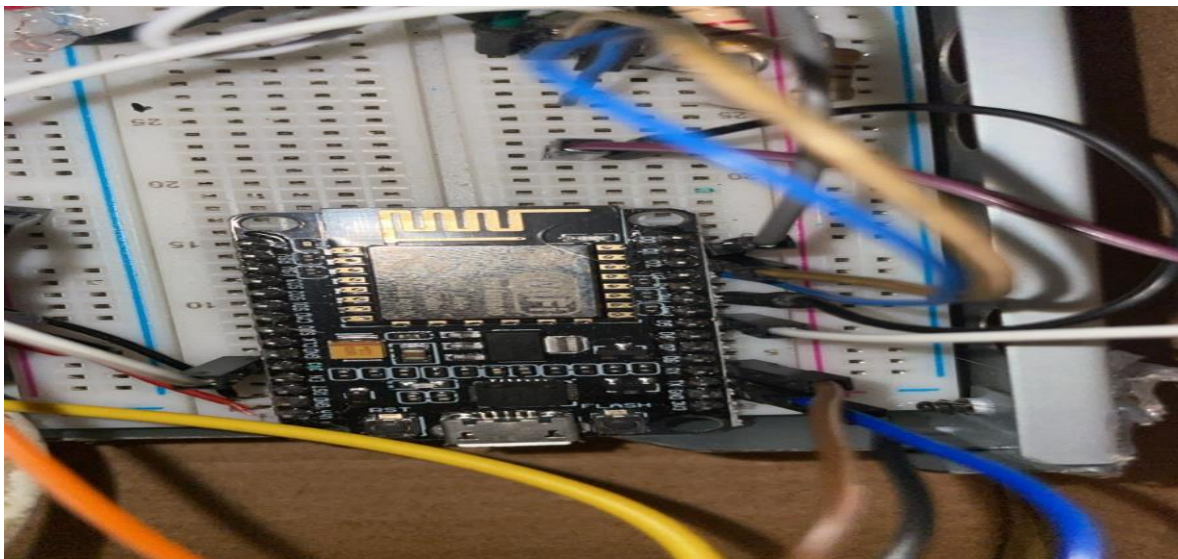


Fig.22: ESP8266 User in the project

Mobile Application:

Provides a user-friendly interface for monitoring power consumption.

Allows users to switch loads on and off remotely.

The application used in the project:

Blynk app

Blynk is an Internet of Things (IoT) platform and users are starting to create custom mobile interfaces to control electronic devices and smart systems remotely. The application allows users to control their electronic projects using smartphones or tablets.

Blynk members

Blynk app

Mobile application that is used to create the user interface. Users can design buttons, indicators, wind effects, and other interactive tools.

Blynk server:

It is the middleman that affects the mobile application and then affects the devices. Users can use Blynk's cloud server or set up their own local server.

Blynk library:

A software library that can be accessed with the code for the device you want to control. The library supports many platforms such as Arduino, Raspberry Pi, ESP8266, and others.

The language Blynk works in

The application is written in several languages, including Java and Swift for mobile applications, in addition to other languages that are integrated into server development such as JavaScript (Node.js) and others.

From any device, programming languages such as C++ and basic software that runs on the controlled devices such as Arduino, Python for Raspberry Pi, etc. are used. The language used depends on the type of device and project-specific requirements.

How to use Blynk

Installing the application :

We download the Blynk application from the App Store (App Store or Google Play).

Create an account:

After installing the application, we log in through a new account or log in with an existing account.

Create the project:

There is a new device project inside the application. We choose the type that you will control, and receive the authentication code (Auth Token) that we will use in the code.

Device setup:

Write the device code using the Blynk library, and add the authentication code (authentication code) to the code.

Download the code to the device:

The code must be uploaded to the desired device (such as Arduino or ESP8266).

Connecting the device to the network:

We make sure that the device is connected to the network (Wi-Fi or Ethernet) to be able to communicate with the Blynk server.

Advantages

Ease of use: Simple visual interface for creating applications and controlling devices.

Multiple Support: Supports multiple platforms and devices.

Remote Control: Appliances can be controlled from anywhere in the world using a mobile phone.

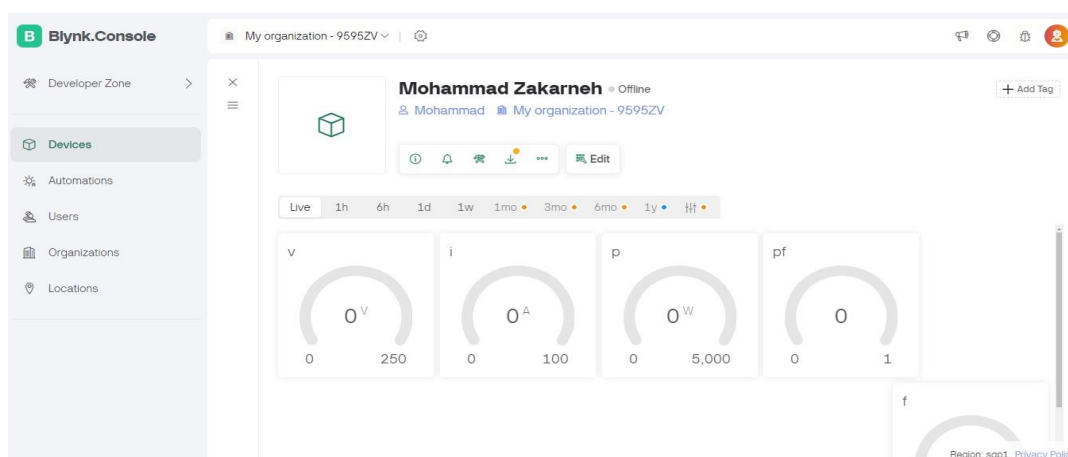


Fig.23: Mobile Application

By integrating relays and ESP8266 microcontrollers into our smart distribution board project, we have significantly enhanced its functionality. The ability to

control individual loads remotely provides users with a powerful tool to manage their energy consumption more effectively. The inclusion of contactors ensures the system can handle high-current loads safely, making it a robust solution for modern residential settings. This development not only improves user convenience and control but also promotes energy efficiency and cost savings.

_Not :The code used to control and program the application is its companions in the software department

5.3 Possible developments on the project

One of the project's most important future ambitions is to make the panel work automatically without user guidance

For example, scenarios are created by the user and saved

It is also possible to add a timer to the power breaker so that we can control specific times on its own. This is necessary in devices that operate at specific hours and can be expanded to include factories. Devices can be disconnected, for example, in the hours when they finish working on their own, without even having to return to the application.

Automation and scenario-based control:

To make the Smart Distribution Board (SDB) operate autonomously based on pre-defined scenarios without the need for constant user intervention.

User-defined scenarios: Users can create scenarios (e.g., “Vacation Mode,” “Workday Routine”) that specify which devices to turn on or off at different times of the day or in response to certain triggers.

Scenarios can be set to respond to specific conditions such as time of day, occupancy, weather changes, or energy consumption levels. For example, a Night Mode scenario might turn off all lights and reduce heating after 11 p.m.

Timer and scheduling functions:

Users can set timers for specific devices to only work during specific hours. For example, water heaters can be programmed to turn on early in the morning and turn off after a few hours.

The ability to create daily, weekly or monthly schedules for different loads. This feature is especially useful for repetitive tasks, such as lighting systems in offices or factories that need to follow a regular schedule.

For industrial settings, it can be programmed to automatically disconnect devices at the end of the work day, enhancing safety and energy efficiency without manual intervention.

Automatically reduces or shifts operation of non-essential equipment during times of peak energy use to reduce energy costs and prevent overloads.

The SDB must integrate seamlessly with existing smart home ecosystems (such as Google Home, Amazon Alexa, or Apple HomeKit) to take advantage of its automation and control capabilities.

By integrating advanced automation, scenario-based control, monitoring and enhanced analytics, a smart distribution panel project can significantly improve its functionality and user experience. These developments will not only make the system more autonomous and efficient, but will also provide users with deeper insights and greater control over their energy consumption, leading to increased savings and sustainability.

There are also many developments that can be added to the project through development on the application and through adding software codes.

For example, to develop software to provide in-app notifications, services such as Firebase Cloud Messaging (FCM) can be integrated to provide push notifications to users. The FCM is set up in the mobile app and the system is configured to send notifications when important events such as high power consumption or power outages occur. This includes developing a programming interface (API) for communication between the smart hub and the notification service, and ensuring stable wireless communication between the various components and the application. Thanks to these notifications, users can better monitor and control energy consumption and system health instantly and effectively.

Chapter6:

6.1 The challenges

The challenges we faced in the smart distribution panel project Integration between different devices

The integration of various components such as ESP8266, relay modules and connectors requires significant effort and complete hardware compatibility.

The control software that communicates between the mobile application and the ESP8266 to turn the relay on and off was a difficult and debugging-intensive challenge.

The biggest challenge was the difference between the version of the component and the libraries on the Arduino, so we replaced the PZEM-004 with the third generation version of it to match the libraries available from the code.

In addition to the difficulty of dealing with the application and connecting it to the device through the code.

Wireless connectivity and connection stability

Ensuring the stability of the wireless connection between the ESP8266 and mobile applications in the presence of interference and other signals was a challenge that required the use of simple interference prevention techniques, as high voltage wires introduce interference.

As for the scope of coverage, it was very good, as the legislator works even at a large distance

User interface in the application

Easy and simple user interface design enables users to control loads individually.

Compatibility with different electronic systems: Ensure that the application works on different operating systems

Scenario programming

Develop a system that allows the user to create and save scenarios. Programs can be written precisely and these scenarios can be understood without any human influence.

Adding the control intent to automatically turn loads on and off at specific times without the need for application intervention was technically challenging and required excellence in testing.

Energy management and efficiency

Effective distribution of loads in terms of consumption and the most important devices requires careful study of the distribution of loads on electrical breakers and analysis of energy consumption.

Conclusion

The challenges of the smart panels project for energy distribution were somewhat difficult. Some of them we were able to overcome and find the necessary solutions, but others remained a challenge left to development processes. Confronting and overcoming them contributes to developing a subscription system capable of effectively controlling energy consumption and enhancing security and user efficiency.

6.2 Future aspirations and recommendations

1- Smart integration: Ensuring smooth integration with smart home systems, as the smart distribution panel system can be integrated with smart home systems and increase its effectiveness, as the system is adaptable to future technological developments.

2- Participate in pilot tests in residential environments to collect real-world feedback, make the necessary adjustments, provide incentives to early adopters, and provide strong customer support to facilitate smooth integration into homes.

3- Continuous improvement by obtaining the necessary certificates and approvals to put the product on the market

Market launch and adoption

4-Partnerships with installers and builders Providing training programs for electricians and installers to ensure that they are familiar with distributing your smart panel. Certified installers can help build trust and credibility with potential customers.

And partnering with home building companies to include smart distribution panels in new construction. This can be marketed as a value-added feature for modern, energy-efficient homes

5- Community participation

Participating in local community events and exhibitions to display our project's smart distribution panels. Provide hands-on demonstrations and answer questions from potential customers.

And provide excellent customer support to address any concerns or questions. Our responsive support team can ease concerns and build confidence in our product

The development of the smart home distribution board represents a major leap forward in residential energy management

The future aspirations of this technology are not only to improve the quality of life for users, but also to contribute to a more sustainable and resilient energy ecosystem.

Beginning development of smart keyboards requires a multi-faceted approach that includes market research, strategic partnerships, technology development, regulatory compliance, beta testing, finance and marketing, and continuous improvement. By following these recommendations, the development process can be streamlined, ensuring that the final product is innovative and well accepted in the market.

Chapter7:

Conclusion:

In summary, the incorporation of a smart panel distribution board represents a noteworthy advancement in optimizing efficiency, safety, and control within electrical systems. Through the incorporation of intelligent technologies, the board not only simplifies monitoring and management but also offers valuable insights for proactive maintenance, resulting in decreased downtime and a reduced likelihood of electrical failures. By providing users with real-time data, remote accessibility, and advanced analytics, the smart panel distribution board facilitates the development of a more robust and agile electrical infrastructure. In the face of ongoing technological progress, the adoption of intelligent solutions such as the smart panel distribution board will become imperative for ensuring a sustainable, secure, and adaptable electrical ecosystem in the years ahead.

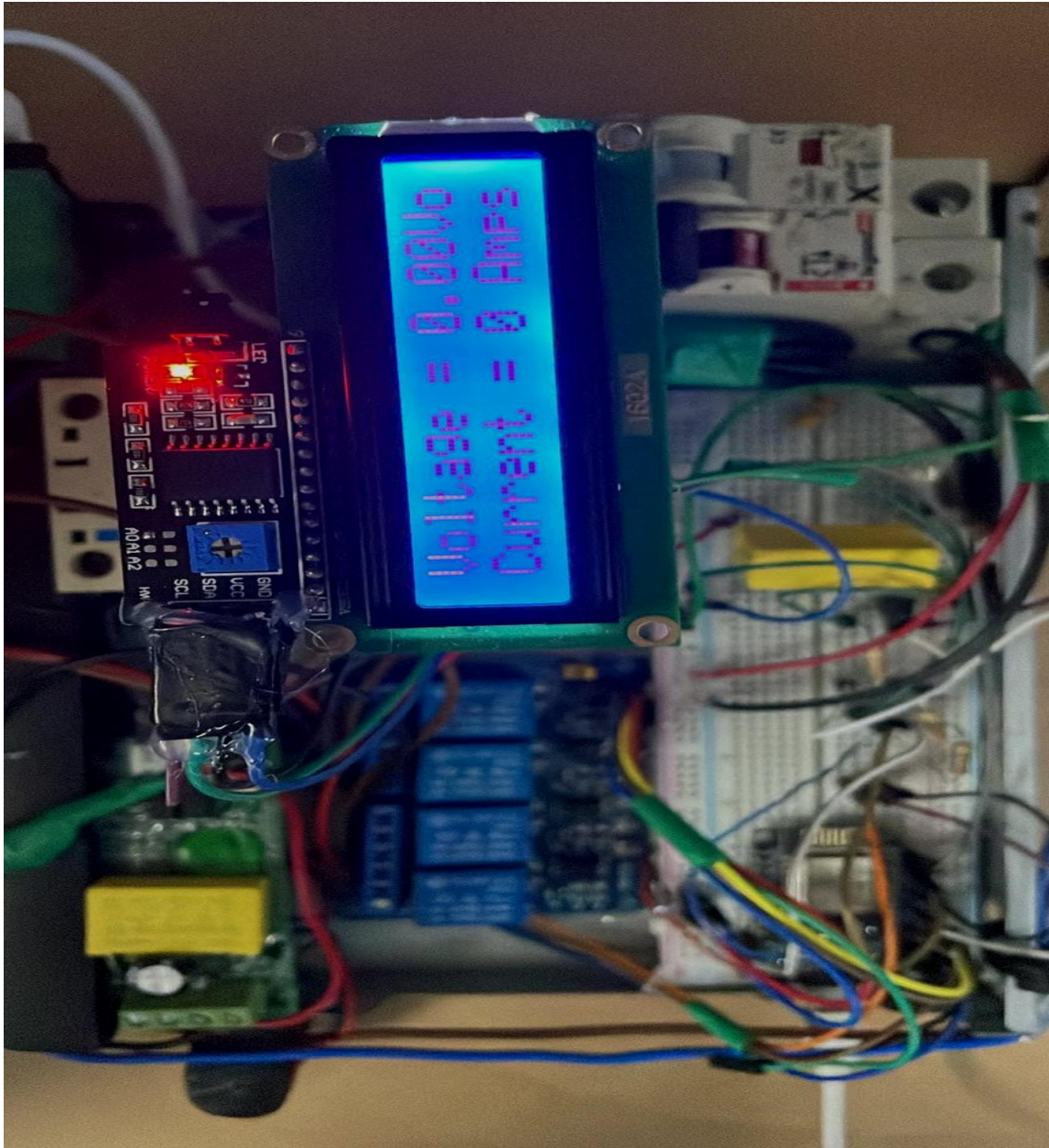


Fig.24: A final image of the project in operation

References:

- [1] Saleem Y, Crespi N, Rehmani MH, et al. Internet of things-aided Smart Grid: technologies, architectures, applications, prototypes, and future research directions. *IEEE Access*. 2017;7:62962–63003. <https://doi.org/10.1109/ACCESS.2019.2913984>.
- [2] Chelloug SA, El-Zawawy MA. Middleware for Internet of Things: Survey and Challenges. *Intell Autom Soft Comput*. 2017;3:70–95. <https://doi.org/10.1080/10798587.2017.1290328>.
- [3] Shrouf F, Ordieres J, Miragliotta G. Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. *Proceedings of the 2014 IEEE International Conference on Industrial Engineering and Engineering Management*; 2014. p. 697–701. <https://doi.org/10.1109/IEEM.2014.7058728>.
- [4] Wang Q, Wang YG. Research on Power Internet of Things Architecture for Smart Grid Demand. 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2). <https://doi.org/10.1109/EI2.2018.8582132>.
- [5] Vu TL, Le NT, Jang YM, et al. An Overview of Internet of Energy (IoE) Based Building Energy Management System. 2018 International Conference on Information and Communication Technology Convergence (ICTC). <https://doi.org/10.1109/ICTC.2018.8539513>.
- [6] Bin X, Qing C, Jun M, et al. Research on a Kind of Ubiquitous Power Internet of Things System for Strong Smart Power Grid. 2019 IEEE

Innovative Smart Grid Technologies - Asia (ISGT Asia).
<https://doi.org/10.1109/ISGT-Asia.2019.8881652>.

- [7] Wang W, Zhou Z. Exploring Novel Internet-of-things Based on Free Space Optical Communications for Smart Grids. 2020 IEEE 4th Conference on Energy Internet and Energy System Integration (EI2).
<https://doi.org/10.1109/EI250167.2020.9347166>.

- [8] Xiang W, Wang Y, Gao X, et al. Design and Implementation of Internet of Things System Based on Customer Electricity Behavior Analysis. 2021 IEEE 5th Conference on Energy Internet and Energy System Integration (EI2). <https://doi.org/10.1109/EI252483.2021.9713593>.

- [9] Amin SM, Wollenberg BF. Toward a smart grid: power delivery for the 21st century. IEEE power and energy magazine. 2005;3:34–41.
<https://doi.org/10.1109/MPAE.2005.1507024>.

- [10] Sehgal, Vivek Kumar, et al. "Electronic Energy Meter with instant billing." 2010 Fourth UKSim European Symposium on Computer Modeling and Simulation. IEEE, 2010.
- [11] Anon: "Electricity Tariff Fundamentals", University of Pretoria Electricity and Energy group, 2008. [Online].