SAKOON: Automating Electric Load of Building

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CERTIFICATE OF APPROVAL

It is certified that the project titled "SAKOON: Automating Electric Load of Building" carried out by SYED MUSA RAZA NAQVI, Reg. No. F19604002, and MUHAMMAD SOHAIL, Reg. No. F19604005 under the supervision of Dr. MUHAMMAD EJAZ KHAN, National University of Technology (NUTECH), Islamabad, is fully adequate in scope and in quality, as a capstone project for the degree of BS of Computer Engineering.

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We sincerely hope that our work on the SAKOON project will contribute meaningfully to the field and stand as a testament to the transformative power of innovative thinking and research, particularly in the sustainable energy sector.

Our deepest appreciation goes to our families for their unwavering affection, prayers, understanding, and backing. Their confidence in our skills has made this academic adventure feasible.

At last, we wish to articulate our aspiration that SAKOON becomes an instrumental asset in the sphere of energy management and conservation, contributing positively towards the creation of a sustainable and energy-conscious future.

DEDICATED

TO

OUR

FAMILY

SUPERVISOR

LOVED ONES

ABSTRACT

"SAKOON: Revolutionizing Energy Management for a Sustainable Future"

Embracing the prowess of cutting-edge technologies, "SAKOON: Automating Electric Load Management" emerges as a game-changer, reshaping our understanding and control of energy utilization. This IoT-enabled platform synergizes the potency of an advanced sensor module with the convenience of an intuitive mobile application, presenting real-time energy consumption details directly to the user. It amalgamates a sophisticated sensor module, a high-performance ESP8266 microcontroller, and user-friendly applications to create a comprehensive and accessible energy monitoring system. The sensor module is tasked with collecting real-time energy consumption data, measuring parameters like voltage, current, power, and energy. This raw data, in the form of analog signals, is then converted into digital data, comprehensible by the microcontroller. The ESP8266 microcontroller utilizes its onboard Wi-Fi capabilities. It receives digital data from the sensor module, processes it, and communicates with mobile and web applications. This process is facilitated by leveraging the TCP/IP and UART communication protocols, allowing seamless and error-free data transmission. The mobile application, compatible with multiple platforms (i.e., Android, IOS) and the web-based dashboard (Industrial Dashboard Control Panel), provides user with a detailed and real-time view of their energy consumption. Data communicated from the microcontroller is rendered in an easily interpretable graphical format, enabling users to make informed energy-saving decisions. Moreover, the system integrates the Blynk platform, enhancing its functionality and user experience. The web server ensures data accessibility in real time, serving web pages to users upon request. SAKOON is more than just a tool; it represents a leap toward sustainable living by empowering users with granular control over their energy usage. Utilizing advanced algorithms and robust communication protocols, SAKOON empowers users to monitor and control energy consumption in real time, fostering an environment of energy consciousness and efficiency. With its innovative web dashboard and seamless integration, SAKOON is more than just an energy management tool - it's a step towards a sustainable future.

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LIST OF ABBREVIATIONS

PZEM……….. Sensor Module (measure current, voltage)

UI………........ User Interface

IoT……….…... Internet of Things

SDGs……….. Sustainability Development Goals by United Nations

UN………...... United Nations

TTL………..... Transistor-Transistor Logic

UART……… Universal Asynchronous Receiver Transmitter

CSR………...... Corporate Social Responsibility

DR..………..... Demand Response

RTP………...... Real-Time Pricing

CPP………...... Critical Peak Pricing

ToU………...... Time of use

PPE………...... Personal Protective Equipment

Chapter 1

INTRODUCTION

1.1 Problem Statement

The high cost of electricity is causing stress among people. Due to rising energy use, depleting resources, and environmental deterioration, the globe is today confronting a severe problem. To address these difficulties, efficient management and energy conservation are essential, but conventional power metering systems cannot provide timely, accurate information on energy use patterns and prices.

Figure 1: News about High Energy Prices

Although digital power meters have advanced, there is still a significant need for an integrated system that combines real-time energy monitoring, precise cost calculation, and user-friendly interfaces for thorough energy management. Furthermore, the absence of specific advice for energy-saving measures and predictive analyses for future energy patterns further exacerbates the issue.

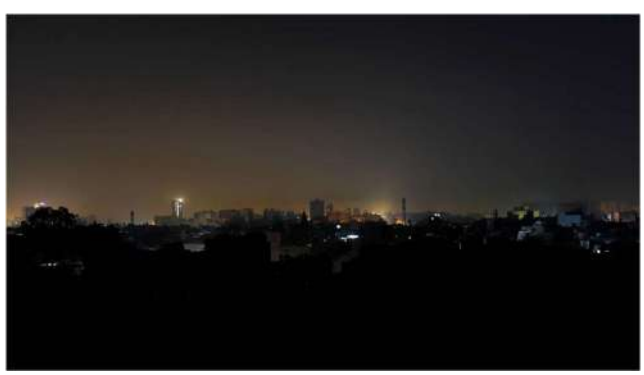


Figure 2: Blackout due to Shortage of Energy

1.2 Background

The significance of effective energy management and conservation has been highlighted by rising energy consumption and worries about resource depletion and environmental impact. Systems for power metering are essential for allowing people and businesses to track and manage their energy use. These technologies let customers get insightful information about patterns of energy use, spot inefficient regions, and make well-informed choices that will lower their energy expenses and environmental impact. Power metering systems have historically depended on simple analog meters that had to be read by people and lacked real-time data-collecting capabilities.

Figure 3: Analog Electric Meter

The development of digital power meters, which provide improved accuracy, automation, and data accessibility, has revolutionized industry. These contemporary power meters offer smooth integration with microcontrollers and software platforms and enable real-time monitoring, analysis, and visualization of electrical data. They are often outfitted with digital communication interfaces.

Figure 4: Digital Electric Meter

Power metering systems now have more possibilities thanks to the development of IoT (Internet of Things) technologies in recent years. IoT-enabled power metering systems take advantage of connectivity and cloud-based platforms to provide interactive user interfaces for simple monitoring and control as well as remote access to energy data. These developments have opened the way for more advanced energy management techniques, allowing users to optimize energy usage, spot chances for energy savings, and save expenditures.

Figure 5: Smart Metering System

The development of SAKOON can improve energy efficiency and save costs. It is intended to enable effective analysis of electrical characteristics, provide users with exact, real-time information about their energy usage, and helps to gain financial independence. This power metering system aims to overcome the drawbacks of conventional metering systems by merging cutting-edge hardware components, durable software, and user-friendly web-based dashboards. It also gives users a potent tool for energy management and monitoring. Furthers help to estimate electricity bills based on data on energy usage and market rates, allowing individuals to save their hard-earned money and cut down on energy waste for the sake of the planet. SAKOON can improve energy management, efficiency, cost savings, as well as environmental sustainability by offering real-time insights, reliable data, and visualization tools.

Figure 6: SAKOON: Save Energy and Money

1.3 Objectives

Effective management and monitoring of electrical power use are essential for development and survival in the modern world. For real-time monitoring, analysis, and the simplification of energy price calculations, a complete power metering system is necessary, which is a low-cost, commercial-grade electric load management system, Works alongside a mobile app to provide real-time information.

Modern hardware and software platforms are used by the system to enable reliable data gathering, processing, and visualization of crucial electrical characteristics. The power metering system allows customers to acquire useful insights into their energy consumption and take proactive steps towards energy saving by merging a strong microcontroller-based platform with a trustworthy energy meter.

Figure 7: Low-cost, commercial-grade electric load management system – Hardware Module

Figure 8: Works alongside mobile app to provide real time information - Software Module

The followings are main objectives to be achieved:

- Create and design a hardware interface that enables reliable data exchange and acquisition between a sensor and a microcontroller that efficiently gathers and processes data, does the required computations, and makes it available for analysis.
- Make a web-based dashboard and a mobile app that is simple to use and offers real-time visualization of key electrical characteristics. Users of the application will be able to efficiently monitor and analyze their energy usage habits thanks to the application's interactive gauges, charts, and graphs that provide data in a visually attractive and instructive way.
- Implement a reliable cost calculation module that makes use of the gathered data on energy use and current energy prices to provide consumers with a precise idea of their power bills. Users will be given the tools they need to utilize this feature to take the required measures to optimize their energy usage and save expenses. The system offers accurate and trustworthy data for use in energy monitoring and analysis.

Figure 9: Industrial Dashboard Control Panel - Software Module

For both residential and commercial customers, the effective adoption of this power metering system will provide several advantages. They will be able to determine energy-intensive appliances or places and make knowledgeable judgments about energy-saving practices thanks to real-time data about their energy consumption. Users' comprehension of their energy consumption patterns will be improved by the incorporation of cutting-edge visualization tools and cost calculation capabilities, which will also provide them the ability to optimize their energy use for optimal efficiency and cost savings.

1.4 Scope

The development of SAKOON can improve energy efficiency and save costs. It is intended to enable effective analysis of electrical characteristics, provide users with exact, real-time information about their energy usage, and helps to gain financial independence. The creation and use of SAKOON, an IoT-based energy monitoring system, opens a wide range of opportunities for thorough energy management and conservation.

Figure 10: Modern concept of Cloud Computing. Both the mobile app and web dashboard using data from cloud

Several important elements may be used to determine the project's scope, including:

- **Hardware Development**: For the system to function, a reliable hardware interface that enables the seamless integration of sensor technologies with microcontrollers for real-time data collection and processing must be designed and developed.
- **Software Implementation**: The project's scope includes developing a specialized mobile app and an online dashboard. They will have intuitive user interfaces and provide essential energy statistics in a comprehensible and aesthetically attractive manner. Through these services, users may track, evaluate, and regulate their energy use in real-time.
- **Cost Estimation**: The scope of the system also includes the incorporation of an accurate cost estimation function. This will be integrated into both the mobile and online platforms and analyze data on energy consumption and current energy costs to forecast future power bills.

- **Real-time Energy Tracking**: The project's scope includes monitoring individual appliances' and the system's overall energy use in real-time. Additionally, there are high energy usage notifications that help consumers spot inefficient equipment or routines. We will provide suggestions for energy-saving measures.
- **Data Security**: It's crucial to ensure user data safety. Part of the scope includes putting strong data security procedures in place to protect against unauthorized access or data leakage.
- **Scalability**: As user acceptance increases or as customers extend their energy monitoring to other appliances or spaces, the power metering system is designed to be scalable and capable of handling growing data loads. The system's architecture places a strong emphasis on interoperability, enabling efficient communication and operation alongside other smart devices and systems, hence improving its use and possible applications.
- **User Training and Support**: Provision of thorough user guides, training, and support, ensuring that users can efficiently use all features and functionalities of the power metering system.

Even though the goal is to build a complete energy monitoring system with all functions, it may be essential to prioritize certain aspects over others due to time, financial, or technological restrictions.

1.5 System Features

The SAKOON system is built with a variety of unique features intended to make tracking energy use easier. It features secure data transfer, an interactive UI, thorough cost estimates, real-time monitoring, and effective hardware integration. It also offers thorough user training and assistance, supported by an effective assessment and feedback system. SAKOON is a potent tool for both individual and business customers looking to increase the efficiency of their energy consumption when these elements are combined.

Figure 11: SAKOON's feature: Realtime, cost eatimation, mobile app, web dashboard.

1.5.1 Real-Time Monitoring

SAKOON provides real-time monitoring of energy usage, allowing users to have instant access to their energy consumption data. This feature aids in making immediate adjustments to energy use and in understanding the patterns of energy consumption.

1.5.2 Friendly and Interactive User Interface (UI)

Both the web-based dashboard and the mobile app for the system have an intuitive UI. Users can rapidly grasp and act on the data.

1.5.3 Cost Estimation

SAKOON features an innovative cost estimation module that calculates an estimate of the energy bill based on current usage rates. This helps users anticipate their expenses and adjust their usage accordingly.

Figure 12: Cost Estimation in Mobile App

1.5.4 Secure Data Transmission

To ensure the safety of user data, SAKOON employs robust security measures. Data transmission between the hardware and software platforms is secured to protect against unauthorized access and potential data breaches.

1.5.5 Efficient Hardware Integration

The system's hardware includes sensors for data collection and a microcontroller for data processing. The hardware components are meticulously integrated to ensure efficient and accurate collection and processing of energy data.

1.6 Synopsis

The story of SAKOON starts with generating electricity, typically from hydroelectric or nuclear power plants. These locations capture and transform nature's untamed force into electrical energy. For instance, hydroelectric facilities spin turbines to produce electricity using the kinetic energy of flowing water. Similarly, nuclear plants utilize nuclear fission to heat water into steam, which again spins turbines to create electrical power.

Figure 13: Water Dam

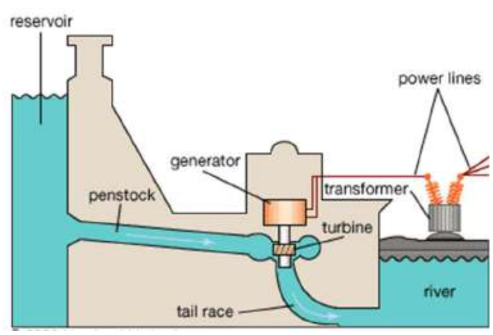


Figure 14: Hydro Plant Working.

Figure 15: Nuclear Plant

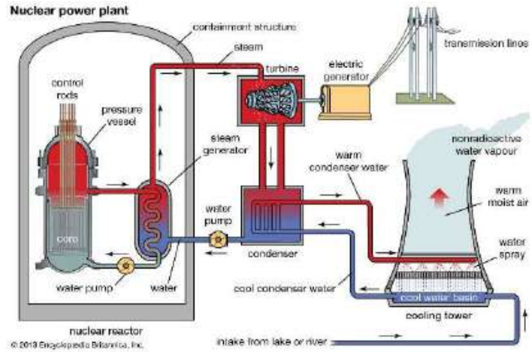


Figure 16: Nuclear Plant Working.

Post-generation, this electrical energy is often at very high voltages, unsuitable for direct consumer use. To facilitate safe transmission over long distances, the voltage is further increased and transmitted through a network of high-tension lines to grid stations. These stations serve as nerve centers in the power distribution network, ensuring electricity reaches different regions as needed.

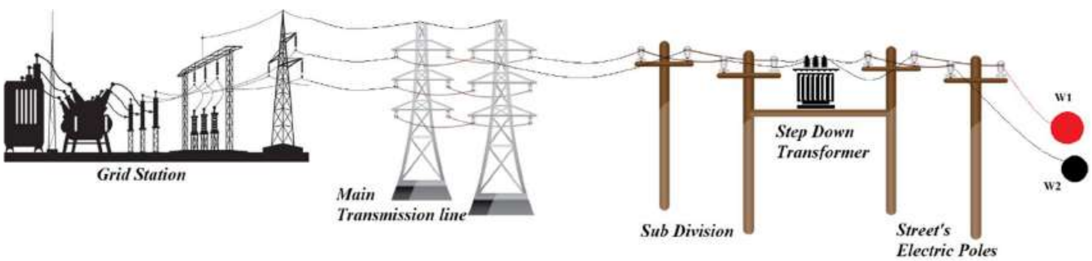


Figure 17: Electricity from Grid Station to Street Poles (cont.)

Upon reaching a specific region, the electricity must be lowered to a safer, usable voltage level. This is where transformers, located at local substations, come into play. They reduce the voltage from the high levels used for long-distance transmission to levels suitable for local distribution, typically around 220 volts in many regions.

Figure 18: Electricity from Street Poles to Homes

From these substations, electricity is distributed via local power lines to homes and businesses. It's here where the power meter enters the picture. Usually located at the point where electrical wiring enters a building, the power meter measures the total amount of electrical energy consumed by that building.

Beyond the meter, the electrical wiring within a home or business distributes power to individual sockets, lights, and appliances. And this is where SAKOON truly shines. Acting as an intelligent gatekeeper at this stage, SAKOON interfaces directly with the power system in a building, continuously monitoring energy consumption at the appliance level.

Figure 19: User Consuming electricity in house after installation of SAKOON

The SAKOON leverages a sophisticated sensor module to measure the electrical power consumed by individual appliances. This data is then processed by a microcontroller and transmitted to a mobile application and web dashboard in real-time. This gives users granular insights into their energy consumption habits, helping them make informed decisions about energy usage, identify wastage, and optimize efficiency.

Figure 20: Industrial Dashboard Control Panel

In essence, SAKOON offers an advanced look into energy usage patterns from the convenience of your phone or computer, presenting a new, contemporary solution for energy management. This technology aims to enable people to regulate their energy use for a sustainable and energy-efficient future, not merely to measure power.

Figure 21: Mobile App showing real time energy consumption and estimated bill.

1.7 Novelty

SAKOON brings a unique blend of technology, accessibility, and user experience to energy management. Its innovation lies in the efficient integration of the sensor module, the powerful ESP8266 microcontroller, and user-friendly applications, all working harmoniously to provide real-time, detailed, and actionable energy consumption data. This IoT-based energy monitoring system offers real-time data access and enables users to understand their energy usage patterns in depth, promoting energy conservation. Moreover, incorporating the Blynk platform and compatibility with a wide array of mobile platforms underscore SAKOON's commitment to user accessibility and convenience. Additionally, the system's capability to calculate and display the energy cost enhances its utility, transforming it from a simple monitoring tool to an essential component of modern, sustainable living.

Figure 22: House from Future

1.8 Application

Figure 23: SAKOON Application (Educational Institute, House, Industry, Corporate)

The SAKOON may be used for a variety of purposes, including:

- **Residential Consumption**: SAKOON enables homeowners to track the energy consumption of their homes in real-time. To reduce their energy costs, they may be able to detect energy-guzzling equipment or times of excessive energy.
- **Government and Municipalities**: To monitor and regulate their energy usage, local governments might employ SAKOON in public buildings or facilities more effectively. Additionally, this could support their attempts to live more sustainably and ecologically.
- **Utility Companies**: SAKOON might be used by energy suppliers to provide their clients with extensive information about their energy usage, encourage energy-saving habits, or develop dynamic pricing schemes based on real-time data on energy use.
- **Research and Development**: SAKOON might be used by scientists for experiments or research on energy use, conservation, or efficiency.
- **Smart Cities**: SAKOON might be widely implemented throughout city infrastructure as part of the smart city project to enable real-time energy monitoring, allowing more effective resource utilization.
- **Energy Consultants**: SAKOON may be used by energy auditors or consultants to provide their customers with accurate and thorough evaluations of their energy use, enabling them to suggest practical energy-saving strategies.

1.9 Industrial Applications

1.9.1 Industrial Significance: Bridging the Energy Management Gap

The SAKOON system is a ground-breaking invention that has the potential to completely change the way energy management is approached in the industrial sector. The timing of this is crucial as businesses everywhere struggle with inflated energy bills and a pressing need to decrease their carbon footprints. SAKOON offers an intelligent solution that helps companies streamline energy usage, improve efficiency, and contribute to global sustainability goals.

As a critical energy monitoring and management system, SAKOON utilizes advanced sensor technology and IoT integration to provide real-time energy consumption data. This granular view of energy usage patterns can be a game-changer for industries, empowering them to identify and rectify energy inefficiencies, plan maintenance schedules, and predict future energy requirements.

1.9.2 SAKOON: Driving Energy Efficiency and Cost Savings

The crux of SAKOON's industrial significance lies in its potential to deliver substantial cost savings. By providing precise insights into energy consumption, SAKOON enables businesses to take proactive measures in mitigating energy wastage. This, in turn, translates into significant reductions in energy bills, creating substantial cost savings that can be channeled back into core business operations. This potential for cost savings places SAKOON as a vital tool for businesses seeking to enhance their financial efficiency and competitiveness.

Figure 24: Conceptual Representation of Industrial cost saving

1.9.3 Sustainability and CSR: Enhancing Industry Reputation

Moreover, as industries become increasingly conscious of their role in environmental conservation, SAKOON stands out as a tool that aligns with their corporate social responsibility (CSR) goals. By facilitating a reduction in energy usage, industries can significantly lower their carbon emissions, contributing positively to the global fight against climate change. The adoption of SAKOON can therefore enhance a company's reputation as a responsible, environmentally conscious entity, a trait increasingly valued by consumers, investors, and stakeholders.

1.9.4 Anticipating the Future: The Role of SAKOON

Looking ahead, the relevance and importance of SAKOON in the industrial landscape are only set to grow. As energy costs continue to rise and global sustainability goals become ever more stringent, the need for effective energy management systems like SAKOON will be paramount. In addition, as industries increasingly turn to digitalization and automation, SAKOON's compatibility with IoT and other digital technologies makes it a vital part of this futuristic industrial landscape.

Figure 25: Industry 4.O

In essence, SAKOON is not just a response to the current energy challenges facing industries; it is a strategic tool for industries to prepare for and shape their future.

1.10 SAKOON Contribution for United Nation's SDGs

SAKOON's innovative energy management system offers valuable contributions to multiple United Nations Sustainable Development Goals (SDGs). It aligns with these global objectives by driving sustainable change and promoting responsible energy usage, ultimately fostering a more sustainable future.

1.10.1 SDG 9: Industry, Innovation, and Infrastructure

As an innovative solution in the energy sector, SAKOON reinforces SDG 9 by leveraging technology for sustainability. It optimizes energy usage in industrial operations, contributing to sustainable and resilient infrastructures.

Figure 26: Industry, Innovation, and Infrastructure – SDG 9

1.10.2 SDG 11: Sustainable Cities and Communities

SAKOON supports SDG 11 by encouraging sustainable energy practices within households, contributing to the creation of sustainable and resilient communities. It aids in the development of 'smart cities' that manage resources efficiently.

Figure 27: Sustainable Cities and Communities – SDG 11

Overall, SAKOON's energy management solution not only enhances energy efficiency but also strongly aligns with the global sustainability goals set by the United Nations. By promoting responsible energy consumption and contributing to the development of sustainable communities, SAKOON helps shape a more sustainable and resilient future.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a thorough review of the relevant literature related to power metering systems is provided. The review addresses key areas such as hardware/component selection, circuit design for voltage and current measurement, application development, calculation and estimation of usage and cost, as well as remote monitoring of electrical appliances.

2.2 Hardware/Component Selection

In a study conducted by Barman et al. (2018)[1], they introduced an IoT-based smart energy meter that measures and controls energy consumption using ESP 8266, a Wi-Fi module. The energy data collected by this meter is then uploaded to a cloud platform for easy accessibility by consumers and producers. This approach exemplifies the possibilities of incorporating IoT technology into power metering systems, which aligns with the aims of the SAKOON system.

2.3 Circuit Design for Voltage and Current Measurement

Preethi and Harish (2016)[2] highlighted the design and implementation of a Smart Energy Meter (SEM) to address the issue of power theft. They underscored the role of the SEM in conserving energy resources by mitigating power theft, especially in countries like India where it is a prominent issue. Their work provides valuable insights into circuit design for measuring voltage and current.

2.4 Blynk App Development

"IoT Based Electricity Energy Meter using ESP32 & Blynk" is an application that displays Voltage, Current, Power, and total unit consumed in kWh on the Blynk Application Dashboard. This provides an example of how user-friendly and real-time data visualization can be achieved on a mobile application.

2.5 Calculation and Estimation of Usage and Cost

A study by Rauf et al. (2016)[3] highlights the importance of enabling end users to understand the major characteristics of their energy consumption during peak and off-peak hours. This understanding can help utilities maintain load demand in extreme conditions, leading to a more reliable system with improved overall efficiency.

2.6 Remote Monitoring of Electrical Appliances

In a paper by Tedla et al. (2021)[4], they present an interoperable automation system that leverages IoT technology for remote control and monitoring of electrical appliances connected to the power supply system. Transducers within the socket outlets collect critical information regarding the status of the electrical network.

2.7 Detail Review

2.7.1 IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid

The modern world revolves around electricity, an energy source that powers the engines of our civilization. Its importance is beyond argument, central to industrial and economic development, shaping our societies, and defining our lifestyles. The demand for electrical power is ubiquitous across households, industries, institutions, and public facilities. However, the current systems for power distribution in numerous countries have far from optimal configurations.

These setups involve service lines that are directly connected to consumer meters without a comprehensive and sophisticated system for load management. The consequences of these flawed systems are manifold and severe. For instance, they contribute to substantial line losses that stem from outdated transmission and distribution networks, leading to significant energy wastage. Additionally, they result in a lack of consumer control and awareness regarding power demand and energy consumption.

Traditional metering systems that are predominantly in use pose significant limitations. Notably, these systems lack the capability for internal power quality measurement. Such a deficiency leads to severe problems, mainly when dealing with power factor issues. Supply companies often cannot respond promptly to these issues due to the meter's inability to provide real-time data, resulting in delayed reactions, often spanning a month-long period. These issues become even more problematic at the consumer end, especially in domestic sectors. In these contexts, systems for measuring power factors or quality levels are virtually non-existent, furthering the gaps in inefficient energy usage and management.

One of the most severe implications of these shortcomings in power management systems is power theft, a prevalent issue that significantly undermines the efficiency of energy distribution. It is an illicit action that brings enormous losses in terms of revenue for power companies and the broader economy. Power theft is rampant in regions where open-wire connections are standard. Given the constraints of existing metering systems, effectively addressing this problem becomes a significant challenge. As such, there is an urgent need for comprehensive measures to mitigate power theft, thereby reducing its adverse impact on economies and making power distribution systems more robust and secure.

In recent years, home automation has begun to challenge conventional energy management and usage modes. This relatively new concept has been receiving significant attention in the engineering field. The objective of this innovative system is to allow users to monitor and control home appliances remotely via the Internet. Although promising and already offering certain conveniences, this technology does not fully address the need for effective load management systems and real-time power quality measurements. To address these pressing concerns, this research proposes a solution in the form of an IoT-based energy meter. This innovative device seeks to overcome the limitations of conventional meters. The intelligent metering kit proposed here is designed to aid traditional single-phase energy meters. It calculates power values by measuring the load side's voltage, current, and power factor. The calculated power values are then uploaded to an online database. This digital integration significantly improves the accessibility of power usage data for consumers, allowing them to understand better and manage their energy consumption.

A dedicated Android-based application has been developed for end-user control. This application provides a user-friendly platform for consumers to observe resultant values, remotely switch loads, and pay electricity bills. It thus offers more than just convenience; it empowers consumers by granting them more control over their energy usage and bills. This system also facilitates real-time load and power factor monitoring, which has immense potential for enhancing energy consumption efficiency.

Another key feature of this IoT-based energy meter is its innovative billing method. The system incorporates online banking, further simplifying consumers' ability to manage their electricity expenses. The ability to pay electricity bills through the app reduces the hassle for consumers and minimizes the operational expenses of power companies in terms of meter reading and bill delivery.

This suggested system has wide-ranging and perhaps revolutionary ramifications. It introduces a much-needed improvement to power management systems, representing a substantial step forward from the existing situation. The system could substantially mitigate power theft and optimize energy use by improving consumer control and providing real-time data on power quality. It does not just offer a more efficient way to manage energy usage; it potentially revolutionizes energy distribution and consumption.

However, it raises fresh issues and problems, just like any new technology. To improve the system, evaluate its applicability in various situations, and investigate possible integration techniques with the current infrastructure, further study is required. This study asks fascinating concerns about what the future of power management could entail in the IoT era and offers a roadmap for further research in this field.

In conclusion, the proposed IoT-based energy meter represents an innovative and promising solution for improving power management systems. It addresses many issues in conventional metering systems and introduces new capabilities. The potential of this system is enormous, but realizing this potential will require substantial further work and research. This research provides an exciting starting point for this journey towards more intelligent and efficient power management systems.

2.7.2 Design and implementation of smart energy meter

The literature review in this research paper delves into the design and implementation of a prepaid electricity connection via an intelligent energy meter system. The study explores the potential drawbacks of post-paid electricity connections. It offers an alternative solution: a prepaid system that prompts users to replenish their electricity meters commensurate with the desired electricity usage.

The notion of a prepaid electricity connection isn't new, with several preceding studies tackling similar themes. Notably, Li, X. et al. (2019), in their research titled "Design and Implementation of a Smart Meter and Its Data Transmission System Based on LoRa Technology[5]," underlined the merits of a smart meter system. This subject find resonance in this study. The paper "A Prepaid Energy Meter using GSM" by Arasu, V.T., et al. (2015)[6] examined the application of prepaid meters to discourage wasteful electricity usage extensively.

The main objective is to develop a prototype intelligent energy meter designed to facilitate energy management. The meter is designed to discontinue power supply upon detecting a low or zero balance, a feature intended to foster judicious electricity usage. The energy meter's modus operandi, which involves reading consumption values that are then displayed on an LCD screen along with the current balance, is elucidated in this paper.
Presenting real-time consumption data and balance information aligns with existing literature. For instance, the study by Duquennoy S. et al. (2013) titled "Leveraging IP for IoT: Benefits and Challenges[7]" investigated similar intelligent metering systems and their capacity to provide real-time consumption information to users.

The proposed intelligent energy meter's novelty in this paper lies in its utilization of a digital energy meter that gauge's electricity consumption and transmits pulses proportional to the energy used. An additional feature is an EEPROM memory for balance storage, a crucial function during power outages that prevent data loss.

The paper is organized into two critical parts: hardware and software components. The hardware component involves wiring a keypad, LCD screen, consumption unit, and digital energy meter to the Arduino board. Conversely, the software component includes the coding solutions in the Arduino IDE, a platform lauded for its usefulness in such projects, as Margolis, M. (2011)[8] highlighted in the book "Arduino Cookbook."

The research includes functional block diagrams, mathematical calculations, and physical implementations for the proposed hardware solution. The meter is depicted as generating a frequency of impulses proportional to the consumed power, an efficient way to communicate energy usage to consumers.

Digital energy meters form the core of the hardware solution. These meters produce pulses proportional to the energy consumed, signified by a blinking LED. This mode of operation aligns with the findings of Sharma V. et al. (2018) in the paper "Smart Metering for Next Generation of Sustainable Energy Systems[9]," which detailed the operation of digital energy meters.

The research paper presents a modern approach to managing electricity consumption using an innovative energy metering system that operates on a prepaid basis. The proposed system encourages mindful electricity usage, averting overconsumption and efficiently managing and controlling energy costs.

The paper overviews the intelligent energy metering system's design and implementation, focusing on hardware and software solutions. The system consists of a digital energy meter, an Arduino Uno board, a 16x2 I2C LCD screen, a 4x4 keypad, and a solid-state relay. All are assembled strategically to realize a practical and functional system.

The Arduino Uno board is employed to count and process the digital energy meter's pulses, effectively translating energy consumption into understandable data for the user. Information regarding energy consumption and remaining credit is displayed on the LCD screen, and the keypad allows the user to recharge the system's balance as necessary. The solid-state relay is used for switching the electricity connection based on the balance available in the system.

The paper includes detailed mathematical calculations demonstrating how the system calculates energy consumption. A 1000 imp/kWh pulse rate energy meter is used in the calculations, with a 75-watt bulb connected to the energy meter serving as the load for demonstration purposes. Through these calculations, the research illustrates how the system converts energy consumed into financial cost, informing the user of their spending on electricity.

Regarding software, the paper discusses using the Arduino IDE for pulse detection from the digital meter and consumption calculations. The system employs interruptions to monitor consumption levels and react accordingly when the balance is low. If the system's balance is not recharged in time, the system cuts off the energy supply to the connected unit, preventing overuse. The system also stores balance values in EEPROM to preserve data during power outages.

The research paper outlines an effective and efficient solution for managing electricity usage. The prepaid system, combined with the visual display of consumption and cost, promotes responsible energy usage. The system is well-designed, and its real-time notifications add value by warning users of low balance, giving them time to recharge the system. With the prototype successfully built and tested, the paper is a promising step toward intelligent, cost-effective energy management solutions.

Furthermore, the user-friendly design allows users to recharge their electricity balance and view their consumption details easily. Assembling all components into a single system demonstrates the feasibility of such a system for mass production and usage. The results shown in the paper could have significant implications for consumers and energy providers, providing a practical and innovative solution for energy management.

The literature review discloses that the research paper is a fusion of established notions and novel suggestions regarding prepaid electricity connection and innovative meter systems. It expands upon the concepts of real-time data representation, energy consumption tracking, and prepaid electricity metering while introducing new elements such as EEPROM balance storage. The research stands on the foundation of previous studies while attempting to advance the field of smart energy meters and management.

2.7.3 Domestic Electrical Load Management Using Smart Grid

The ongoing technological revolution in the energy sector, characterized by the evolution of Smart Grid technologies, offers significant boundless opportunities to enhance energy efficiency and reliability. These progressive solutions, aimed at modernizing conventional power grids, employ sophisticated components, including real-time sensor technology for power flow adaptation, Phase Measurement Units (PMUs), and Phasor Data Concentrators (PDCs). By leveraging these advanced tools, grid capacity, and productivity are substantially enhanced, with resilience fortified through improved phase or power flow measurement capabilities.

In the complex web of a Smart Grid system, interconnected transmission components such as load stations and substations are vital players. Their interconnectedness, reinforced by Smart Grid tools, including intelligent sensors, PMUs, and robust communication components, significantly heightens system reliability and power quality. However, more than these hardware enhancements are needed to harness a Smart Grid's potential fully. Instead, it requires complementing hardware infrastructure with innovative Information and Communication Technologies (ICTs), such as tailored protocols and advanced wireless networks. The creation of a communication link between customers and utilities is made possible by integrating ICTs into the grid ecosystem, enabling prompt and effective bi-directional communication.

This strategy not only keeps the lines of communication open between the parties but also gives customers and utilities the capacity to make data-driven choices about energy supply and usage. One practical manifestation of this bidirectional communication is the widespread adoption of smart energy meters. These devices offer a compelling illustration of how Smart Grid technologies have begun to transform the energy landscape. Providing two-way communication that monitors power flow in real time, smart meters give consumers unprecedented control over their energy use. In instances of local distribution generation, smart meters can even guide excess power back into the national grid. This unique feature presents a win-win scenario, benefiting energy suppliers and users by ensuring the most efficient use of available power. With the increasing prevalence of smart meters, it's hard to overlook the role of Advanced Metering Infrastructure (AMI) in driving this technological shift. AMI presents a quantum leap over older systems such as Advanced Meter Reading (AMR), offering capabilities that extend beyond basic consumption tracking. Features such as automatic billing, intricate data logging, and various user-friendly incentives make AMI a linchpin in pursuing an energy-efficient future.

In parallel with the progress on the consumption side, Smart Grid technologies are also making strides in the way we manage renewable energy sources. Consider the example of solar PV systems. The intermittent nature of these sources necessitates using intelligent storage solutions that seamlessly align supply with demand. Commonly used storage devices include batteries, capacitors, and mechanical flywheels. Despite their somewhat high expense, batteries frequently serve as the preferred choice for extended storage owing to their adaptability and diverse applications. Progress in the durability of battery technology also significantly contributes to reducing the overall system expenses, making batteries an increasingly appealing option for sustaining long-term energy reserves.

To further understand the impact of Smart Grid technologies, we must delve into domestic load management. Here, loads are typically classified into three types: baseline, regular, and burst. Baseline loads encompass applications such as lighting, fans, television, and internet modems, which operate as per necessity and can be utilized at any time. Although persistent, these loads do not constitute a significant part of the total load. Regular loads, on the other hand, comprise refrigeration, cooling, and heating loads. These are more variable, tend to fluctuate with weather conditions and account for roughly 15-20% of the total domestic load.

Lastly, busted loads, which are anticipated to operate for specific periods, such as during cooking, heating, washing, drying, ironing, and cleaning. To improve energy efficiency, it's essential to prioritize managing baseline loads for seamless system operation and employ energy-efficient devices for the regular load. Implementing these strategies can increase the system efficiency, saving an estimated 10-30% of total domestic electrical power. One of the key strategies to achieve such efficiency is integrating diverse ICT techniques with demand-side load management techniques. While most people traditionally focus on the generation side, demand-side energy efficiency offers immense potential. However, it requires considerable effort and innovation to fully harness this potential and make the energy system more reliable and efficient.

Reducing the existing load through energy-efficient alternatives can significantly decrease the problem of load shedding faced by countries like Pakistan. Utilities can help increase grid efficiency by focusing on demand-side management, even though they do not directly control the consumer load. Such management involves monitoring, planning, and implementing various techniques to ensure the smooth operation of the system.

With the strategic implementation of these demand-side management strategies, researchers estimate that CO_2 emissions equivalent to those from 16 million cars could be mitigated if the power grid becomes at least 10% more efficient than the existing system. These estimates underscore the environmental significance of these efforts, pointing towards a sustainable energy future.

In conclusion, the transition to Smart Grid, effective load management strategies, and comprehensive ICT integration hold immense promise. This progression paves the way for an era of unparalleled energy reliability, sustainability, and efficiency, emphasizing technological innovation's transformative role in shaping our energy future. As we continually refine and advance these technologies, we incrementally approach this envisioned future of enhanced sustainability and efficiency in energy utilization.

2.7.4 Development of an Internet of Things based Electrical Load Management System

The research article[10] outlines a novel strategy for overcoming the difficulties of contemporary power supply systems. The authors' solution advanced the development of intelligent home systems, which allow remote control and monitoring of electrical appliances utilizing Internet of Things (IoT) technology. The investigation's key findings should be analyzed and condensed in this review.

Understanding the conditions of this investigation's execution is crucial to appreciating its significance. The World Energy Council predicts that in 2040 the power demand will significantly increase. This is mainly due to industries like heating, manufacturing, and transportation shifting towards electricity as their primary energy source. Over a century old, current power supply system’s lack transparency and transparent information about appliance energy consumption. Moreover, present remote appliance monitoring and control technologies are often too complex or unaffordable for many consumers. These challenges necessitate an innovative and practical solution, which is precisely what the authors propose.

The IoT-based automation system proposed in the paper capitalizes on the transformative potential of IoT technology to provide controllability, interconnectedness, and reliability. It integrates several elements, including transducers, NodeMCU microcontroller, Wi-Fi transceivers, Raspberry Pi, RFID tags, and an HD night vision camera, to gather essential data about the operation and status of electrical appliances. This data encompasses AC consumption, appliance status, and RFID tag information, offering a comprehensive overview of the system's operations.

The system's brain is the NodeMCU microcontroller, which has an integrated Wi-Fi transceiver. Data from each socket outlet is processed and sent to the Raspberry Pi computer via the central processing units microcontroller. This information and a live video feed from an integrated HD night vision camera enable the power supply system to be observed in real-time.

Each socket outlet in the system has an RC522 RFID module, a non-intrusive current sensor, and a solid-state relay. The RFID module recognizes tagged appliances and communicates their connection status to the microcontroller. Each RFID transponder assigned to an appliance carries a unique alphanumeric code, which aids in identification.

The proposed automation system excels in identifying various power quality issues frequently encountered in electrical networks. By offering a clear view of daily electrical energy usage, it encourages consumers to adopt more efficient energy consumption habits, thereby contributing to energy conservation.

The researchers' meticulous attention to detail extends to calibrating the sensors integrated within the IoT system. Before their integration, the sensors are calibrated using active loads with differing ratings. A digital multimeter (DMM) measures the load's actual current and voltage consumption. At the same time, the Root Mean Square (RMS) value of the sensor's output is calculated and recorded for each load. A subsequent statistical analysis generates a trendline equation of the sensor readings, which aids in developing a C++ function that allows the NodeMCU to convert sensor readings into amperes accurately.

Next, the authors delve into the design of the communication infrastructure. The OSI network model provides the foundation for a data transmission system capable of accommodating the complex requirements of an IoT automation system. The authors analyze and compare a range of wireless protocols, assessing their frequency, data transmission rate, range, power consumption, openness/decency, and module cost.

The authors chose Wi-Fi for the system due to its high data rates, small coverage area, and less complex integration, given the built-in Wi-Fi transceivers in the NodeMCU and the Raspberry Pi. This decision reflects careful consideration of the technical specifications and compatibility with existing system components.

Furthermore, the authors discuss the selection of a suitable application layer protocol for the OSI network model, a critical component responsible for identifying communication partners, resource availability determination, and communication synchronization. The authors consider several messaging protocols crafted specifically for IoT systems, including CoAP, XMPP, MQTT, AMQP, and DDS protocols.

The MQTT protocol was chosen for its suitability in handling sizeable wireless sensor networks managed by a single server. Based on the Publish/Subscribe model, the MQTT architecture involves three elements: the Publisher, Broker, and Subscriber. The broker implemented in the proposed system is MOSQUITTO, a lightweight and open-source message broker that uses the MQTT protocol.

The depth and breadth of the authors' research are highlighted in this section, emphasizing their careful selection and implementation of the communication infrastructure in the automation system. This thoughtful approach, along with its intricate system of interconnected components, enhances the reliability and efficiency of its IoT system.

In conclusion, the interoperable automation system leveraging IoT for remote control and monitoring presents a strong case for modernizing power supply systems. It offers a comprehensive, affordable solution for remote appliance management and promotes energy conservation, thereby addressing many current challenges in power supply systems. Future research should optimize this system for various scenarios and enhance its energy efficiency and user-friendliness. The presented paper thus constitutes a significant contribution to IoT and power supply systems, offering an innovative solution to revolutionize how we monitor and control our electrical appliances.

2.7.5 Multi-Agent Systems for Resource Allocation and Scheduling in a Smart Grid

From the beginning of humanity, energy has been a fundamental need, especially in modern society. This paper[11] highlight the pivotal transition from pollutant-laden, non-renewable fossil fuels to purer, renewable energy alternatives is not just an environmentally conscious choice but a vital necessity for the well-being of our planet. Given the challenges of climate change and unsustainable energy usage, a clear and robust global initiative is unfolding toward more environmentally friendly energy options.

The accelerating pace of energy consumption further compounds this urgency. With expanding economies and exponential technological advancements, the global thirst for energy intensifies. It's a complex predicament; juxtaposed with the environmental threats posed by our energy sources, our need for energy to drive progress makes it critical for us to explore renewable energy options and devise inventive strategies for efficient and sustainable energy utilization.

Traditionally, high-capacity systems depend on the Supervisory Control and Data Acquisition (SCADA) system. The SCADA system, a centralized platform, was pivotal for making intelligent decisions in the energy sector. However, the centralized nature of SCADA systems meant that many computational and decision-making responsibilities were placed on the central processor. This often led to inefficiencies, especially when the system processed vast real-time data.

The limitations of the SCADA system paved the way for the emergence of Distributed Control Systems (DCS). Instead of relying on a single centralized system, DCS distributed the responsibilities among smaller controllers. Such a setup proved to be versatile, more reliable, and more secure. From an economic standpoint, DCS became a cost-effective alternative to traditional centralized systems. This innovative approach to energy management provided the foundation for the evolution of "Smart Grids (SGs)."

Smart Grids are a testament to technological advancement in the energy sector. These grids are not just systems for energy distribution; they are comprehensive platforms that leverage advanced sensing, superior control mechanisms, and state-of-the-art communication technologies. The shift from conventional to intelligent grids marks a substantial paradigm shift in the energy industry. Unlike their predecessors, intelligent grids emphasize real-time monitoring, foster continuous dialogue between energy providers and consumers, and, most importantly, prioritize using renewable energy sources.

The energy landscape of SGs is diverse, harnessing power from the sun, wind, and underground heat. The beauty of smart grids is their ability to tap into multiple energy sources, offering unparalleled reliability. Moreover, decentralizing power systems, a defining feature of SGs, has democratized energy generation. Today, consumers are not just passive recipients of energy; they can generate their energy and feed the excess back into the grid. However, the journey of intelligent grids is full of challenges. The fact that SGs largely depend on consumers for investment in energy-generation infrastructure has been a topic of debate and criticism.

Enter Multi-Agent Systems (MAS). These systems, defined by their autonomous intelligent agents, can collaboratively solve complex problems, offering a novel solution to the challenges faced by smart grids. MAS has demonstrated immense potential in streamlining power system operations. Their versatility is evident from their wide range of applications, from power market modeling to network protection and troubleshooting.

Integrating MAS into smart grids has catalyzed the development of sophisticated tools like Intelligent Energy Electronic Devices (IEDs), which are crucial in managing power flow and ensuring optimal equipment functioning. MAS's real-time energy management capabilities ensure that energy grids remain secure and that faults are handled efficiently. Their applications also permeate realms like energy scheduling, pricing, and marketing. Recent innovations have also highlighted the potential role of MAS in seamlessly integrating SGs with electric vehicles and building energy systems.

However, as with any transformative technology, the broader implementation of MAS is fraught with challenges. The coordination between various agents in a MAS, ensuring the security of these systems, and equitable distribution of tasks are hurdling that researchers and engineers are striving to overcome. These challenges are not just technological; they intertwine with regulatory, environmental, and economic considerations that redefine SG technology.

One can only discuss modern energy management using home power generation systems. In the wake of significant power outages, these decentralized energy generation units have emerged as more than alternatives; they are becoming mainstays that supplement the existing power infrastructure. Such advancements underscore the need for intelligent management systems that ensure energy efficiency, optimize demand profiles, prevent energy losses, and are cost-effective. Integrating machine learning and artificial intelligence into these systems will further empower them to troubleshoot, diagnose, and rectify network issues.

In conclusion, the fusion of MAS with smart grids signifies a promising future in energy management. The path is riddled with challenges, but the potential of MAS in revolutionizing how we produce, distribute, and consume energy is enormous. As global communities collectively work toward a sustainable future, MAS stands at the forefront, ready to reshape the energy landscape. This comprehensive exploration underlines the importance of ongoing research aimed at surmounting the challenges faced by MAS. Overcoming these challenges is not just about optimizing the performance of MAS in intelligent grids; it is about fully unlocking their potential to redefine energy management for a sustainable tomorrow.

2.7.6 Integrating Smart Energy Management System with Internet of Things and Cloud Computing for Efficient Demand Side Management in Smart Grids

This paper[12] highlight the emerging challenges of high energy demand and increased energy costs necessitate intelligent strategies for tracking, controlling, and conserving energy. Demand-side management emerges as a crucial strategy in averting significant supply disruptions and enhancing energy efficiency. This perspective is reinforced by Palensky and Dietrich's study, which underlines the crucial role of demand-side management in energy conservation. The study implies that with the proper implementation of demand-side management, energy efficiency can be substantially improved while avoiding the adverse effects of supply disruptions (Palensky & Dietrich, 2011)[13].

An integral part of demand-side management is an intelligent energy management system that can help cut expenses, fulfill energy requirements, formulate customers' energy consumption patterns, and respond to energy-saving algorithms and directives. Moreover, the Internet of Things (IoT) has shown immense potential in effectively managing energy consumption across various industrial, commercial, and residential sectors. Liang et al. (2019)[14] illuminate the contributions of IoT to energy efficiency in their work. Their emphasis on the significant contribution of IoT to enhancing energy efficiency aligns with the central concepts of this study.

Integrating an energy controller with an IoT middleware module can result in efficient demand-side management. The controller, installed with numerous sensors and actuators, can collect data on energy consumption from each intelligent device. Faria and Vale (2018) provide insights into using energy controllers for optimizing energy consumption, specifically concerning air conditioning systems. They also discuss the role of IoT middleware in collecting and analyzing energy data, which informs the proposed system's architecture.

By focusing on air conditioning systems, which contribute significantly to electricity consumption, particularly in regions like Pakistan, the energy conservation potential of the system is validated. This intelligent combination of the IoT, demand-side management, and innovative energy management systems facilitate real-time monitoring, allows better control over the air conditioning systems, and contributes to cost savings, environmental benefits, and prolonged equipment life. When tested and implemented in four buildings, the proposed system demonstrated substantial energy savings ranging from 15% to 49%, underlining the system's significant benefits.

In conclusion, the reviewed literature offers valuable insights into developing an intelligent energy management system. The integration of demand-side management principles, intelligent energy management systems, IoT applications in energy management, and the incorporation of energy controllers and IoT middleware significantly guide the design and implementation of this project. The continuous review and analysis of literature in this field will further shape the direction and outcomes of this project.

2.7.7 IOT Based Smart Grid Monitoring Using Arduino Controller

The research encapsulates the conversion of load energy consumption readings over the internet, eliminating human involvement in power maintenance. Utilizing the Internet of Things (IoT), allowing the connecting of standard devices makes this feasible. These devices may be monitored and analyzed remotely to bridge the gap between the actual world and computer-based systems. The importance of IoT keeps expanding as the market experiences an exponential rise in wireless devices (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014)[15].

The proposed system allows the user to monitor energy consumption in watts through a webpage by providing a channel id for the load. The webpage uses THINGSPEAK analytics to analyze energy usage, which delivers visualization of the energy use metrics. These insights have been further validated by Patel and Patel (2015)[16], who discuss the role of analytics in transforming raw energy data into actionable information.

The system uses an Arduino microcontroller, a testament to its flexibility and robustness, essential for handling real-time energy data (Banzi & Shiloh, 2014)[17]. In this system, the Wi-Fi unit conducts IoT operations by transmitting the energy data of the load to the webpage, which can then be accessed through the device's channel id. This mechanism demonstrates the utility of Wi-Fi communication in real-time energy data transmission, as underscored by Hussein et al. (2017)[18].

The concept of consumer-driven management by providing real-time energy usage data. This way, consumers can make informed decisions and adopt energy-saving practices. Earlier research by Strengers (2013)[19] shows the positive impact of similar initiatives, where consumer awareness of their energy use patterns leads to more efficient usage.

Electricity is increasingly demanded in the contemporary global environment for various uses, including agriculture, industry, home usage, healthcare, etc. The difficulty of managing power maintenance and demand has increased, therefore. Power use must be reduced as much as feasible. The proposed system presents a technical twist to conventional energy meters using IoT technology.

Additionally, it addresses problems like electrical theft, which costs capital. The main goals that may be accomplished for a better system are monitoring, optimizing power use, and decreasing power waste. The suggested system aims to support the effective and sustainable use of energy resources. Capitalizing on IoT technology, it aims to improve the accuracy and efficiency of energy consumption data, reducing power wastage (Pérez-Lombard, Ortiz, & Pout, 2008)[20].

In conclusion, the research literature strongly supports employing IoT and analytics to address energy consumption issues. The use of Arduino microcontrollers, Wi-Fi communication, and real-time energy data analysis, coupled with the principles of consumer-driven management, contribute significantly to optimizing power usage and reducing power wastage. IoT technology in energy meters presents an innovative approach to dealing with increasing power demand and the need for efficient energy consumption.

2.7.8 Optimal Energy Management System of IoT-Enabled Large Building Considering Electric Vehicle Scheduling, Distributed Resources, and Demand Response Schemes

Energy management in large buildings constitutes a complex, multifaceted problem. With sprawling infrastructure and diverse energy demands, these buildings often fall beyond the scope of traditional energy management methods. Consequently, innovative and technology-driven solutions are required to meet these requirements efficiently and sustainably. As such, an integrative system encompassing solar Photovoltaics (PVs), energy storage systems, and electric vehicles is emerging as a significant contender in pursuing more sophisticated methods.

Solar PVs have long been recognized for their benefits, primarily their contribution to a greener environment and cost-effectiveness. In the face of escalating concerns over climate change and the associated need for more sustainable energy solutions, the importance of renewable energy resources like solar PVs cannot be overstated (Hernandez, Bird, & Adler, 2012)[21]. However, their role in large buildings' energy portfolios has gained prominence recently. Solar PVs provide a compelling solution for these buildings as they can be installed on rooftops, utilizing otherwise wasted space. Furthermore, the energy produced can be used directly, reducing the need for transmission and, consequently, energy losses (Alstone, Gershenson, & Kammen, 2015)[22]. Integrating solar PVs in significant buildings' energy systems is becoming an increasingly significant field of research and development as renewable energy technology quickens.

The energy management systems of significant buildings become even more complicated and provide new opportunities when they include energy storage devices and electric cars. Batteries and other energy storage devices enable storing extra energy produced while demand is low for later use. The resilience and efficiency of the energy system are improved by the capacity to balance supply and demand in real-time (Budischak et al., 2013)[23]. Similarly, when connected to the grid, electric vehicles can function as movable energy storage units, providing a flexible resource to aid demand response strategies (Pearre et al., 2011)[24]. However, integrating these elements requires careful management and coordination to maximize their potential benefits.

In this context, the role of demand response (DR) strategies, like real-time pricing (RTP), critical peak pricing (CPP), and time of use (ToU), is pivotal. DR strategies can significantly increase energy efficiency by providing consumers with price incentives to reduce or shift their electricity use during peak periods, thereby aligning demand more closely with supply (Borenstein, Jaske, & Rosenfeld, 2002)[25]. While the potential of these strategies is well established, their dynamic nature and impact on operational costs are often overlooked aspects that deserve further investigation. In the paper under discussion, these dynamic DR schemes have been incorporated into the model, offering a more comprehensive approach to energy management.

To handle the complexity and multifaceted nature of this integrative system, linear programming (LP) has been utilized. As a mathematical method, LP has found extensive use in resource allocation and decision-making problems across various fields, including energy management. It provides a rigorous and systematic approach to optimizing the system, considering its constraints and objectives (Dantzig, 2002)[26]. The proposed system can be accurately modeled and optimized by formulating the energy management problem as a linear program.

The results obtained from the model indicate that the RTP scheme achieves the highest savings (58%) compared to CPP and ToU. This finding aligns with previous research, suggesting that by reflecting the real-time electricity production costs, RTP can encourage more cost-effective and efficient electricity consumption (Borenstein, 2005)[27]. However, this research also brings attention to the dynamic nature of RTP, adding a novel perspective to understanding these strategies.

The suggested solution further highlights the model's efficiency by reducing operating expenses and greenhouse gas (GHG) emissions. Numerous research has confirmed the link between using renewable energy and reducing GHG emissions .The proposed model aligns with this trend by integrating renewable energy resources and adopting DR strategies, further strengthening its potential.

However, achieving the efficient operation of such a complex system requires robust enabling technologies. In this regard, the Internet of Things (IoT) is necessary. With many sensors, actuators, and other storage and protective components, IoT brings intelligence and interactivity to the energy management system. It provides end-users with detailed real-time information, empowering them to make more informed decisions regarding their energy consumption (Sisinni, Saifullah, Han, Jennehag, & Gidlund, 2018)[28].

Beyond large buildings, the versatility of IoT extends to various domains, including industries, healthcare centers, and smart cities. The ability to gather, evaluate, and analyze data from multiple devices enables more effective and sustainable energy usage. This data-driven method allows the creation of more specialized and efficient energy-saving programs by offering insightful data on end-user energy usage behavior.

In conclusion, an integrated approach to energy management, encompassing renewable energy sources, dynamic DR strategies, and IoT technologies, offers a promising solution for large buildings. The study's findings show the possibility for lower operating expenses, greenhouse gas emissions, and higher energy efficiency. But this system has some limitations, including the legal issues surrounding the adoption and execution of DR strategies, assembling various technologies, cash, and others. As a result, detailed research is required. Future work should enhance these systems' performance and scalability and evaluate their application and influence in the real world. These interconnected systems will become crucial in helping us meet our energy and environmental objectives as knowledge and technology advance.

Chapter 3

METHDOLOGY

3.1 Research and Planning

The initial stage of this project was an extensive study of the power metering systems currently available on the market, customer requirements, and the capabilities of existing technologies. Current technologies' capabilities, advantages, and disadvantages were assessed, identifying any areas the SAKOON system could enhance.

This necessitated understanding the technical specifications and standards in the power metering industry. The SAKOON system's design and development stages were influenced by the knowledge gained during this stage, which helped to ensure that the SAKOON system would be well-suited to its target audience and capable of addressing identified gaps in the present landscape of energy metering systems.

3.1.1 Market Research

A detailed market study of current energy metering systems was conducted before the design and development process began. The existing technologies, their functionality, user feedback, and pricing structures were analyzed. Focus was given to the features they provide, such as real-time monitoring, device integration capabilities, mobile or online interfaces, and energy-saving techniques.

Figure 28: Energy Meter

Figure 29: Acuvim II

Figure 30: Electricity Management System

Some of the products with their features are listed below:

Table 1: Related Products with their Features

FEATURES	**DEVICES**		
	Energy Meter	***Electricity Management System***	***Acuvim II***
Real Time	Yes	Yes	Yes
Integration with Mobile App/Web Dashboard	The platform is not accessible via a web-based or mobile app.	The platform is currently accessible via a web-based dashboard and mobile application. But will be available when user is on same Wi-Fi.	The platform is currently accessible via a web-based dashboard and does not yet extend to a mobile application.
Load Management Technique	Does not support any suggestion regarding load management	Notify the user for manual load management or automatically shut down everything connected with the device	Help user to analyzing Industrial Dashboard for manual load management,
Cost Estimation	No	No	No

3.1.2 Evaluation of User Needs

Understanding the requirements of potential users was a critical component of the research process. User surveys, interviews, and market trend analyses were all part of this evaluation. The aim was to understand the issues users face with current systems, their expectations, and the additions they would find most beneficial. This process illuminated what an ideal power metering system would need to meet user requirements.

Table 2: User Need Analysis

Method of Evaluation	Key Findings	User Expectations	Beneficial Additions
User Surveys	Users struggle with inaccurate readings in current systems	Users expect real-time accurate readings	A feature to monitor energy usage trends over time
Interviews	Users face difficulty in comprehending complex meter readings	Users expect an easy-to-understand, user-friendly interface	An intuitive dashboard with simplified metrics and visualizations
Market Trend Analysis	Current systems lack efficient energy usage predictions	Users expect predictive analysis for future energy planning	A feature that uses AI to predict future energy consumption based on past trends

3.1.3 Technology Evaluation

A thorough evaluation of the existing technologies was conducted, identifying their advantages, drawbacks, and the level of user demand satisfaction. This included analysis of hardware components such as sensors and microcontrollers, software platforms such as mobile applications and web dashboards, and data analysis tools like real-time monitoring and cost estimation.

The following table gives a technology evaluation:

Table 3: Technology Evaluation

Technology Type	Examples	Advantages	Drawbacks
Hardware Components	Sensors, Microcontrollers	Accurate data collection, automation	Limited processing capabilities, physical wear, and tear
Software Platforms	Mobile Apps, Web Dashboards	User-friendly, remote access	Dependent on device compatibility and internet connection
Data Analysis Tools	Real-time monitoring, Cost estimation	Enables immediate action, financial management	Accuracy dependent on data quality, need constant updates

3.1.4 Analysis of Gaps

After the market research, user needs, and technological evaluations, a gap analysis was carried out to identify opportunities for the SAKOON system. This analysis revealed where existing products fall short in terms of meeting user needs, system functionality, or technical capabilities. The goal of this analysis was to identify unique market niches where SAKOON could provide value. The following gaps are identified after researching products in the market and interacting with users:

Table 4: Gap Analysis

User Needs	Current Market Solutions	Identified Gaps	Potential Value Provided by SAKOON
Real-time energy tracking	Only some systems provide real-time tracking	Inconsistent and not universally available	SAKOON can provide consistent real-time energy tracking
User-friendly interface	Complex interfaces, not user-friendly	Users require easier interaction with the system	SAKOON can provide a simple and intuitive interface
Cost-effective solutions	High-end solutions are expensive	Affordable solutions with high functionality are lacking	SAKOON can offer high functionality at a competitive price

3.1.5 Understanding Technical Standards and Requirements

A comprehensive understanding of technical requirements and industry standards was essential to ensure that the system designed would comply with all relevant regulations and perform safely and effectively. This included an overview of data security policies, national and international standards for power metering systems, and any regulations controlling the use and transmission of energy data.

Table 5: Technical Requirement and Industrial Standard

Technical Requirements and Industry Standards	SAKOON's Compliance
Data Security Policies	SAKOON is designed with robust data protection measures to secure user data
National and International Power Metering Standards	SAKOON complies with all relevant national and international standards for power metering systems

3.2 System Design

Based on the results of the research, the SAKOON system was designed, including its hardware components, software platforms, and data analytics capabilities. This phase involved creating detailed schematics of the hardware interface, outlining software functionality, and defining the techniques that would be used for data analysis.

3.2.1 Hardware Design

The hardware, a key component of the SAKOON system, is mainly comprised of sensors and microcontrollers.

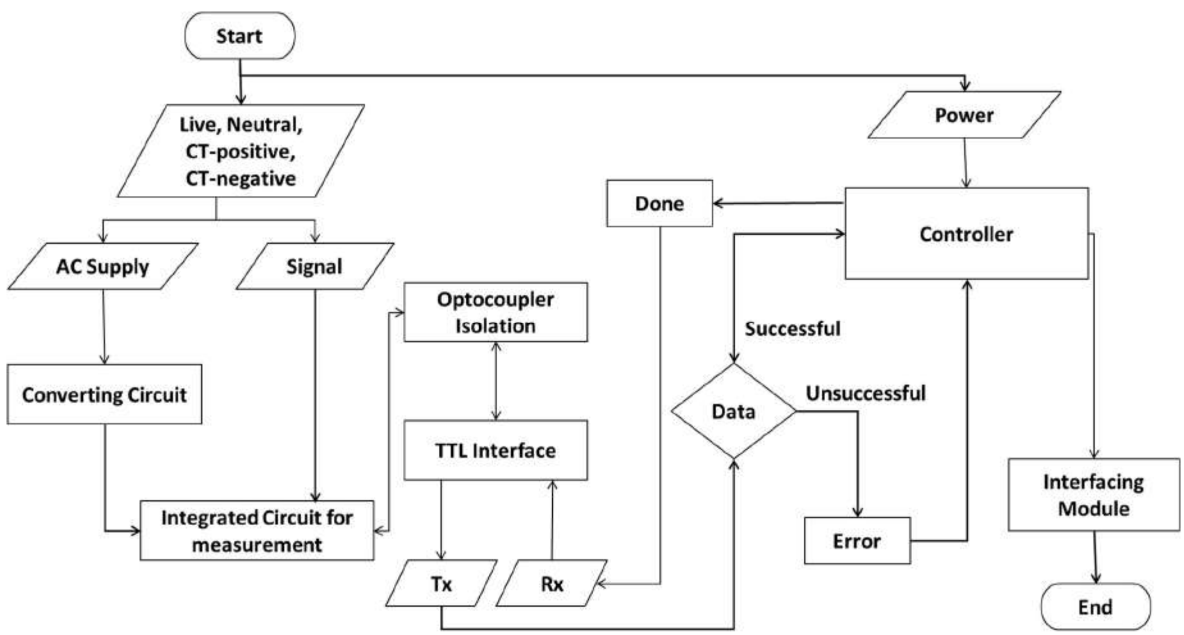


Figure 31: Flowchart for overall working of Hardware

1. **Sensor Design:** The sensors were used to measure important readings like voltage and current with features like precision, dependability, and lower power consumption.

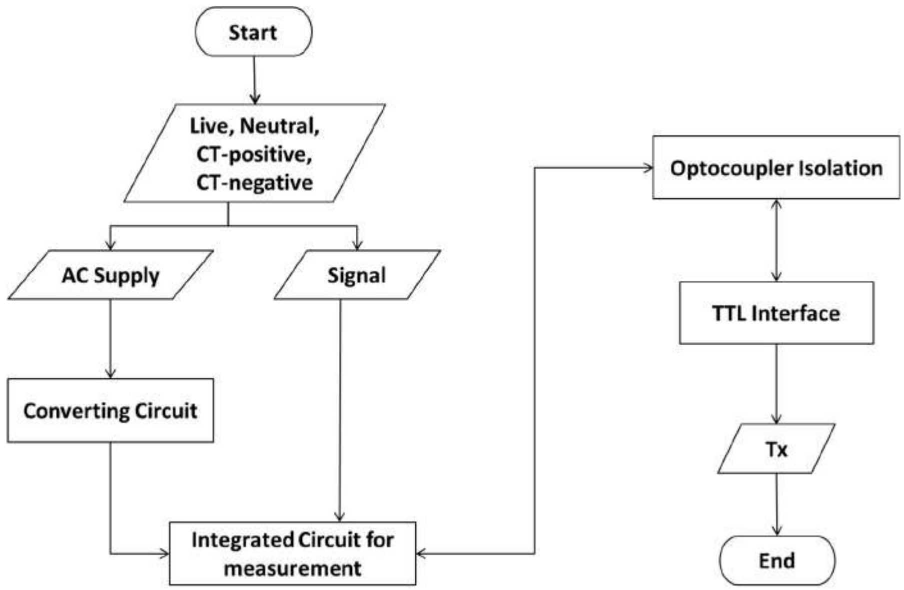


Figure 32: Flowchart foe working of Sensor Module

2. **Microcontroller Design:** The microcontroller analyses the information gathered by the sensors. The microcontroller's design took several factors into account, including processing speed, memory capacity, power requirements, and an effective communication protocol.

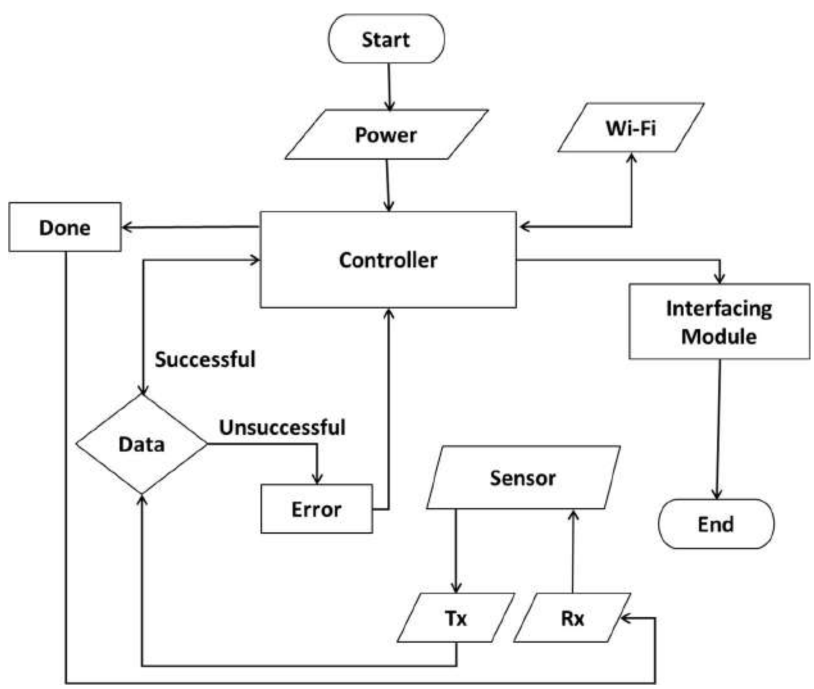


Figure 33:Flowchart for working of Microcontroller.

3.2.2 Software Design

The software platforms of the SAKOON system included a web-based dashboard and a user-friendly mobile app. Both platforms were designed to provide users with real-time access to critical energy statistics in a visually appealing and approachable manner.

Figure 34: Mobile Appliction (In Development Phase)

2. **Web Dashboard Design:** Users can monitor their energy usage from any internet-connected device via the web-based dashboard. Its functionality is like the mobile app's but may include additional features designed for a larger screen, such as in-depth energy reporting and analytics.

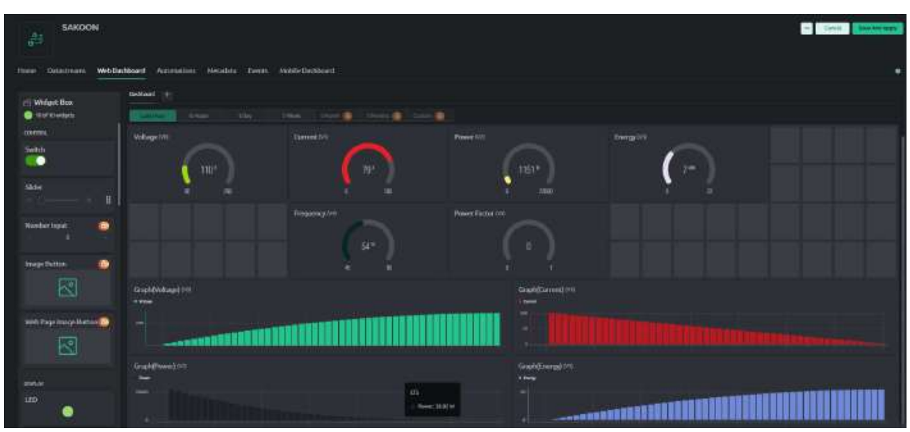


Figure 35: Web Dashboard UI (Under Development)

3.2.3 Design of Data Analytics

The data analytics capabilities of the system were designed to provide users with meaningful insights. This required defining the techniques and algorithms for analyzing the collected energy data, including real-time monitoring, predictive analysis, cost estimation, and formulation of energy-saving measure recommendations. These functions were designed to operate seamlessly and provide valuable insights.

3.2.4 System Architecture

Based on the designs of the hardware components, software platforms, and data analytics capabilities, a detailed system architecture was developed. This architecture provided a comprehensive overview of the SAKOON system's functionality by outlining the interactions between each component and the user.

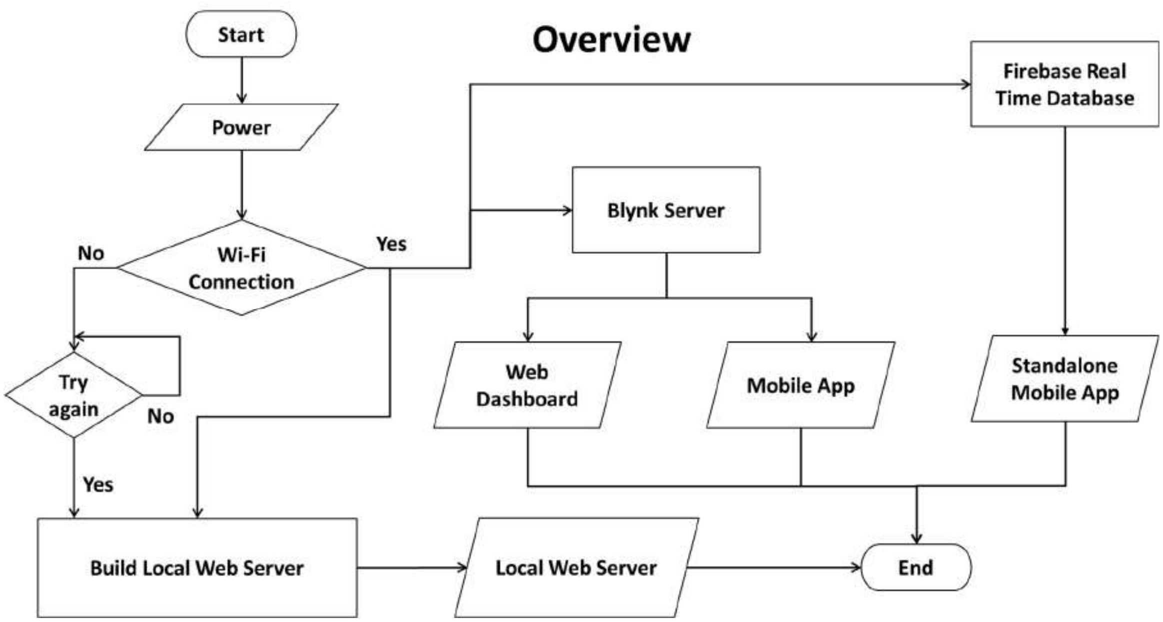


Figure 36:Flowchart overall system working.

3.3 Hardware Development

The assembling of the hardware components marked the beginning of the development phase. A sensor and a microprocessor were included in the hardware for data collection and processing, respectively. These elements were carefully integrated, providing the precise and effective gathering and processing of energy data.

3.3.1 Sensor Unit

One of the earliest phases in the hardware development process was the sensor module's assembly. These sensors were created to precisely monitor a variety of power usage-related characteristics. The sensors were carefully chosen to be strong, dependable, and accurate. To avoid any data errors, their integration into the system was done carefully.

Figure 37: Sensor Module - PZEM 004t

3.3.2 Integration of Microcontrollers

The microprocessor, acting as the system's brain, was integrated after the sensors were put together. The microcontroller's purpose was to quickly and effectively process the data gathered by the sensors so that it was prepared for analysis. The microcontroller was carefully chosen for its function and carefully integrated with the rest of the equipment.

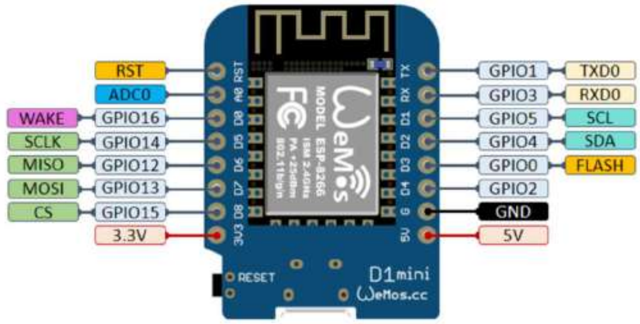


Figure 38: Microcontroller - Wemos D1 mini

3.3.3 Hardware testing

In-depth hardware testing was done once the sensors and microcontroller were put together and integrated. To assure the system's dependability and accuracy in gathering and processing energy data, intensive testing was done. Before going on to the software development phase, any problems or malfunctions discovered during the testing phase were swiftly fixed to guarantee the hardware components functioned as intended.

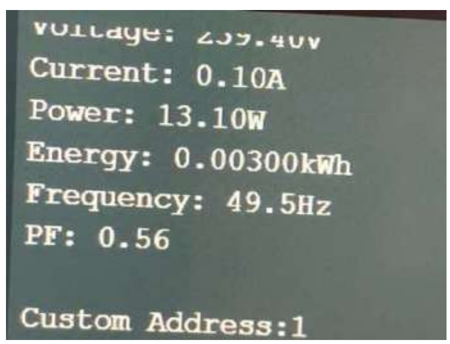


Figure 39: Hardware Testing on Serial Monitor

3.3.4 Final Assembly

The final assembly of the whole system was carried out after the successful conclusion of the testing on each hardware component. For everything to work together, all hardware components had to be integrated. To ensure that the hardware was prepared for the next phase of software development and data processing, the complete system underwent another round of extensive testing after final assembly.

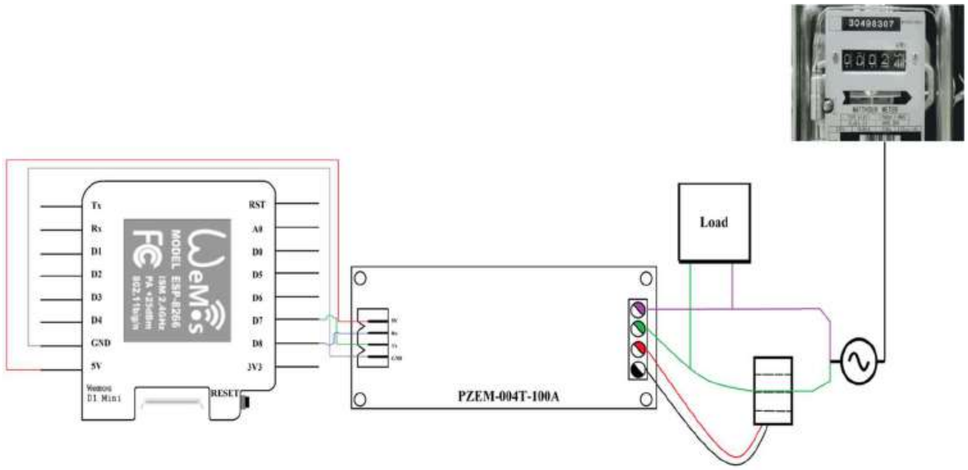


Figure 40: Hardware Final Assembly

3.4 Software Development

After the hardware components had been developed and tested successfully, the software development phase was started. A mobile application and a web-based dashboard were the two main platforms that needed to be designed and developed throughout this project. A cost estimation module was also developed; it was intended to calculate energy costs based on usage and market prices. The software's user-friendliness and data display in an aesthetically pleasing and understandable style were key design considerations.

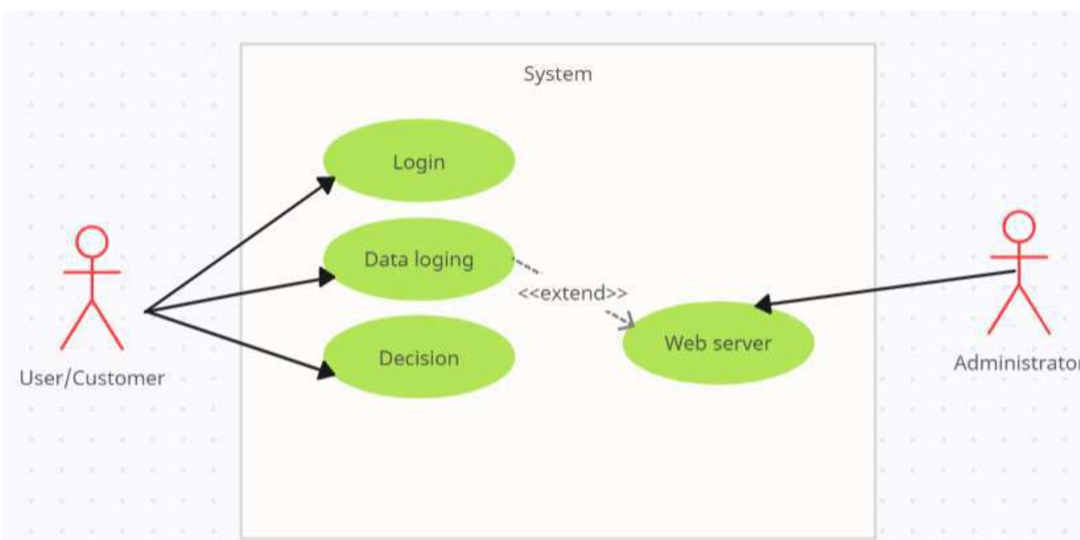


Figure 41: Use Case Diagram

3.4.1 Development of Mobile Applications

Software development includes app development which customers to obtain real-time energy information on their smartphones. It was created to provide customers with interactive GUI, charts, and other visual aids so they could readily comprehend their energy consumption. Before being released, the mobile application underwent extensive testing to verify its usability, performance, and usefulness.

It was decided to use the Agile software development technique. The iterative creation and testing of software in smaller, more manageable portions is a common practice in the field of software engineering, known as agile. This makes it possible for the team to react to modifications and new needs throughout the development process swiftly and efficiently.

Here is a more thorough explanation of the Agile software development process:

3.4.1.1 Adoption of the Agile Methodology

The flexibility, reactivity to change, and customer satisfaction emphasis of the agile approach define it. The development team adopted an iterative method for the SAKOON project, with each iteration including a unique set of tasks.

3.4.1.2 User Story Creation

User story creation was the first step in the Agile development process. These were succinct, straightforward explanations of a feature or function from the viewpoint of the user. The team used user stories to assist them in staying focused on the requirements and experiences of the end user throughout the development process.

3.4.1.3 Iterative Development and Testing

The group broke up the software development process into several iterations, commonly known as sprints. The team determined the user stories and tasks to be accomplished during each sprint at the planning meeting that preceded each sprint. The features were then created by the team and tested throughout that sprint.

3.4.1.4 Adding a Real-Time Database

During the software development phase, a real-time database was incorporated. The online and mobile apps accessed this database to give users the most recent statistics on energy use. It held the data gathered by the hardware in real-time.

3.4.1.5 Networking

A networking component was also a part of the software, which made it easier to move data from the hardware to the software platforms and from those platforms to the database.

3.4.1.6 Continual Criticism and Adjustments

Input from stakeholders (supervisor, co-supervisor, and faculty) and end users was often asked while using the Agile approach. This feedback was used to adjust the program while it was being produced, rather than waiting till the project was finished to make important modifications.

Table 6: Agile Development

Development Stage	Description
Adoption of the Agile Methodology	The Agile methodology was chosen for its flexibility, ability to react quickly to changes, and emphasis on customer satisfaction. This method involves iterative development, with each iteration having a unique set of tasks.
User Story Creation	User stories, simple and concise descriptions of a feature from a user's perspective, were created. These helped to keep the focus on the end-user's requirements and experiences during the development process.
Iterative Development and Testing	The development process was broken down into multiple iterations, or sprints. The user stories and tasks to be completed in each sprint were determined during the preceding planning meeting. The team then developed and tested the features within each sprint.
Addition of a Real-Time Database	A real-time database was integrated during the software development process. The web and mobile applications utilized this database to provide users with up-to-date energy usage statistics. It stored the data collected by the hardware in real time.
Networking	A networking component was included in the software to facilitate the transfer of data from the hardware to the software platforms, and from those platforms to the database.
Continuous Feedback and Adjustments	Throughout the Agile process, feedback from stakeholders (including supervisors and faculty) and end users was frequently sought. This feedback was used to adjust the program during its development, rather than waiting until after its completion.

3.4.2 Creation of Web-Based Dashboards

A web-based dashboard was created concurrently with the mobile application. Users of this platform will be able to check their energy use from any internet-connected device. The dashboard offered visualizations of energy statistics and consumption trends, just as the mobile application did. The style was made to provide a thorough view of energy reporting and analytics that would be appropriate for a bigger screen. To guarantee its faultless functioning, security, and user-friendliness, the dashboard completed several testing phases.

3.4.3 Development of the Cost Estimation Module

The cost computation module was a key component of the SAKOON system. This module was created to make use of the energy data gathered and, using the current energy pricing, to provide users with an estimate of their energy expenses. This module's correctness was crucial; thus, it was carefully created and tested to guarantee its accuracy and dependability.

3.5 Testing and Debugging of Software

To assure the program's dependability, performance, and security, intensive testing and debugging procedures were implemented after the construction of the software components. Before going on to the system integration phase, any found faults or performance problems were swiftly fixed to guarantee the software components worked as intended.

3.5.1 White Box Testing

As part of the software testing process, white box testing—also referred to as transparent box testing or structural testing—was used. This method focused on analyzing the logic and internal structure of the code. White Box testing is applied on certain software components to ensure that the code was working as intended. This included evaluating database interfaces, validating the proper data flow throughout the system, and testing conditional and loop logic.

3.5.2 Black Box Testing

This method did not consider the internal code structure while evaluating the software's functioning. It evaluated if the program complied with the criteria, reacted appropriately to inputs, managed errors, and produced the desired results.

3.5.3 User Interface and Experience Design

The design of the user interface and user experience received considerable consideration throughout the software development process. The platforms were intended to be simple to use and comprehend. User input was valued and utilized to hone and enhance the mobile applications and web-based dashboard's overall user interface and user experience.

3.6 Hardware and software integration

The project steps red the integration phase once each hardware and software development step were finished. This key phase filled the gap between sensor-based data gathering and software platform-based data visualization and analysis.
After completing this phase, the SAKOON system was able to collect real-time data on energy use, analyze it, store it in a real-time database, and show it on the software platforms for in-depth study and intuitive visualization.

3.6.1 Using the Microcontroller to Program

The microcontroller's programming was the main effort at this point. To allow the microcontroller to comprehend sensor outputs, precisely analyze the collected data, and securely communicate it to the authorized software platforms, the team created a new software code.

3.6.2 Establishing a Network Connection

A solid network connection was created to enable the real-time data flow from hardware to software. The team made sure the microcontroller could communicate data reliably using the appropriate networking protocols, enabling the mobile app and online dashboard to provide real-time energy use statistics.

3.6.3 Integrating a Real-Time Database

The system's integration with a real-time database was the project's main objective. The microcontroller-processed data was kept in this database and made available to the software platforms as required. It made sure that both history and current data were accessible to the software platforms, allowing for in-depth data analysis and visualization.

3.6.4 Data Integrity Verification

Rigid testing procedures were implemented to preserve data integrity throughout the data transmission process. These tests made sure that the software platforms correctly represented the sensor- and microcontroller-processed data. To maintain the system's accuracy and dependability, discrepancies found throughout this testing were thoroughly investigated and fixed.

3.6.5 Ensuring a Stable and Reliable Connection

The success of the system depended heavily on the hardware and software components having a strong and dependable connection. To verify the dependability and stability of the data connection, which is essential for real-time data updates on the software platforms, the team put rigorous connectivity standards into place and exhaustively tested the system under various circumstances.

3.6.6 Coordination of Hardware and Software Activities

The synchronization of the activities of the hardware and software components was a crucial component of the integration process. This synchronization made it possible to create schedules for data collection, processing, and visualization that ran without interruption and efficiently.

3.7 Testing and Debugging

After integration, it underwent a thorough testing and debugging process. This phase's goal was to make the system deliver accurate and trustworthy data on energy use and operate as planned. With the ability to provide accurate and practical energy usage statistics to end users, the SAKOON was made robust, dependable, and deployment ready.

3.7.1 System testing

A thorough system testing procedure was performed on the constructed system. This included looking at the system rather than simply its parts. It evaluated the cohesion and performance of the fully integrated system, confirming that the hardware and software parts communicated effectively and consistently carried out their intended functions.

3.7.2 Performance Testing

Performance testing was done to evaluate the SAKOON's effectiveness and dependability under different loads and situations. By doing this, the system was guaranteed to function flawlessly under normal operating conditions as well as under adverse circumstances or excessive loads.

3.7.3 Functional Testing

Functional testing ensured that the system was operating in accordance with the functional specifications. The SAKOON's features and functions were all put to the test to make sure they worked as planned and behaved as predicted.

3.7.4 Testing Network Connectivity

Considering the crucial part that network connection plays in the SAKOON's real-time data transmission. Testing of network connectivity was done. This evaluated the system's real-time data capabilities and assured smooth and continuous data movement between the hardware elements and the software platforms.

3.7.5 Debugging

A crucial step in the testing procedure was the debugging phase. It involves locating, isolating, and fixing any problems that were discovered during the testing phases. If a problem was found, it was initially investigated to ascertain its root cause before a fix was applied. The system was retested after these adjustments to be sure the problem had been entirely fixed.

3.7.6 User Acceptance Testing

The system was tested with actual users in the real-world. To ensure that the system has good UX and meets all the requirements of the end user. Feedback from this testing phase was very helpful in identifying possible areas for development and how the user interacts with the system.

Chapter 4

TECHNICAL CONCEPT AND TOOLS

4.1 Power Electronics

Power electronics deals with the study and design of electronic circuits and systems that convert and control the flow of electrical energy. This branch of electronics revolves around the transformation of electric power into a form that can be conveniently used. The technology utilizes solid-state electronics for the control and conversion of electric power. Power electronics played a pivotal role, primarily implemented through the PZEM sensor module, responsible for measuring energy parameters.

4.1.1 Current and Voltage Measurement

The sensor module uses a combination of a current transformer and a voltage divider circuit for current and voltage measurements.

- **Current Measurement:** The current transformer, an integral part of the sensor module, is used to measure the current. The transformer works on the principle of electromagnetic induction. When primary coil changes its current, a proportional current is induced in the secondary coil, providing a safe and isolated measurement.

Figure 42: Current Transformer - for current measurement

- **Voltage Measurement:** A voltage divider circuit serves to measure voltage. It is made up of two resistors that are series-connected to divide the input voltage (V_{in}) between them. The midpoint voltage (V_{out}), which is a scaled-down representation of the input voltage, is then measured.

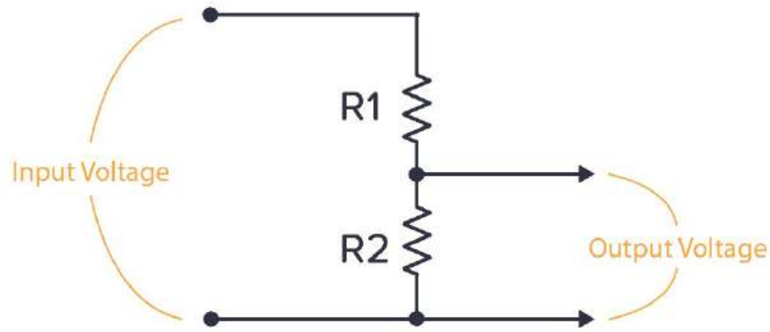


Figure 43: Voltage Divider Circuit

The formulas for current (I) and voltage (V) measurement are as follows:

$$I = N * I_{secondary}$$

$$V_{out} = V_{in} * \frac{R_2}{R_1 + R_2}$$

- ❖ N is the turn ratio of the transformer and R1 and R2 are the resistances in the voltage divider circuit.

4.1.2 Power and Energy Calculation

The power consumption (P) can be calculated using Voltage and Current, mathematically:

$$P = V * I$$

- ❖ Voltage and current together make up power.

Power over time is expressed as the integral of the energy used (E), expressed in kilowatt-hours (kWh), mathematically:

$$E = \int P(t)dt$$

- ❖ where P(t) is the power consumed at time t.

In practical terms, for discrete measurements, energy is commonly approximated as:

$$E_{kw} = \frac{P * t_{hrs}}{1000}$$

- ❖ where P is the power measured.

Using measured and calculated values, the user can keep an eye on energy consumption in real-time, thereby facilitating more effective energy management.

4.2 Internet of Things-IoT

The Internet of Things-IoT is an advanced technology that has woven itself into various aspects of our daily lives. It's like a giant invisible web that connects everything from our daily household items to complex industrial machinery. This network isn't just limited to computers or humans; it even connects animals and other physical objects, allowing them to communicate data seamlessly across this intricate network, all without the need for direct human-to-computer or human-to-human interaction. IoT is crucial to the SAKOON system's overall operation. It was used to connect several devices, principally the energy meter and the microcontroller, into a network. This network of linked devices gathers important information about energy use and then disseminates it online.

The main node in this Internet of Things network is the microcontroller in the SAKOON system. It is linked to the energy meter, which provides real-time data collection and processing on energy use. The web-based dashboard and mobile application get this processed data once it has been sent over the Internet.

By using IoT, SAKOON can offer end users real-time data logging (energy consumption), enabling the users to monitor their consumption and take the necessary actions to manage it more effectively. The system will become even more adaptable and UI friendly because of the openings for future improvements like automation and control over appliances that consume a lot of energy.

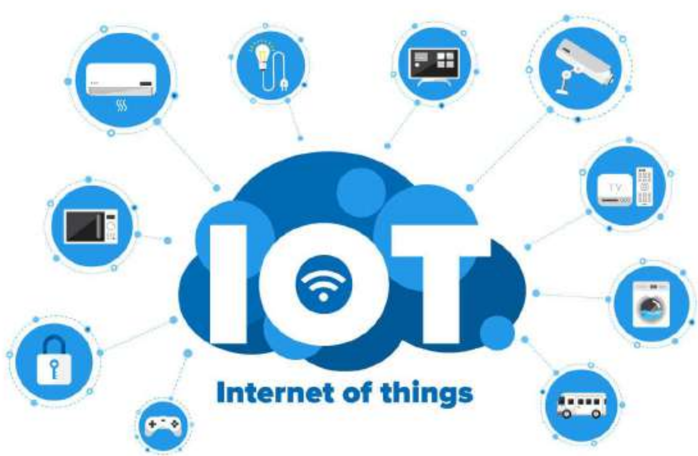


Figure 44: IoT - Internet of Things

4.3 Microcontroller Communication

The SAKOON system relies on TCP/IP and UART protocols for accurate data transmission. TCP/IP serves as the digital postmaster, maintaining a steady internet connection. UART creates a crucial channel for communication between the sensor module and the microcontroller, acting as a translator and encoding/decoding information. The synergistic collaboration between these protocols forms the foundation for the system's seamless functioning.

4.3.1 The Microcontroller's Function and Architecture

The microcontroller serves as the CPU of a smart system, collecting data and performing analysis to make decisions and execute. Wemos D1 mini ESP8266 microcontroller is renowned for its outstanding capabilities and small design, and built-in WIFI that will work with other IoT platforms and devices, particularly in situations where power and space are limited.

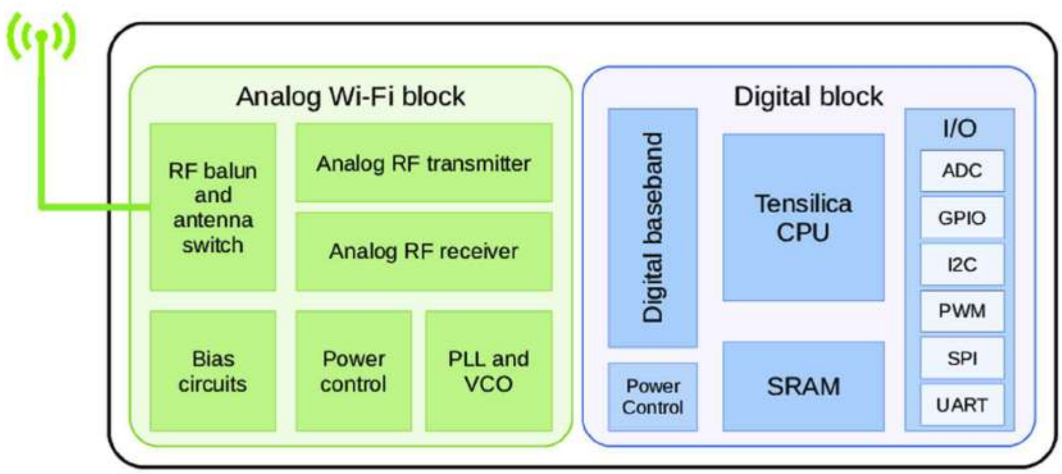


Figure 45: ESP8266 Architecture

Features

- Mini
- Fast
- Portable
- Built in Wi-Fi
- Open-Source Libraries available

4.3.2 TCP/IP Network Stack Integration

The SAKOON operates using the ESP8266 microcontroller's TCP/IP network stack. After establishing a secure communication route through a mobile app and web-based dashboard, the system sends and receives data over the Internet. Each internet-connected device's unique IP address enables precise identification and communication across the complex internet network. Data is divided into packets for internet transmission, with each one being individually routed to the destination IP address. So, in essence, the IP is a key component of the internet's design and the functionality of our IoT-based SAKOON, guaranteeing that data packets arrive at their intended locations accurately and on time.

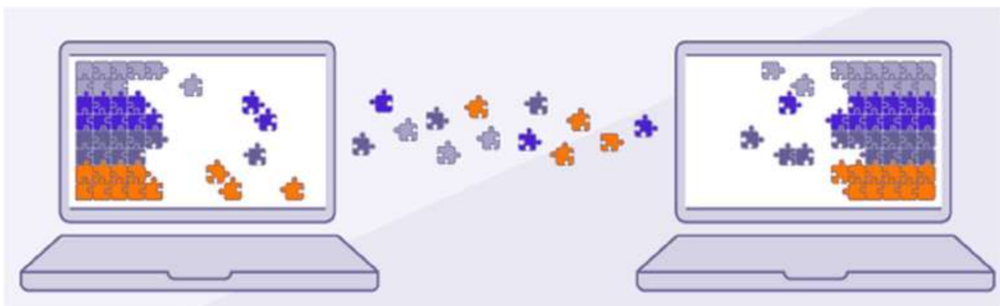


Figure 46: TCP/IP

1. The TCP/IP network stack's integration ensures that the SAKOON system can reliably and accurately communicate over the internet. This is critical to real-time monitoring of energy consumption and real-time control of connected devices, which are central features of the SAKOON system.
2. The postal address system is analogous to the Internet Protocol (IP). It gives each internet-connected device a distinct address (IP address), ensuring that data packets are accurately routed across the intricate internet network. The IP makes sure the data packets arrive at their intended location.

The inclusion of the TCP/IP network stack guarantees the accuracy and dependability of internet communication for the SAKOON system.

4.3.3 UART

Sensors, modems, and other microcontrollers may all be communicated via the Universal Asynchronous Receiver Transmitter (UART) communication protocol. A peripheral interface unit (PIU) is a physical circuit that controls asynchronous serial communication (one bit at a time). The system relies on the UART protocol to make it possible for the ESP8266 microcontroller and the sensor module to communicate with one another. The UART protocol serves as a communication bridge between these two essential system parts, enabling the precise and effective transmission of data.

The following actions are necessary for UART to function:

- ❖ Receiving parallel data from the microcontroller, the transmitting UART device converts it to serial format before sending it. The serial data is received by the receiving UART device, which then transforms it back to parallel format and sends it on to the sensor module.
- ❖ A clock signal is not necessary for this asynchronous serial connection, made possible by the UART protocol, to synchronize the outgoing bits from the broadcasting UART to the arriving bits on the receiving UART. Instead, the baud rate—the pace at which data is sent and received—must be agreed upon by both devices.

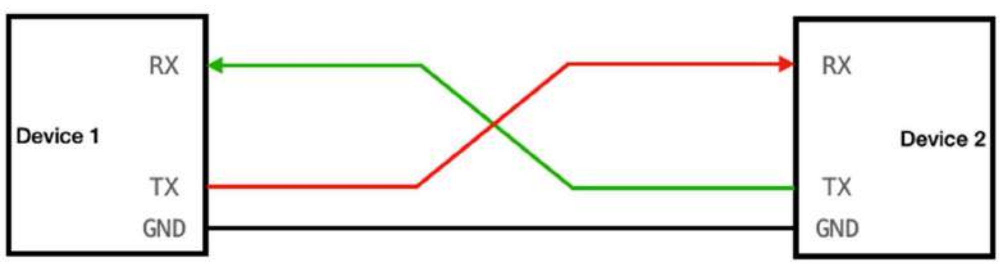


Figure 47:UART Asynchronous Communication

UART plays a crucial role in systems like SAKOON, where precise and real-time energy data collection is essential. The usefulness and dependability of the whole system are considerably improved by UART, which guarantees the accurate and effective bit-by-bit transfer of data through a serial port.

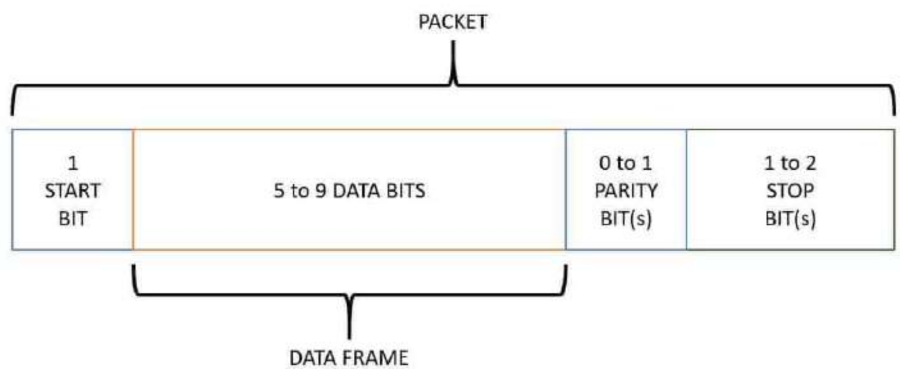


Figure 48: UART Data Packet

4.4 Sensor Module

The sensor module enables precise measurements of energy use and makes it easier to communicate with the microcontroller.

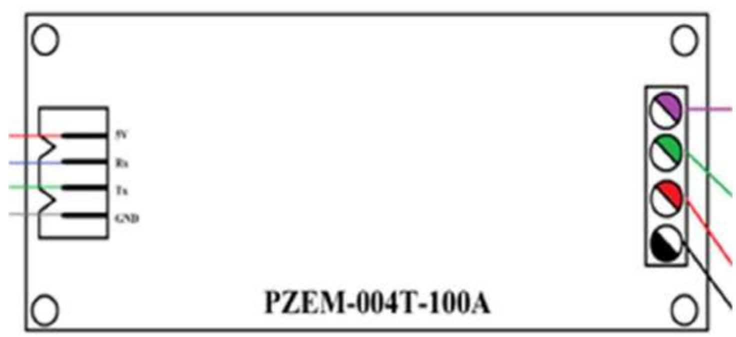


Figure 49: Sensor Module

4.4.1 Measurement of Current and Voltage

The SAKOON makes use of the PZEM sensor module. used to determine how much energy is used by electrical devices that are linked. The current transformer in this sensor module measures the current passing through the circuit. The voltage across the circuit is measured simultaneously using a voltage divider circuit.

4.4.2 Analogue to digital conversion

The values of the current and voltage are analog measurements. These values must be transformed into digital signals for the microcontroller to handle them. An analog-to-digital converter included inside the sensor module makes this conversion easier. The microcontroller can now handle and process these numbers since they have been transformed into digital signals.

4.4.3 Calculation of Power and Energy

The microcontroller may then determine the power by multiplying the current and voltage using the digital data for current and voltage. Additionally, by integrating the power over time, the microcontroller determines the energy usage in kilowatt-hours (kWh).

$$Cost = Energy_{kWh}\ X\ Tariff$$

- ❖ Where tariff is defined by government or electricity supplier

4.4.4 TTL Protocol communication

The TTL (Transistor-Transistor Logic) protocol facilitates communication between the sensor module and the microcontroller. The interaction and information exchange between the sensor module and the microcontroller is made possible by this digital logic protocol, which aids in the efficient running of the system.

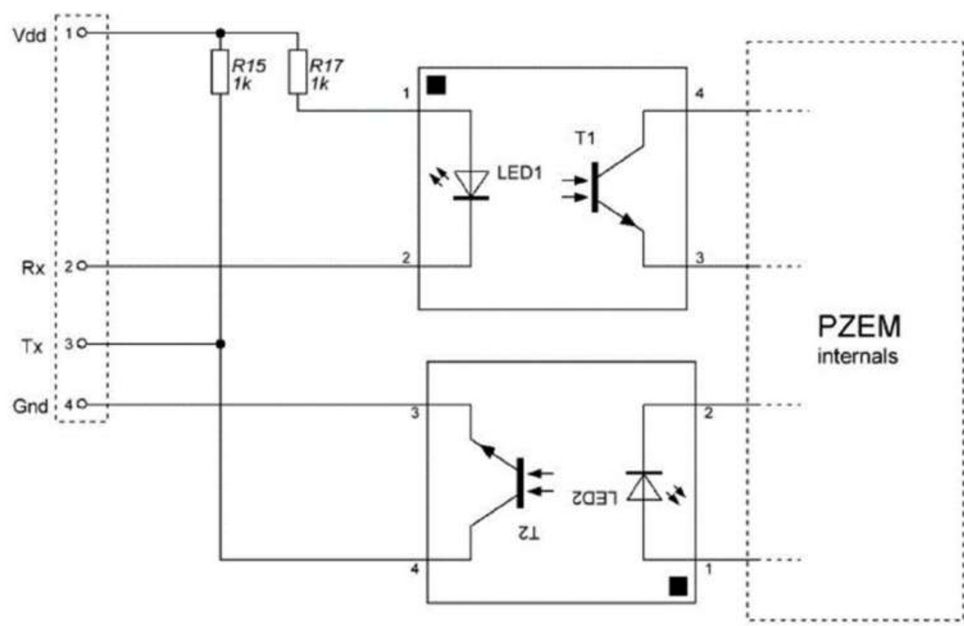


Figure 50: TTL Protocol in PZEM

4.5 App Development

The process of creating computer programs for usage on mobile devices like smartwatches, tablets, and smartphones is referred to as app development. To transfer desktop computer capability to portable devices, mobile applications are created. They provide users services that are comparable to those obtained on PCs.

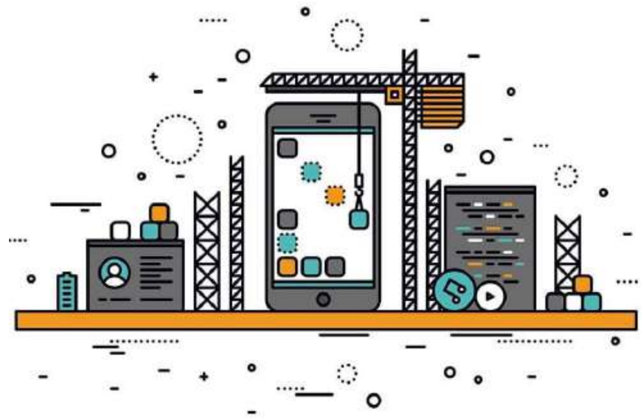


Figure 51: Development of app

4.5.1 Design of App Interface

The app's visual design, which includes the layout, typography, color schemes, buttons, and icons, is involved here. To promote customer happiness and engagement, the interface design must be simple to use, intuitive, and visually appealing.

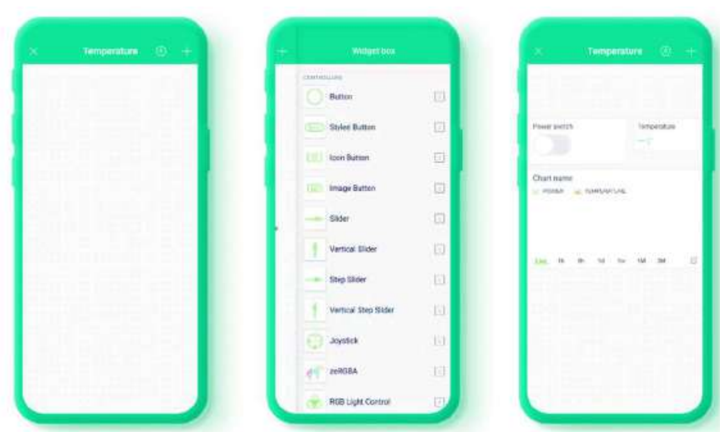


Figure 52: App Interface

4.5.2 Real-time Functionality

Instantaneous results are provided by real-time applications, which analyze and report data as it is generated. With SAKOON, this feature enables customers to keep an eye on their energy use as it occurs.

4.5.3 Support for Multiple Platforms

A bigger audience may be reached by an app if it is compatible with several mobile operating systems like Android and iOS. This entails creating an app that works effortlessly on a variety of platforms and devices via design and code.

Figure 53: Android Platform

Figure 54: IOS Platform

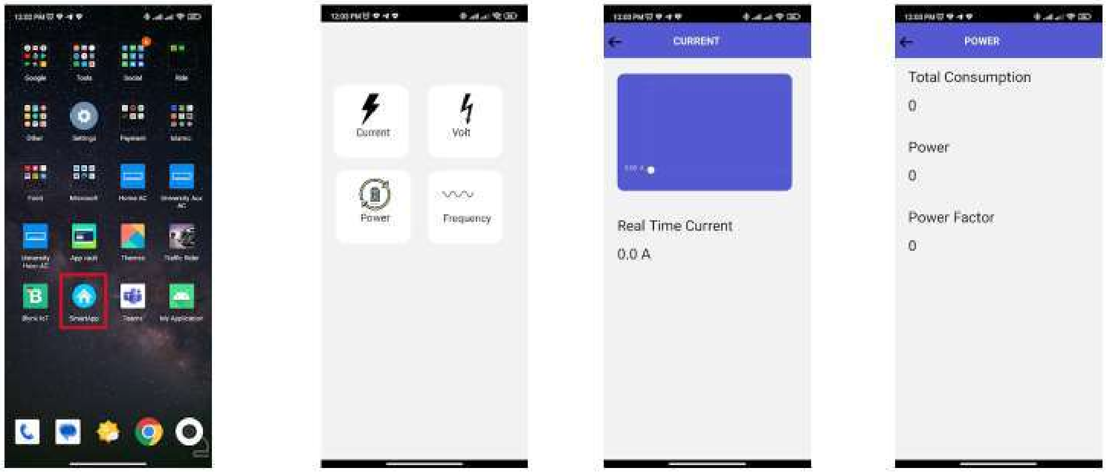


Figure 55: Stand-alone Android App

4.6 Integration with Blynk

A platform called Blynk enables mobile device control of microcontrollers like Arduino and Raspberry Pi. This IoT platform makes it easier to interface these devices with mobile apps and link them to the internet.

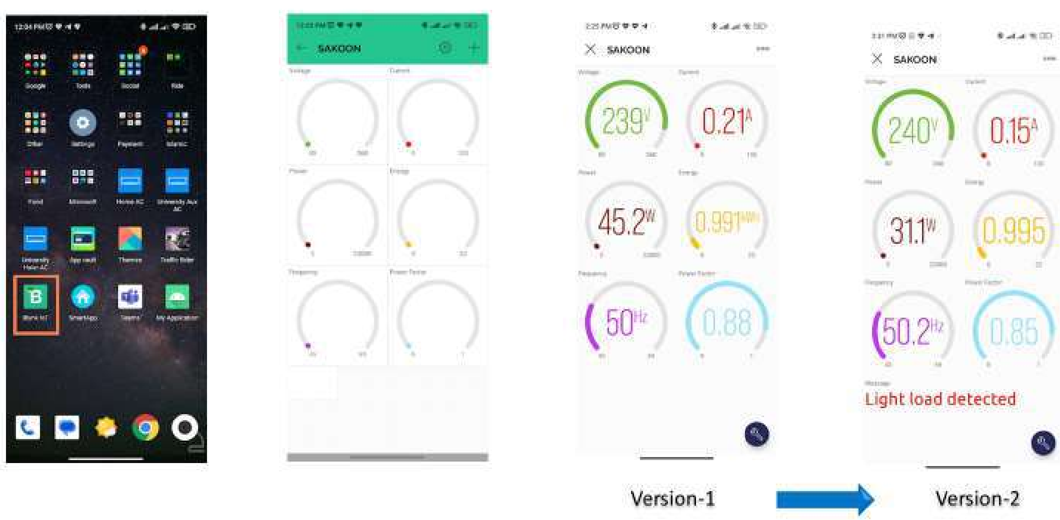


Figure 56: Blynk Integration Android Platform

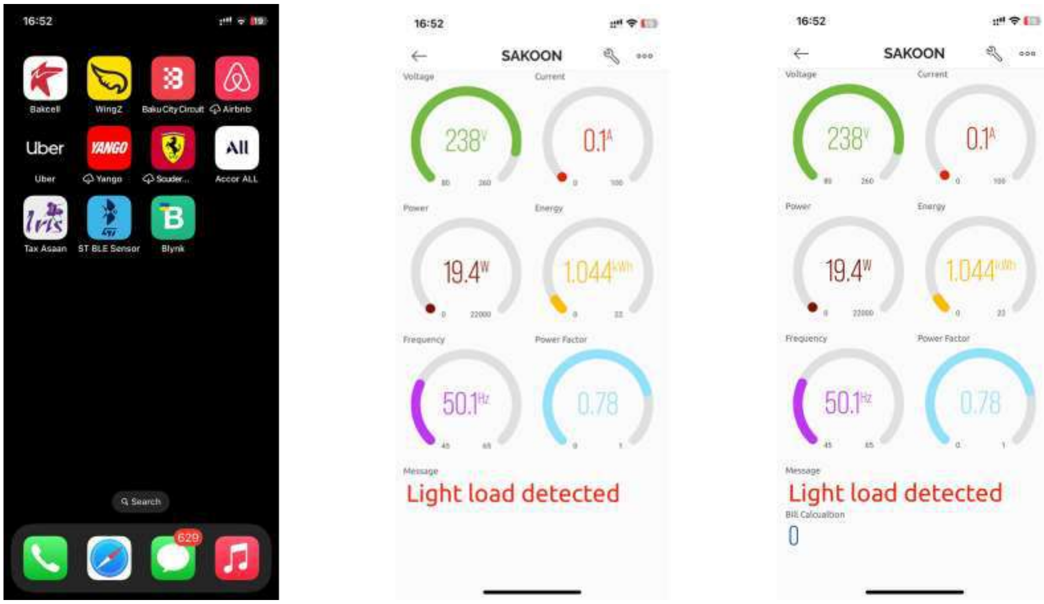


Figure 57: Blynk Integration IOS Platform

4.6.1 Blynk in App Development

To make the integration of IoT capability in mobile applications easier, Blynk offers a collection of tools and APIs. It aids programmers in designing user interfaces, managing hardware, reading sensor data, and writing firmware.

4.6.2 Communication between a microcontroller and Blynk

Blynk offers libraries that provide internet-based communication between the mobile app and the microcontroller. These libraries make ensuring that data transfers go smoothly, making real-time monitoring possible.

4.7 Interfacing with Web Dashboard

The process of building a web-based interface for a dashboard that consumers can use to engage with their data. It is often used for data processing and visualization.

- Data Visualization: Information is graphically represented in data visualization. It offers a simple means of comprehending patterns, outliers, and trends in data.

Figure 58: Data Visualization Industrial Dashboard

- Web-Based Accessibility: Data may be viewed using any internet-connected device and from any location using web-based dashboards, giving customers ease and flexibility.

4.8 Web Server

A web server is a device that stores, manages, and sends users' online page.

Figure 59: Local Web Server

- Serving Web Pages: Providing Web Pages Web servers take care of user requests and provide the correct web pages. They manage the HTTP protocol that is required for the transmission of online pages.
- Serving Real-Time Data: Web servers often deal with real-time data in the IoT setting. Then, they transfer it to the user's device after receiving the data from IoT devices and processing it if required.

Chapter 5

DESIGN AND DEVELOPMENT

Several parts interact to create a working system. The SAKOON is no different; it synthesizes many technologies that successfully manage and monitor energy. One must manage the design and development of a system like SAKOON efficiently to guarantee its efficient operation. Tools, including algorithms, flowcharts, block diagrams, and circuit diagrams, are helpful in this situation. These tools act as the framework, enabling a systematic way to visualize, comprehend, and effectively carry out the complex activities that regulate the system.

The algorithm serves as the cornerstone for every job the system completes. The algorithms choreograph the dance of information flowing continuously throughout the system, from data collecting to data processing and transfer. They establish the guidelines, the operating procedures, and the sequence in which the various duties are carried out. Essentially, algorithms convert the project's goals into directions that the hardware and software can understand and carry out. Algorithms allow a complete and effective execution of the system's operations by providing a step-by-step method, but this is sometimes insufficient, particularly in a complicated system like SAKOON.

One needs a tool to visualize these algorithms, observe the events they order, and understand their effects on the system. In this situation, flowcharts are helpful. They provide a visual depiction of the algorithms, making the algorithm's operating flow obvious. Flowcharts in the SAKOON outline the data acquisition, processing, and transmission processes. They make it possible for efficient deployment by providing a clear roadmap of the many tasks needed.

We now reach circuit diagrams. These schematics serve as the SAKOON's electrical connections' building blocks. They provide the information required for the system's physical realization. The SAKOON's creator depends on circuit schematics to assemble the hardware the way a builder would while constructing a structure. They clearly explain the connections between the electronic parts, such as the sensor, microcontroller, and communication modules. This accurate illustration helps ensure that every component is properly positioned and connected, allowing impeccable assembly.

Algorithms, flowcharts, block diagrams, and circuit diagrams are not simply extras but essential components in creating a system like SAKOON. They provide a systematic approach to comprehending, creating, and putting into practice complicated systems. These tools enable developers to traverse the system's complexity, ensuring that each component performs as intended and the system accomplishes its goals. They also encourage clarity, make troubleshooting more accessible, and provide a solid reference for future improvements or revisions. Therefore, knowledge of and proficiency with these tools is essential for the SAKOON project's success.

However, just comprehending and using algorithms is insufficient.

5.1 Algorithm

At its essence, an algorithm is a step-by-step process used to solve problems or accomplish objectives. Algorithms are a collection of instructions that direct a system's functioning in computer science and electronics. Algorithms in the project might be seen as the master planners, controlling the flow and modification of data to get the intended result—real-time energy monitoring.

For instance, an algorithm is created to specify how the microcontroller should interact with the sensor when to request data, how to interpret the receiving data, and where to properly store it to gather data from the sensor module. When followed, this algorithm's carefully organized set of directives ensures precise and effective data collection.

Similarly, specialized algorithms are created for data processing and transmission via the Internet. These algorithms describe how to transform the sensor's raw data into helpful energy values, format the data for transmission, and transfer the information over the Internet to the Blynk platform and the web server. Each of these algorithms fills a specific jigsaw piece, and when combined, they create the SAKOON system's operational backbone, allowing it to run smoothly and serve its intended purpose.

5.1.1 Algorithm for Connecting the PZEM-004T Sensor Module

1. **Preparation:** Make sure the load's power source is shut off before you do anything else. This ensures security during the connection procedure.

Figure 60: Shutdown Dower Source before starting.

2. **Wiring Live Wire:** Determine the live wire supplied to the load (often red or brown in color). Connect this live wire to the PZEM-004T sensor module's first terminal.

Figure 61: Detection of live wire using tester.

3. **Wiring Neutral Wire:** Next, locate the neutral wire (often blue or black in color). This neutral wire should be connected to the sensor module's second terminal.

Figure 62: Detection of neutral wire using electric detector.

4. **Current Transformer (CT) Connection:** Pass the live wire from step two to CT. Make sure the CT's arrows are pointing in the direction of the load.

Figure 63: Live Wire Through CT connected to Load.

5. **Connect CT to Sensor Module:** Find the two wires from the CT, which are typically red and black. They should be connected to the third and fourth sensor module terminals. The CT is not polarity sensitive. Thus, it doesn't matter which wire connects to which terminal.

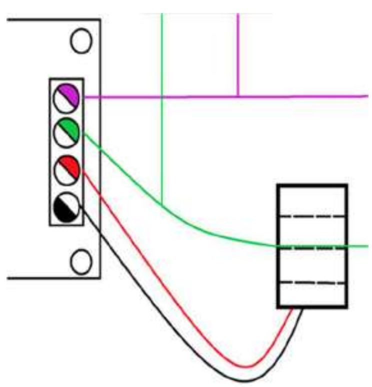


Figure 64: CT Connection with PZEM Schematics

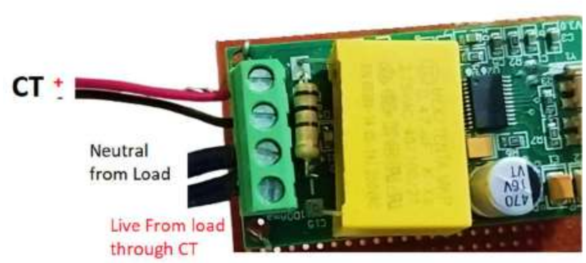


Figure 65: CT Connection with PZEM

6. **Verify Connections Again:** Verify all connections once more before turning on the power. Make sure each connection is safe and that no bare wire is visible.

7. **Powering Up:** Restart the power source. Now that the sensor module is properly attached, it should be able to detect energy use.

Figure 66: Power on the System

Remember: When working with electricity, takfe these precautions:

Even if the algorithm offers a step-by-step tutorial for attaching the PZEM-004T sensor module, it's critical to stress the significance of safety precautions while dealing with electricity. No matter the size of the project, from modest home DIY endeavors to large-scale industrial installations, electricity offers serious risks, such as electrocution, fire, and equipment damage.

The following are important safety measures to follow:

- **Always Disconnect Power:** Before beginning any electrical work, always make sure the power supply is unplugged. The first and most important safety guideline is this one. Disconnecting a gadget completely from the power supply is preferable to just turning it off.

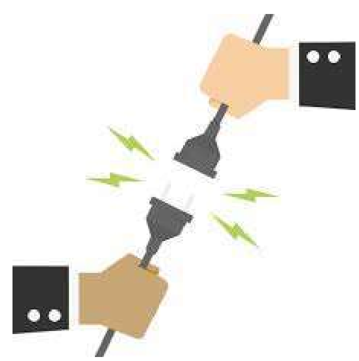


Figure 67: Disconnect Electricity

- **Use Insulated Tools:** Always use insulated handle tools while working with electrical cables. Insulation prevents energy from entering your body via the gadget.

Figure 68: Insulated Tools

- **Protective Gear:** Wear appropriate safety equipment, such as rubber gloves and boots, to lower your chance of receiving an electric shock. Your eyes may be shielded from sparks or debris by wearing safety glasses.

Figure 69: PPE

- **Avoid Water:** Unless you are properly educated, you should never operate on electrical systems or equipment in damp environments. Electric shock danger is increased by water's ability to carry electricity.

Figure 70: Do not touch electricity with wet hands.

- **Verify Connections:** Check to make sure all connections are securely fastened and that no naked wires are visible. Sparks from loose connections may start electrical fires.

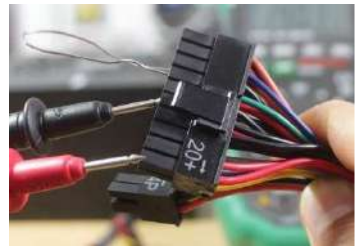


Figure 71: Verify Connection

- **Understanding the System:** Be certain that you have a thorough understanding of the system you will be using before starting work. A detailed understanding of the system helps you to foresee potential issues and take the necessary safeguards.

Figure 72: Deep Understanding

- **Consult a Professional:** Beginner in the field of electricity is at greater risk. So, always consult your senior or professional to start working. It is safer and often more economical to do tasks correctly the first time.

Figure 73: Consult a Professional

5.1.2 Algorithm for Connecting PZEM-004T to Wemos D1 Mini:

1. For safety reasons, first, turn off the PZEM-004T and the Wemos D1 mini. Never attempt to connect powered devices.
2. Locate the PZEM-004T module's power supply pins. These are commonly identified as ground (GND) and 5V (for power). Similarly, locate the Wemos D1 mini's GND and 5V pins.
3. Use a connecting wire to join the PZEM-004T's 5V pin to the Wemos D1 mini's 5V pin. The Wemos D1 mini powers the PZEM-004T module through this wire.
4. Using a different connecting wire, attach the GND pin of the PZEM-004T to the GND pin of the Wemos D1 mini. A ground connection is required to complete the circuit and enable electricity to flow.
5. Identify the PZEM-004T module's TX (transmit) and RX (receive) pins. These pins enable data transfer between the microcontroller and the sensor module.
6. Find the Wemos D1 mini's digital pins. We are utilizing D7 (for RX) and D8 (for TX) for this project. The PZEM-004T module's RX and TX pins will be connected to these pins.
7. Connect the D8 pin of the Wemos D1 mini to the TX pin of the PZEM-004T module. To the Wemos D1 mini in this configuration, the PZEM-004T module transfers data; remember that TX stands for "transmit."
8. Similarly, connect the D7 pin of the Wemos D1 mini to the RX pin of the PZEM-004T module. The PZEM-004T module will receive data from the Wemos D1 mini since the letter RX stands for "receive."
9. Make sure all connections are secure and accurate by checking them twice. The PZEM-004T sensor module and the Wemos D1 small are now attached and prepared for use.

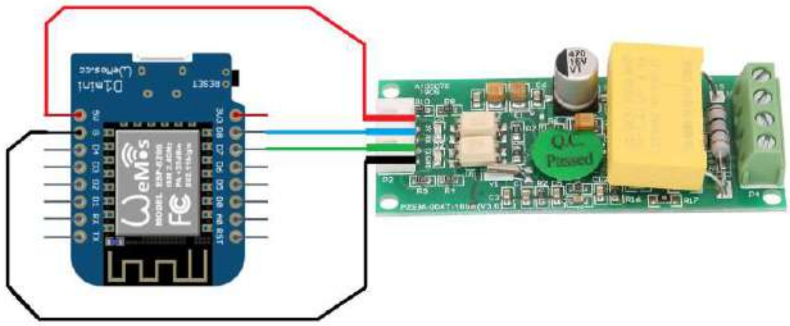


Figure 74: Sensor Connection with Controller

Remember: Always maintain safety while dealing with electricity; never forget that. Before making any connections or changes, always turn the system off. Inadequate connections might endanger your safety or do irreversible harm to your gadgets. Carefully read the Datasheet of the sensor and microcontroller to avoid any loss.

5.1.3 Algorithm for Data Acquisition

1. **Start with the initial setup:** Turn on the system, including the PZEM-004T sensor module and Wemos D1 small. Make sure that every connection is made correctly according to the prior method.
2. **Initialize the sensor module:** Run the command to initialize the PZEM-004T sensor module on the Wemos D1 mini to start the sensor module. This usually entails loading the proper library for PZEM-004T and configuring the TX and RX pins (in the project, D8 and D7, respectively).
3. **Start the acquisition loop:** This ongoing procedure will operate if the machine is switched on. Start a loop in the program that keeps looking for fresh information from the sensor module.
4. **Request data:** The first step in this loop is to request the current measurement data to the PZEM-004T sensor module.
5. **Check for data:** After submitting the request, see whether the sensor module has sent any data by checking for it. It could be essential to wait briefly before the data is released since there might be a little delay.

6. **Read data:** Once data is available, read it onto the Wemos D1 mini into an appropriate variable. If the sensor delivers many readings simultaneously, this might be a more complicated data structure or a single value for current or voltage.
7. **Validate data:** Verify the validity of the data retrieved from the sensor module. This might include looking for numbers outside the expected range or ensuring the checksum matches the data.
8. **Data processing:** Now that we have accurate data, process it as necessary. Calculations, such as calculating power from current and voltage or unit conversions, may be necessary.

Note: The specific instructions and functions used in implementing this method depend on the programming language used; in our case, that is Arduino IDE. The PZEM-004T sensor module and the Wemos D1 micro libraries, which include but are not limited to PZEM and ESP8266, are also essential. To maintain a smooth development process and efficient problem-solving, it is always advantageous and highly advised to refer to the appropriate library documentation when building and debugging your product.

5.1.4 Data Processing and Calculation Flowchart

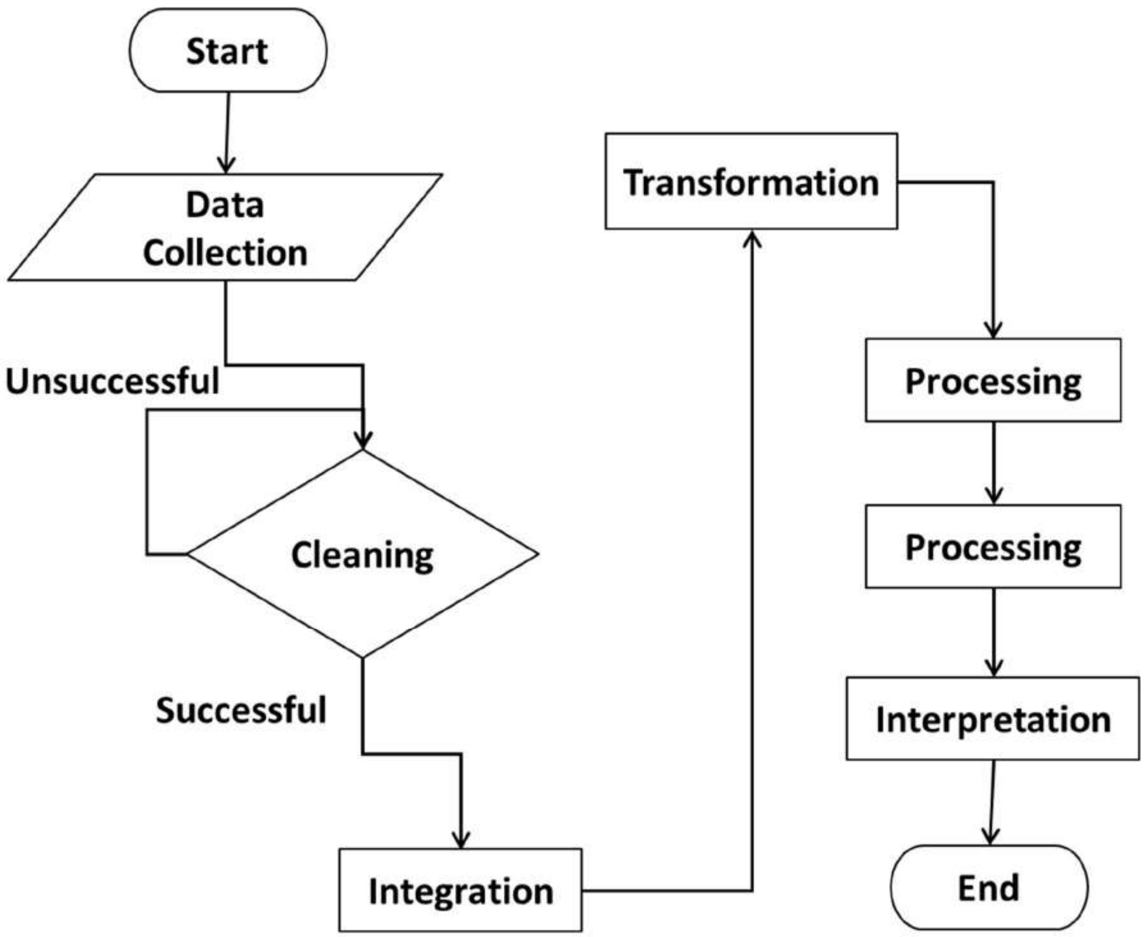


Figure 75: Data Processing Flowchart

5.1.5 Data Transmission Algorithm

The Data Transmission Algorithm is a critical component of the SAKOON, enabling seamless transmission of computed energy usage data from the hardware system to the server and, eventually, to the user interface. This algorithm follows sequential steps for an effective and efficient data transmission process.

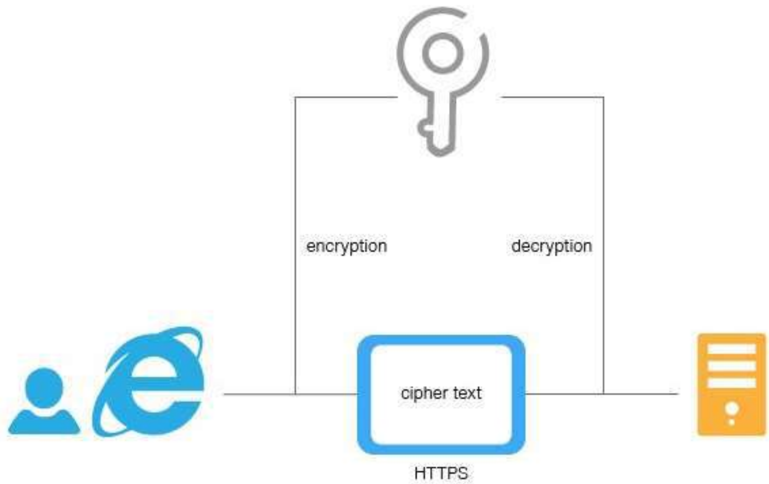


Figure 76: HTTP Protocol

1. **Data Serialization**: The computed data, including measurements of voltage, current, power, and energy usage, is serialized into a format suitable for network transmission. The data serialization ensures that it retains its structure and integrity during transmission.
2. **Packet Formation**: The serialized data is then encapsulated into data packets. These packets include the serialized data and essential metadata such as timestamps, device IDs, and checksums for error detection.
3. **Data Transmission to Server**: The prepared data packets are sent from the SAKOON hardware system to the server via a predefined communication protocol like MQTT, HTTP, or CoAP, depending on the requirements. We are using HTTP protocol for the SAKOON.
4. **Server-Side Data Reception and Decoding**: Upon receiving the data packets, the server decodes the packets and extracts the serialized data. The decoding process reverses the serialization process, converting the serialized data to its original format.
5. **Data Storage on Server**: The decoded data is stored in the server's database. Data is categorized and organized according to different parameters, like device ID and time, to facilitate easy retrieval in the future.
6. **Data Retrieval for User Interface**: When a user requests data on their user interface, the server retrieves the corresponding data from the database and prepares it for transmission to the user interface.

7. **Transmission to User Interface**: The retrieved data is then transmitted to the users' platform (Mobile application or Web dashboard), presented in a user-friendly format. Depending on the user interface design, this could include graphs, charts, or tables showing energy usage data.
8. **Data Presentation**: The transmitted data is displayed on the desired platform (Mobile application or Web dashboard). It may include visual aids, such as consumption patterns, that help users understand their energy consumption patterns.

The SAKOON Data Transmission Algorithm is the backbone of the real-time energy monitoring capability of the SAKOON system, ensuring users have access to accurate and up-to-date information about their energy consumption.

5.2 Libraries

5.2.1 PZEM

The PZEM-004T v3.0 is a current and energy monitor manufactured by Peacefair. This monitor is designed to provide accurate measurements for power systems, and it has become quite popular among hobbyists and professionals alike due to its affordable price and high accuracy. The PZEM004Tv30.h library is an essential tool for working with the PZEM-004T v3.0 energy monitor in the Arduino environment. The library provides a high-level interface to the hardware, making it possible to interact with the device without needing to handle low-level details like serial communication or data interpretation.

The library provides several methods to access real-time data about a power system. These include voltage (Volts), current (Amperes), power (Watts), energy (Watt-hours), frequency (Hertz), and power factor. These values are crucial for many energy-related applications, such as energy monitoring systems, home automation, and renewable energy projects.

The primary purpose of this library is to facilitate the easy collection and processing of data from the PZEM-004T v3.0. It does so by establishing communication between the device and an Arduino board using a serial connection, typically through hardware or software serial ports. Once communication has been established, the library provides straightforward methods for requesting and retrieving the various measurements that the device can produce.

Additionally, the PZEM004Tv30 library also supports commands for resetting energy totals, setting device addresses for multiple sensor networks, and modifying the device's baud rate. These additional features provide flexibility and control when integrating the PZEM-004T v3.0 into a broader system.

Another crucial feature of this library is its support for error handling. The PZEM-004T v3.0 communicates using a protocol that includes error checking. This library handles the verification of received data, ensuring that the values read from the device are accurate. In case of errors, the library provides a method to check the error code, helping the user to identify and fix issues.

The library also provides an object-oriented interface, which makes it easy to manage multiple PZEM-004T v3.0 devices in a single application. Each device can be represented by an instance of the PZEM004Tv30 class, and each instance maintains its state, making it possible to work with multiple devices in a straightforward way.

In conclusion, the PZEM004Tv30.h library is an indispensable tool for anyone working with the PZEM-004T v3.0 energy monitor in the Arduino platform. It abstracts away the complexities of interfacing with the device, providing a simple and user-friendly way to collect and process energy data. By using this library, developers and hobbyists can quickly build projects involving energy monitoring and control, contributing to more efficient and sustainable use of energy.

5.2.2 ESP8266 Wi-Fi

The Arduino platform needs the ESP8266 Wi-Fi library to use the ESP8266's Wi-Fi. With the library, it is easier to drive the Wi-Fi of ESP8266, which requires a deep knowledge of the embedded system so programmers may quickly interface with the built-in Wi-Fi capability of the ESP8266.

Developers may concentrate on more crucial application logic than the minute details of the Wi-Fi connection since the ESP8266 Wi-Fi library lessens the complexity of managing the built-in Wi-Fi capability. Most IoT projects using the ESP8266 chip use this library as the primary structural support.

This library is equipped to handle Wi-Fi connections on the ESP8266, whether it involves creating a new network (AP mode), joining an existing Wi-Fi network (STA mode), or operating both concurrently (STA+AP mode). It also gives users the liberty to control connection settings, including the network's SSID and password.

Moreover, the ESP8266WiFi library can scan for accessible Wi-Fi networks, a useful feature when locating networks within the ESP8266's range or pulling specific information about a network, like signal strength (RSSI), encryption type, and channel.

The library also aids in the IP configuration of the ESP8266. It supports assigning static IP addresses, subnet masks, and gateway addresses to the ESP8266, an essential feature when the ESP8266 needs to be reachable at a fixed IP address consistently. Another key capability of the ESP8266WiFi library is managing TCP/IP protocols. This includes initiating connections, sending data, and terminating them. Additionally, it supports both unsecured and secured (SSL) connections, enhancing its use in projects requiring secure data transfer.

The library also supports DNS (a protocol within the TCP/IP suite) which provides domain name like "www.sakoon.com" into an Internet Protocol (IP) address like "10.4.18.73" that computers utilize for network communication. The ESP8266WiFi library even includes Wi-Fi multi-functionality, a more effective method for handling Wi-Fi connections. Wi-Fi multi enables the ESP8266 to connect to the strongest Wi-Fi from a list of recognized networks, negating the need for active user intervention in the connection process.

Furthermore, the library backs WPS (Wi-Fi Protected Setup), a network security standard aiming to make home network protection user-friendly. The ESP8266WiFi library has a wide range of features that ease user for developing IoT applications using the ESP8266 module. It empowers developers to concentrate on the intricacies of their projects by handling the complex aspects of managing Wi-Fi connections. Numerous IoT applications, from intelligent household appliances to industrial monitoring systems, have been developed due to their versatility, affordability, and popularity.

5.2.3 Blynk ESP8266

The BlynkSimpleEsp8266.h library is a part of the Blynk platform, which gives programmers the resources they need to create Internet of Things (IoT) applications. The ESP8266 Wi-Fi module may be used to construct IoT applications more easily using Blynk platform. By making it easier to connect ESP8266-based devices to the Blynk Cloud or a local Blynk server, this library makes it possible to remotely manage and monitor these devices using the Blynk app. The BlynkSimpleEsp8266.h library gives developers a high-level interface so they can concentrate on building IoT apps rather than having to learn about the more complex details of network connection and data exchange.

The Blynk server connection, Blynk account authentication, data transmission to the Blynk app, and command reception from the Blynk app are all supported by the library. Furthermore, it takes care of the periodic heartbeats required to maintain the connection to the Blynk server and offers immediate reconnection if the connection is lost.

One of the key features of the BlynkSimpleEsp8266.h library is its use of "virtual pins", a concept that extends the physical input/output pins of the ESP8266. These virtual pins allow developers to exchange almost any data between the Blynk app and their hardware. Data sent to these virtual pins from the Blynk app can trigger events in the ESP8266 program, and data written to these pins in the ESP8266 program can be displayed or used in the Blynk app.

In conclusion, the BlynkSimpleEsp8266.h library is a powerful tool that simplifies the process of connecting ESP8266-based IoT devices to the Blynk platform. By handling the lower-level details of the Blynk protocol, it enables developers to focus on creating innovative applications for AI detection and other IoT scenarios.

5.2.4 Firebase ESP8266

Firebase is a comprehensive mobile development platform from Google, which provides a suite of cloud-based tools, including a real-time database, authentication services, storage, and hosting. Firebase ESP8266 client is a library developed for Arduino projects to interface with Firebase services seamlessly.

Its main feature is authentication, database, cloud, Realtime database which simplify integration of Firebase's cloud services with Internet of Things (IoT) projects that use the ESP8266 Wi-Fi module. The Firebase ESP8266 library provides an API (Application Programming Interface) for communicating with Firebase's services. This includes making requests to Firebase's Real-time Database, a NoSQL cloud database that syncs data across all clients in real time. Firebase Real-time Database enables you to build collaborative and live-updating applications without managing complex synchronization code.

In IoT applications where the ESP8266 is used to collect or produce data that has to be saved or accessed across different devices, this might be very helpful, Firebase Cloud Messaging (FCM) is a free service that lets you send messages and alerts to your devices. For instance, you may alert a mobile device when an event is detected by a sensor connected to the ESP8266.

Additionally, by using Firebase's login service, which can provide users safe access to your Firebase resources and recognize people across multiple devices, the library streamlines the login process. This library makes it simple to work with JSON data, which is the main standard for storing and transmitting data in Firebase. It offers a collection of JSON encoding and decoding methods to make sending and receiving complicated data structures to and from Firebase easier.

The Firebase ESP8266 library is a modern ease for developers creating IoT applications with ESP8266 and Firebase. It includes set of functions that simplify interacting with Firebase's cloud-based services, thus enabling developers to focus on building their applications without getting caught up in the intricacies of network programming and data synchronization.

5.3 Firebase

5.3.1 Introduction

Firebase was produced by Google, is intended to facilitate the creation and expansion of online and mobile apps. It functions as a Backend-as-a-Service (BaaS), freeing developers from the burden of overseeing server infrastructure so they can concentrate on creating better user experiences. It's crucial to remember that Firebase is more than simply a database; it's a group of services that can handle most server-side tasks. This vast platform has revolutionized the way developers create and maintain apps.

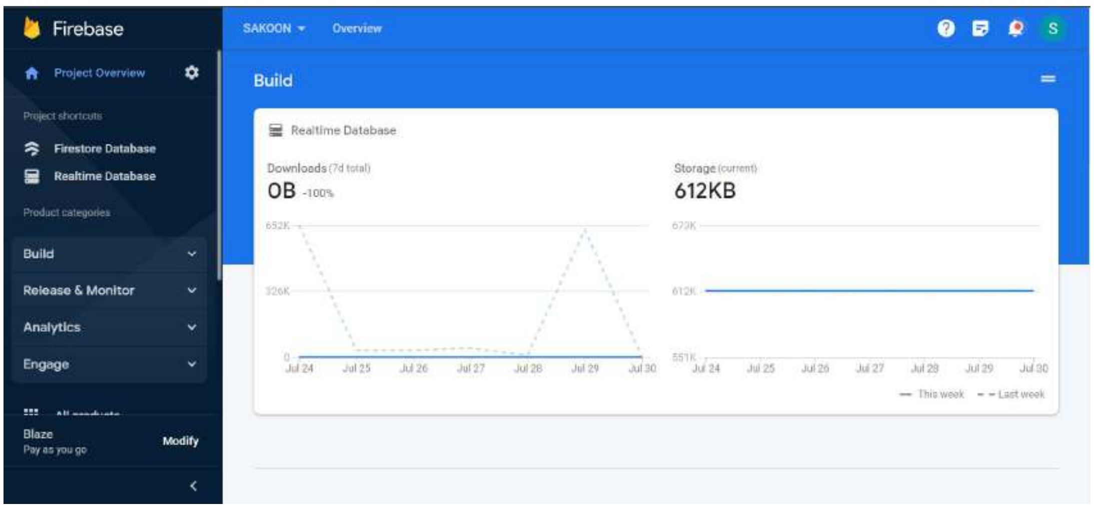


Figure 77: Real-Time Database Environment on Firebase

The Real-time Database does not require SQL allow user to store and sync data in real-time, NoSQL is Firebase's initial standout feature. Because of this, it's a great option for real-time applications like chat apps, gaming, and collaboration tools. The usage of WebSocket, which is quicker and more effective than conventional HTTP queries for data transfer, is one of the Firebase Real-time Database's distinctive features. By storing data on the client side and synchronizing it with the server once the connection is restored, the Real-time Database may also function when a connection is lost.

Additionally, Firebase offers more recent and scalable NoSQL cloud database created to store, sync, and query data for mobile, web, and Internet of Things applications. Although Fire store offers more advanced querying capabilities, transaction features, and hierarchical data structures, it retains its predecessor's real-time aspect. Data may be organized by developers into collections and documents that can be effectively queried even at scale.

Firebase Authentication, which supports several sign-in methods, including email and password, phone, and well-known federated identity providers like Google, Facebook, Twitter, and GitHub, is another crucial feature. By offering a simple secure sign-in capability to incorporate into your app, this service removes the need for developers to construct their own authentication system.

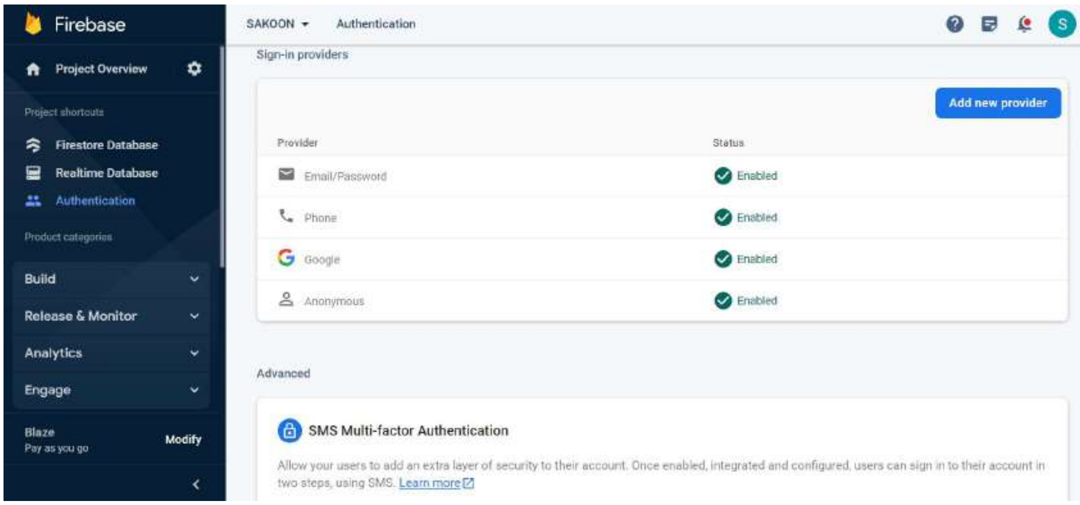


Figure 78: Authentication Firebase

A potent tool for sending messages and alerts to clients on many platforms, such as Android, iOS, and the web, is Firebase Cloud Messaging (FCM). It may be used for a variety of things, such as broadcasting alerts to huge audiences or delivering direct messages to specific devices. FCM is very useful since it doesn't need any special client-side code to receive messages.

A scalable and secure cloud file storage option is offered by Firebase's Storage service. It supports the archiving of user-generated material from mobile applications, including images and videos. Due to Google Cloud Storage's support, Firebase Storage can grow to handle petabytes of data. Firebase Storage files are immediately accessible over HTTP, making it easier to integrate them into your program.

Firebase Hosting provides dynamic and static web hosting that is quick and safe. It is perfect for using a single command to distribute static and web content to a global content delivery network (CDN). The deployment is simple and effective by Firebase Hosting's SSL security, availability of a worldwide CDN.

Along with Firebase Test Lab for iOS and Android, Firebase Crash Reporting, Firebase Performance Monitoring, Firebase Predictions, and Firebase App Indexing, Firebase also offers other tools for app development. These technologies provide insights about app use and user behavior in addition to aiding in the quality improvement of the application.

In conclusion, Firebase is a strong, user-friendly platform that can manage server-side activities to significantly speed up application development. Because of the variety of services it offers, including real-time databases, authentication, storage, messaging, hosting, and testing, developers can concentrate on creating cutting-edge, user-centered apps. Its cross-platform compatibility makes it a fantastic option for developers who want to support various operating systems. The use of Firebase in the construction of strong apps is crucial. It significantly increases productivity and efficiency.

5.3.2 SAKOON – Real time Data base

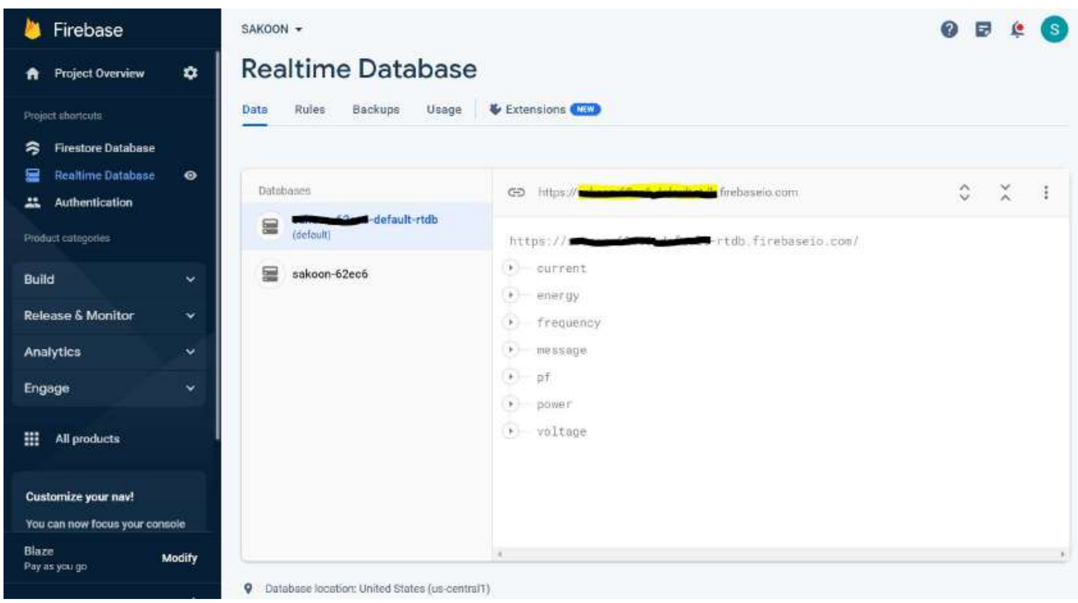


Figure 79: SAKOON Realtime Database on Firebase

Figure 80: Readings on Firebase

Chapter 6

CONCLUSION

The literature review provides an essential foundation for developing SAKOON, a project at the intersection of energy management, IoT technologies, circuit design, and user application development. Each component - IoT integration, circuit design, user-friendly data visualization, and remote monitoring - plays a crucial role in the successful execution and overall effectiveness of the project. The insights gathered through reviewing existing literature help understand the current situation and identify potential opportunities and challenges that may arise in the project's lifecycle.

Firstly, integrating IoT technologies within the project signifies a shift towards more sophisticated, connected, and real-time energy management systems. IoT allows for enhanced automation and control, which is vital in modern energy management. With IoT, energy usage data from various appliances can be collected, processed, and transmitted in real-time, enabling more efficient energy use and improved decision-making processes (Sisinni et al., 2018). However, IoT integration in energy management has limitations and challenges, including data security, privacy, and interoperability of various IoT devices. Understanding these challenges and developing effective strategies is essential for successfully implementing IoT in SAKOON.

Secondly, circuit design for voltage and current measurements is fundamental to any energy management system. Accurate voltage and current measurements enable precise energy consumption readings, which form the basis for monitoring and controlling energy usage. Several factors, such as the choice of measurement devices, the accuracy of these devices, and the methods employed for data collection and transmission, significantly impact the system's effectiveness (Lin, Lee, & Huang, 2013). The literature provides numerous circuit design methodologies and techniques, each with advantages and disadvantages. Therefore, careful consideration must be given to selecting and implementing these methods in the context of SAKOON.

The third critical aspect is the development of user-friendly data visualization. In the era of big data, effective data visualization is essential for presenting complex datasets in an understandable and accessible way. Creating an interactive UI-user interface can help users to visualize his/her energy usage patterns and make informed decisions to optimize their energy consumption (Few, 2009). However, creating an effective data visualization requires a deep understanding of the target users, their needs, and their abilities. It balances functionality and simplicity, providing users with the necessary information without overwhelming them. As such, user interface design principles, usability testing, and user feedback are critical in this project phase.

Lastly, remote monitoring of electrical equipment gives end customers even more convenience and control. With this capability, consumers may use their smartphones or other connected devices to monitor and manage their appliances whenever and wherever they are. This provides users with greater flexibility and allows for more efficient use of energy, as appliances can be switched off or their operation modified remotely based on real-time energy consumption data (Pal, Funilkul, Charoenkitkarn, & Kanthamanon, 20.18). Despite its benefits, remote monitoring brings new challenges, particularly regarding data security and privacy. Ensuring secure data transmission and protecting users' privacy is paramount for successfully implementing this feature.

The development of SAKOON involves a comprehensive understanding and careful integration of various components, each with its own set of opportunities and challenges. The literature review is a valuable guide, providing insights into existing methodologies, potential hurdles, and best practices. It helps shape the project's direction and design, ensuring that SAKOON is not only technologically advanced but also user-friendly, secure, and effective in achieving its goal of improved energy management. As the project progresses, continuous literature review and analysis will be integral to adapting to the evolving technology landscape and user expectations, ensuring the project’s ongoing relevance and success.

We have detailed the different phases of the SAKOON power metering system, from the initial conception to the final implementation and testing. The core vision of SAKOON was to design an IoT-based power metering system that would facilitate better power usage monitoring, enable cost-effective energy utilization, and contribute to global sustainability efforts. We can conclude that the project has successfully fulfilled these objectives.

In the global drive towards energy efficiency and sustainability, the SAKOON system contributes significantly to the industrial sector. Industries are one of the largest energy consumers; therefore, even minor improvements in energy efficiency can have a considerable impact. By providing real-time monitoring and visual analytics of energy consumption pattern, SAKOON aids industries in identifying inefficiencies, assessing power quality, and optimizing energy use. This, in turn, reduces energy costs and improves overall productivity. Furthermore, by leveraging IoT technology, SAKOON enables remote monitoring, thus simplifying energy management and contributing to Industry 4.0.

The value of SAKOON extends beyond industries, offering significant advantages to utilities and individual consumers. For utilities, SAKOON provides a powerful tool for demand response strategies, enabling peak load management and reducing strain on the power grid. The system empowers individual consumers with real-time energy consumption information and cost estimates, leading to better energy usage habits and savings on energy bills.

Globally, SAKOON aligns with multiple Sustainable Development Goals (SDGs) defined by United Nation to save planet and provide a good life to humanity, by mitigating the need for additional power generation infrastructure, SAKOON contributes to Goal 9: Industry, Innovation, and Infrastructure, Goal 11: Sustainable Cities and Communities. Through this project, we have demonstrated how multidisciplinary collaboration, innovative use of technology, and user-centered design can lead to solutions that address global challenges.

The SAKOON power metering system represents a significant advancement in energy management, benefiting multiple stakeholders, from industries and utilities to individual consumers. Moreover, the project showcases the pivotal role of innovative technological solutions in realizing sustainable development goals. As we move towards an IoT-dominated future, projects like SAKOON serve as a guiding beacon, illuminating the path to sustainable, efficient, and responsible energy consumption.

APPENDICES

APPENDIX A

PZEM-004T V3.0 User Manual

Overview

This document describes the specification of the PZEM-004T AC communication module, the module is mainly used for measuring AC voltage, current, active power, frequency, power factor and active energy, the module is without display function, the data is read through the TTL interface.

PZEM-004T-10A: Measuring Range 10A (Built-in Shunt)

PZEM-004T-100A: Measuring Range 100A (external transformer)

1. Function description

1.1 Voltage

1.1.1 Measuring range:80～260V

1.1.2 Resolution: 0.1V

1.1.3 Measurement accuracy: 0.5%

1.2 Current

1.2.1 Measuring range: 0～10A（PZEM-004T-10A）; 0～100A（PZEM-004T-100A）

1.2.2 Starting measure current: 0.01A（PZEM-004T-10A）; 0. 02A（PZEM-004T-100A）

1.2.3 Resolution: 0.001A

1.2.4 Measurement accuracy: 0.5%

1.3 Active power

1.3.1 Measuring range: 0～2.3kW（PZEM-004T-10A）; 0～23kW（PZEM-004T-100A）

1.3.2 Starting measure power: 0.4W

1.3.3 Resolution: 0.1W

1.3.4 Display format:

＜1000W, it display one decimal, such as: 999.9W

≥1000W, it display only integer, such as: 1000W

1.3.5 Measurement accuracy: 0.5%

1.4 Power factor

1.4.1 Measuring range: 0.00～1.00

1.4.2 Resolution: 0.01

1.4.3 Measurement accuracy: 1%

1.5 Frequency

1.5.1 Measuring range: 45Hz～65Hz

1.5.2 Resolution: 0.1Hz

1.5.3 Measurement accuracy: 0.5%

1.6 Active energy

1.6.1 Measuring range: 0～9999.99kWh

1.6.2 Resolution: 1Wh

1.6.3 Measurement accuracy: 0.5%

1.6.4 Display format:

＜10kWh, the display unit is Wh(1kWh=1000Wh), such as: 9999Wh

≥10kWh, the display unit is kWh, such as: 9999.99kWh

1.6.5 Reset energy: use software to reset.

1.7 Over power alarm

Active power threshold can be set, when the measured active power exceeds the threshold, it can alarm

1.8 Communication interface

RS485 interface。

2 Communication protocol

2.1 Physical layer protocol

Physical layer use UART to RS485 communication interface

Baud rate is 9600, 8 data bits, 1 stop bit, no parity

2.2 Application layer protocol

The application layer use the Modbus-RTU protocol to communicate. At present, it only supports function codes such as 0x03 (Read Holding Register), 0x04 (Read Input Register), 0x06 (Write Single Register), 0x41 (Calibration), 0x42 (Reset energy).etc.

0x41 function code is only for internal use (address can be only 0xF8), used for factory calibration and return to factory maintenance occasions, after the function code to increase 16-bit password, the default password is 0x3721

The address range of the slave is 0x01 ~ 0xF7. The address 0x00 is used as the broadcast address, the slave does not need to reply the master. The address 0xF8 is used as the general address, this address can be only used in single-slave environment and can be used for calibration etc.operation.

2.3 Read the measurement result

The command format of the master reads the measurement result is(total of 8 bytes):

Slave Address + 0x04 + Register Address High Byte + Register Address Low Byte + Number of Registers High Byte + Number of Registers Low Byte + CRC Check High Byte + CRC Check Low Byte.

The command format of the reply from the slave is divided into two kinds:

Correct Reply: Slave Address + 0x04 + Number of Bytes + Register 1 Data High Byte + Register 1 Data Low Byte + ... + CRC Check High Byte + CRC Check Low Byte

Error Reply: Slave address + 0x84 + Abnormal code + CRC check high byte + CRC check low byte

Abnormal code analyzed as following (the same below)

- 0x01,Illegal function
- 0x02,Illegal address
- 0x03,Illegal data
- 0x04,Slave error

The register of the measurement results is arranged as the following table

Register address	Description	Resolution
0x0000	Voltage value	1LSB correspond to 0.1V
0x0001	Current value low 16 bits	1LSB correspond to 0.001A
0x0002	Current value high 16 bits	
0x0003	Power value low 16 bits	1LSB correspond to 0.1W
0x0004	Power value high 16 bits	
0x0005	Energy value low 16 bits	1LSB correspond to 1Wh
0x0006	Energy value high 16 bits	
0x0007	Frequency value	1LSB correspond to 0.1Hz
0x0008	Power factor value	1LSB correspond to 0.01
0x0009	Alarm status	0xFFFF is alarm, 0x0000is not alarm

For example, the master sends the following command (CRC check code is replaced by 0xHH and 0xLL, the same below)

0x01 + 0x04 + 0x00 + 0x00 + 0x00 + 0x0A + 0xHH + 0xLL

Indicates that the master needs to read 10 registers with slave address 0x01 and the start address of the register is 0x0000

The correct reply from the slave is as following:

0x01 + 0x04 + 0x14 + 0x08 + 0x98 + 0x03 + 0xE8+0x00 + 0x00 +0x08 + 0x98+ 0x00 + 0x00 + 0x00 + 0x00 + 0x00 + 0x00 + 0x01 + 0xF4 + 0x00 + 0x64 + 0x00 + 0x00 + 0xHH + 0xLL

The above data shows

- Voltage is 0x0898, converted to decimal is 2200, display 220.0V
- Current is 0x000003E8, converted to decimal is 1000, display 1.000A
- Power is 0x00000898, converted to decimal is 2200, display 220.0W
- Energy is 0x00000000, converted to decimal is 0, display 0Wh
- Frequency is 0x01F4, converted to decimal is 500, display 50.0Hz
- Power factor is 0x0064, converted to decimal is 100, display 1.00
- Alarm status is 0x0000, indicates that the current power is lower than the alarm power threshold

2.4 Read and modify the slave parameters

At present,it only supports reading and modifying slave address and power alarm threshold

The register is arranged as the following table

Register address	Description	Resolution
0x0001	Power alarm threshold	1LSB correspond to 1W
0x0002	Modbus-RTU address	The range is 0x0001~0x00F7

The command format of the master to read the slave parameters and read the measurement results are same(descrybed in details in Section 2.3), only need to change the function code from 0x04 to 0x03.

The command format of the master to modify the slave parameters is (total of 8 bytes):

Slave Address + 0x06 + Register Address High Byte + Register Address Low Byte + Register Value High Byte + Register Value Low Byte + CRC Check High Byte + CRC Check Low Byte.

The command format of the reply from the slave is divided into two kinds:

Correct Response: Slave Address + 0x06 + Number of Bytes + Register Address Low Byte + Register Value High Byte + Register Value Low Byte + CRC Check High Byte + CRC Check Low Byte.

Error Reply: Slave address + 0x86 + Abnormal code + CRC check high byte + CRC check low byte.

For example, the master sets the slave's power alarm threshold:

0x01 + 0x06 + 0x00 + 0x01 + 0x08 + 0xFC + 0xHH + 0xLL

Indicates that the master needs to set the 0x0001 register (power alarm threshold) to 0x08FC (2300W).

Set up correctly, the slave return to the data which is sent from the master.

For example, the master sets the address of the slave

0x01 + 0x06 + 0x00 + 0x02 + 0x00 + 0x05 + 0xHH + 0xLL

Indicates that the master needs to set the 0x0002 register (Modbus-RTU address) to 0x0005

Set up correctly, the slave return to the data which is sent from the master.

2.5 Reset energy

The command format of the master to reset the slave's **energy** is (total 4 bytes):

Slave address + 0x42 + CRC check high byte + CRC check low byte.

Correct reply: slave address + 0x42 + CRC check high byte + CRC check low byte.

Error Reply: Slave address + 0xC2 + Abnormal code + CRC check high byte + CRC check low byte

2.6 Calibration

The command format of the master to calibrate the slave is (total 6 bytes):

0xF8 + 0x41 + 0x37 + 0x21 + CRC check high byte + CRC check low byte.

Correct reply: 0xF8 + 0x41 + 0x37 + 0x21 + CRC check high byte + CRC check low byte.

Error Reply: 0xF8 + 0xC1 + Abnormal code + CRC check high byte + CRC check low byte.

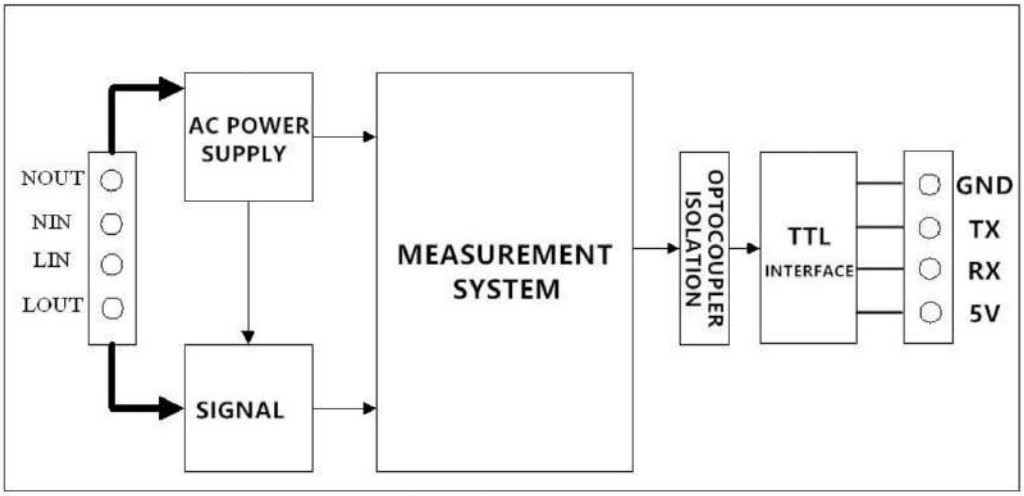
It should be noted that the calibration takes 3 to 4 seconds, after the master sends the command, if the calibration is successful, it will take 3 ~ 4 seconds to receive the response from the slave.

2.7 CRC check

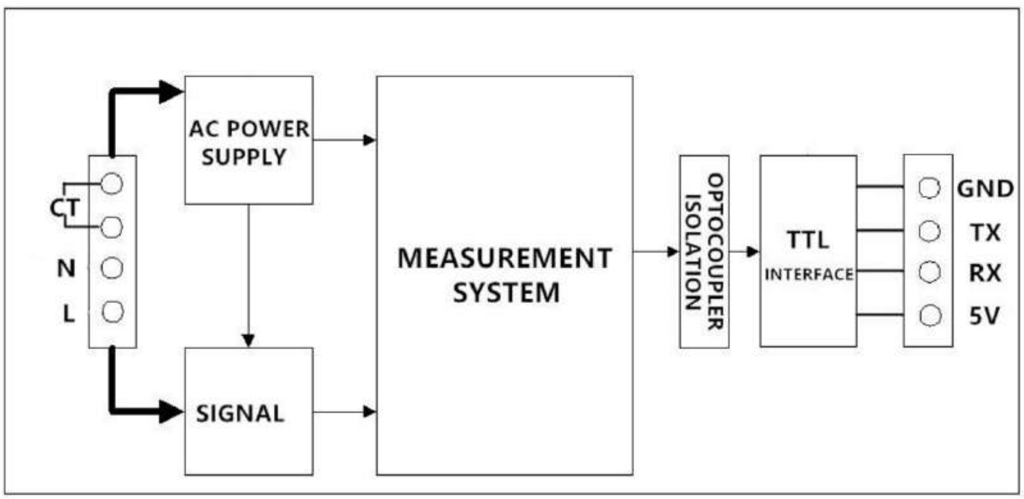
CRC check use 16bits format, occupy two bytes, the generator polynomial is X16 + X15 + X2 +1, the polynomial value used for calculation is 0xA001.

The value of the CRC check is a frame data divide all results of checking all the bytes except the CRC check value.

3 Functional block diagram

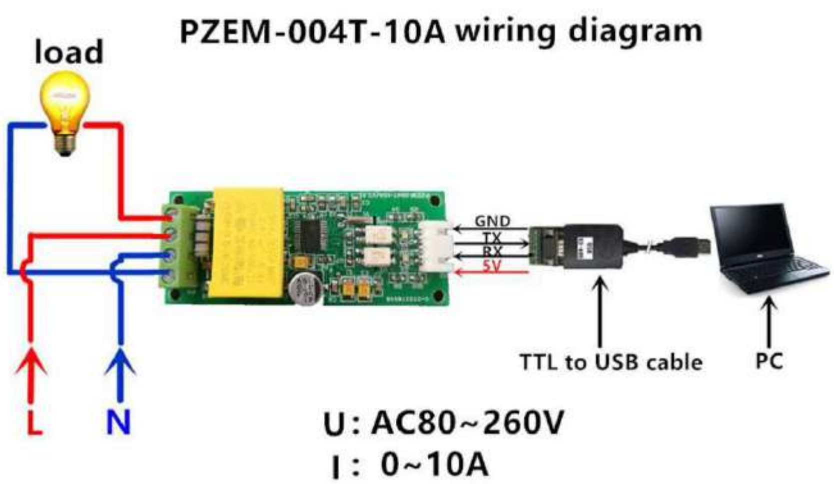


Picture 3.1 PZEM-004T-10A Functional block diagram

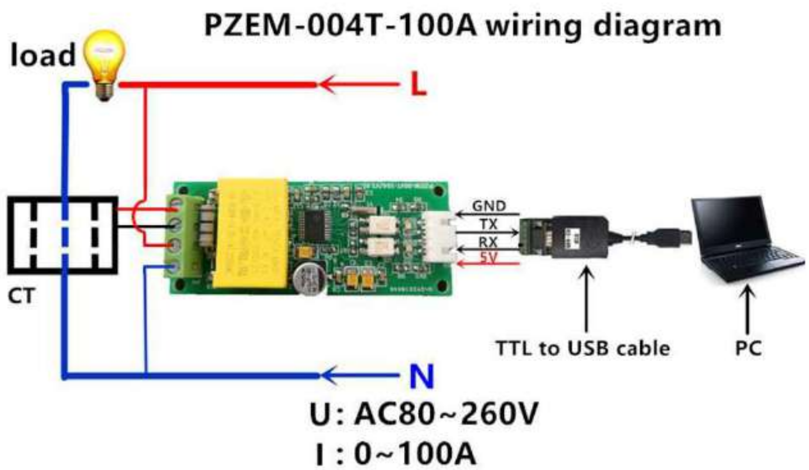


Picture 3.2 PZEM-004T-100A Functional block diagram

4 Wiring diagram



Picture 4.1 PZEM-004T-10A wiring diagram



Picture 4.2 PZEM-004T-100A wiring diagram

5 Other instructions

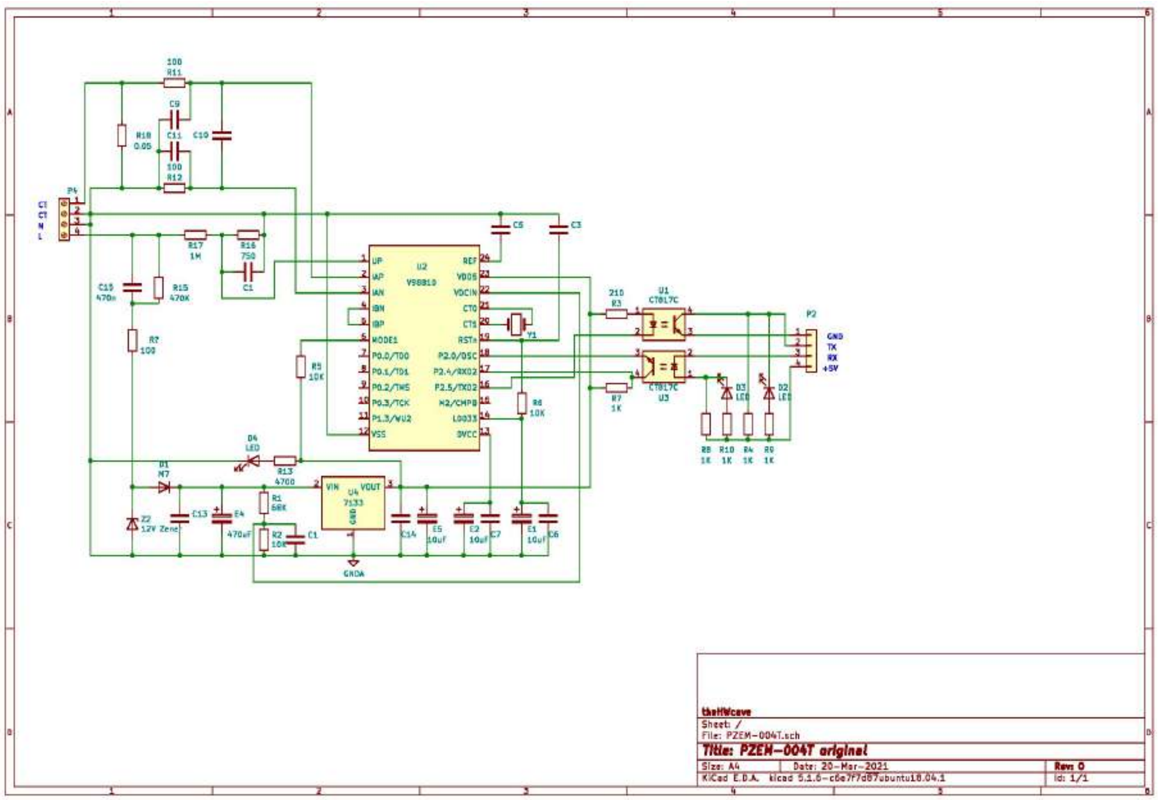
5.1The TTL interface of this module is a passive interface, it requires external 5V power supply, which means, when communicating, all four ports must be connected (5V, RX, TX, GND), otherwise it cannot communicate.

5.2 Working temperature

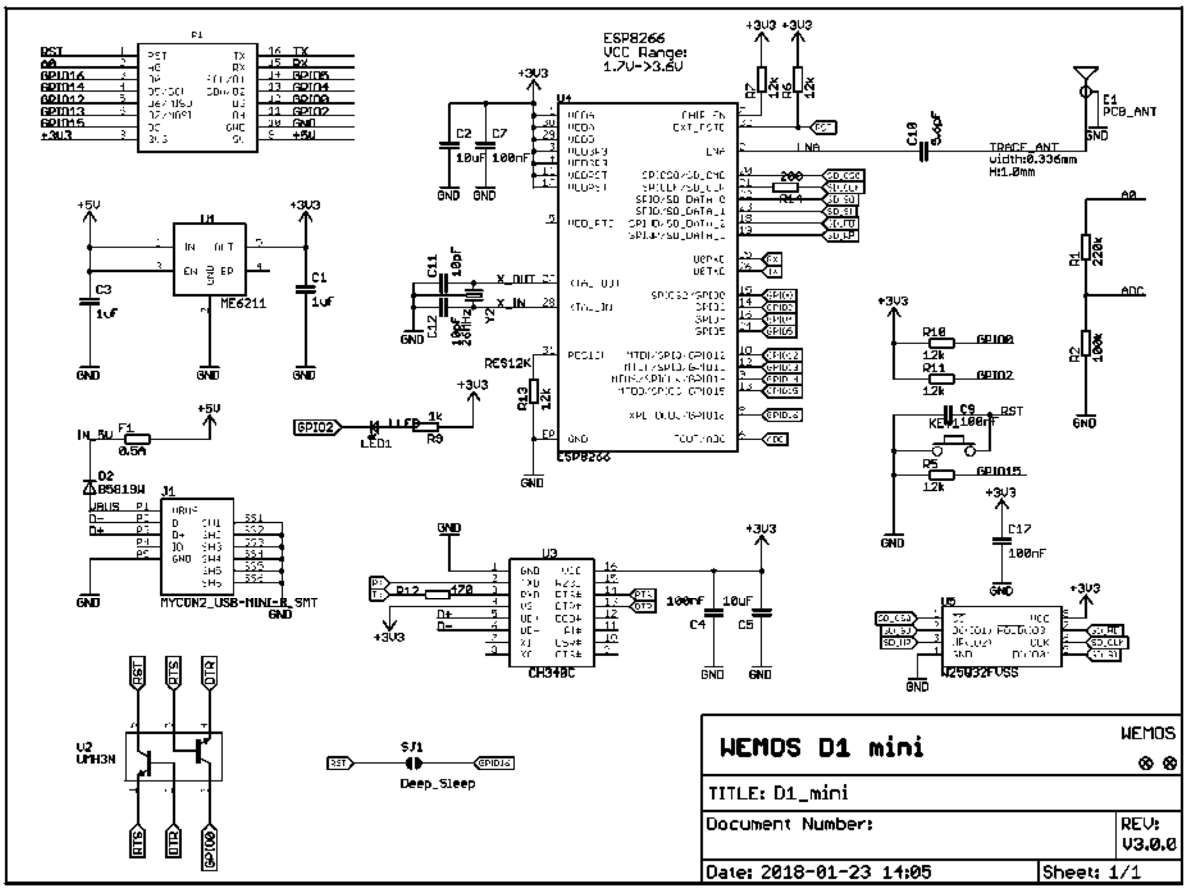
-20'C ~ +60'C。

APPENDIX B

PZEM Schematics



Microcontroller Schematics



APPENDIX C

Figure 81: Project Standee

Figure 82: Project Brochure Page 1

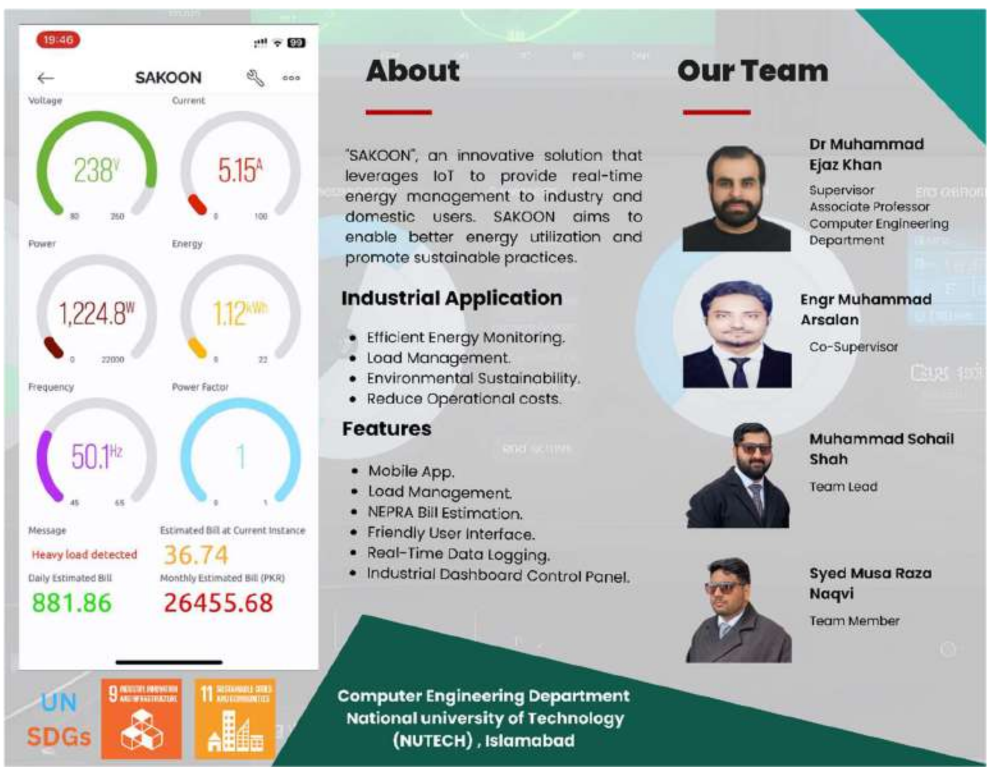


Figure 83: Project Brochure Page 2

APPENDIX D

Market Research Survey

SAKOON: Revolutionizing energy management with real-time data, fostering a sustainable future. Unleash the power of smart, green living with SAKOON's intelligent energy solutions.

We sincerely appreciate your valuable participation in this survey. Your time and insights have been immensely beneficial to us. Thank you for helping us make a difference!

1. How many units did you consume last month?

   Mark only one.

   - <100
   - Greater than 100 less than 300
   - Greater than 300

2. Are you satisfied with your energy consumption?

   Mark only one.

   - Yes
   - No

3. Are you using any device for Load Management?

   Mark only one.

   - Yes
   - No

4. If the previous answer was yes: are you satisfied with the device?

Mark only one.

- ( ) Yes
- ( ) No

5. Will you buy our proposed device?

Mark only one.

- ( ) Yes
- ( ) No
- ( ) Maybe

APPENDIX E

BUSSINESS CANVAS

Team or Company Name: SAKOON Powered by RASS

The Business Model Canvas

Date: 07/25/23

[X] Primary Canvas
[ ] Alternative Canvas

Key Partners
- **IoT device manufacturers:** These are the partners who provide the necessary hardware components such as the microcontroller and sensor modules.
- **Energy suppliers:** Collaborations with energy suppliers can help RASS offer comprehensive solutions that integrate energy provision and management.

Key Activities
- **Development and maintenance of the IoT energy management system:** This is the core activity, involving everything from hardware setup to software development and updates.
- Customer service and technical support

Key Resources
- **IoT devices:** The microcontroller and sensor module are key hardware components of the system.
- **Mobile and web platforms:** These are the interfaces through which customers interact with the system.

Value Proposition
- **Real-time Energy Oversight:** Enables customers to control energy use and conserve power through real-time monitoring.
- **Intuitive User Interface:** Offers easy interaction with energy data through user-friendly mobile and web platforms.

Customer Relationships
- **Direct and interactive:** Customers can interact directly with SAKOON through the mobile app and web platform.
- **Regular updates:** Keeping customers informed and engaged through newsletters, blog posts, and social media.

Channels
- **Direct online sales:** Customers can buy the product directly from the SAKOON website.
- **App stores:** The mobile app is available for download on iOS and Android app stores.

Customer Segments
- **Residential households:** Homeowners who are keen to manage and potentially reduce their energy consumption.
- **Educational Institutions:** Schools, colleges, universities, and other educational institutes that can significantly benefit from tracking and optimizing their substantial energy usage.
- **Industries:** Various sectors of the industry can leverage real-time energy management for their heavy machinery and vast plants.

Cost Structure
- **IoT hardware manufacturing and maintenance:** This includes the costs associated with producing and maintaining the IoT devices.
- **Software development and updates:** Costs related to the development, testing, and updating of the mobile and web platforms.
- **Cloud services:** Expenses for cloud storage and computing services.
- **Marketing and sales:** Costs for marketing activities and managing the sales process.

Revenue Streams
- **Sales of IoT devices:** Revenue is generated from the sale of the IoT energy management system.
- **Subscription fees:** Customers might pay subscription fees for access to premium features on the mobile app.
- **Data analysis and reporting services:** Offering advanced data analysis and customized reports as additional services can also generate revenue.

Source: www.businessmodelgeneration.com

Team or Company Name: SAKOON Powered by RASS

The Business Model Canvas

Date: 07/25/23

[ ] Primary Canvas
[X] Alternative Canvas

Key Partners
- **Cloud service providers:** These partners provide the storage and computing capabilities necessary for data processing and storing large volumes of energy data.
- **Mobile app development partners:** Partnerships with experienced app developers can ensure the creation of a user-friendly mobile interface.

Key Activities
- Data analysis and reporting
- Marketing and Sales.
- Relationship management with key partners

Key Resources
- **Technical expertise:** Human resources with skills in IoT technology, software development, data analysis, and energy management.
- **Mobile** and **Web** platforms.

Value Proposition
- **Personalized Alerts:** Allows users to set custom alerts for specific conditions, ensuring prompt actions.
- **Cost Efficiency:** Promotes substantial savings over time by fostering better energy management.

Customer Relationships
- **24/7 customer service and technical support:** Providing round-the-clock support to help resolve any issues promptly.

Channels
- **Partner channels:** Collaborations with IoT device manufacturers and energy suppliers can also serve as distribution channels.

Customer Segments
- **Small to Medium-sized Businesses:** Firms that are exploring ways to monitor their real-time energy use and uncover potential energy-saving opportunities.
- **Large Corporations:** Bigger entities with extensive energy usage, where even minor improvements in energy management can translate to substantial cost savings.

Cost Structure
- **Customer Service and Technical Support:** Resources required to provide customer support, including personnel and infrastructure costs.

Revenue Streams
- **Partner commissions and referrals:** Revenue may also come from collaborations with partners, for example through commission on referred sales.
- **Government Entities:** As a part of the energy conservation initiatives, these bodies could greatly benefit from real-time energy management systems.

Source: www.businessmodelgeneration.com

BUSSINESS PLAN

A comprehensive business plan for the SAKOON energy management system involves defining the company's mission, outlining the market strategy, setting financial goals, and describing the organizational structure.

Here is a high-level business plan for SAKOON:

- **Executive Summary:** SAKOON is a cutting-edge energy management system designed to provide consumers with real-time energy usage data and cost estimation. By promoting better energy consumption habits, SAKOON aims to contribute towards a sustainable and energy-efficient future.

Figure 84: SAKOON: an initiative towards future

- **Company Description:** RASS is a tech startup focused on revolutionizing how consumers interact with their energy usage. Our main product, "SAKOON," leverages IoT technology and data analytics to provide users with actionable insights about their energy consumption.

- **Market Analysis:** The global energy management system market is growing due to increasing energy costs and environmental concerns. The primary target market for SAKOON includes households and small to medium sized businesses looking to save energy and reduce costs. Our secondary market includes energy companies interested in better load management and personalized customer service. However, with the B2B model, we are ready to serve the industry.

Figure 85: Market Analysis

- **Organization and Management:** SAKOON Energy Solutions will be led by a management team experienced in tech startups, energy solutions, and business development. The company will also employ a skilled team of software engineers, data analysts, and marketing professionals.

- **Service or Product Line:** The SAKOON offers features such as real-time energy monitoring, cost estimation, and personalized energy-saving recommendations. The system provides a mobile application for domestic or small businesses and a web-based dashboard with industrial control panel for the industry with interactive UI.

- **Marketing and Sales Plan:** The marketing plan will emphasize digital channels like social media, SEO, and content marketing. Sales will be mostly online, including direct-to-consumer and B2B options for energy firms.

Figure 86: SEO

- **Request for money:** The startup will seek seed money from venture capitalists, angel investors, and government grants encouraging energy-efficient activities. The money will go toward product development, marketing, and operating expenses.

Figure 87: Request for finance

- **Financial Projections:** SAKOON expects to achieve profitability within the first three years of operation. The financial projection includes increasing revenue as the product gains market penetration, and operating expenses decrease as a percentage of sales.

Figure 88: Profit

- **Exit Strategy:** The company's long-term plan could involve an acquisition by a larger technology or energy company or possibly an IPO if market conditions are favorable.

ANNEXURE

Algorithm for setting up the ESP8266 board in Arduino IDE

1. Install Updated Arduino IDE.

Figure 89: Double Click on Setup or Right Click -> Run as administrator ->ok.

Figure 90: Click on "I Agree" to continue installation.

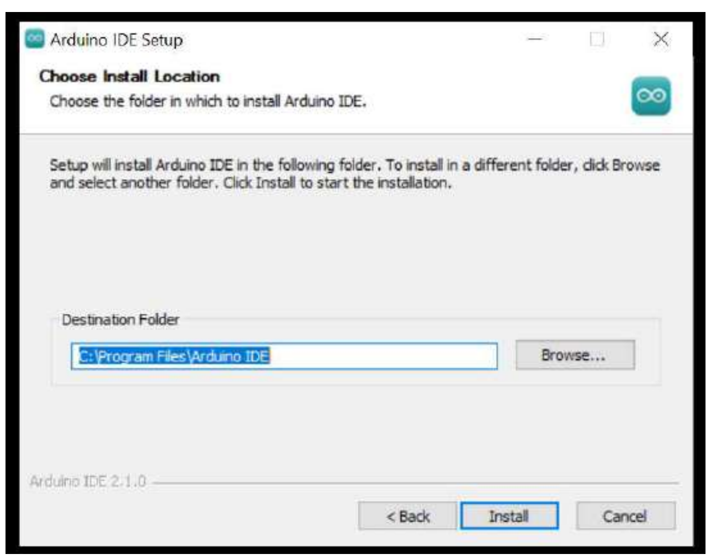


Figure 91: Select Destination Folder where you want to install setup.

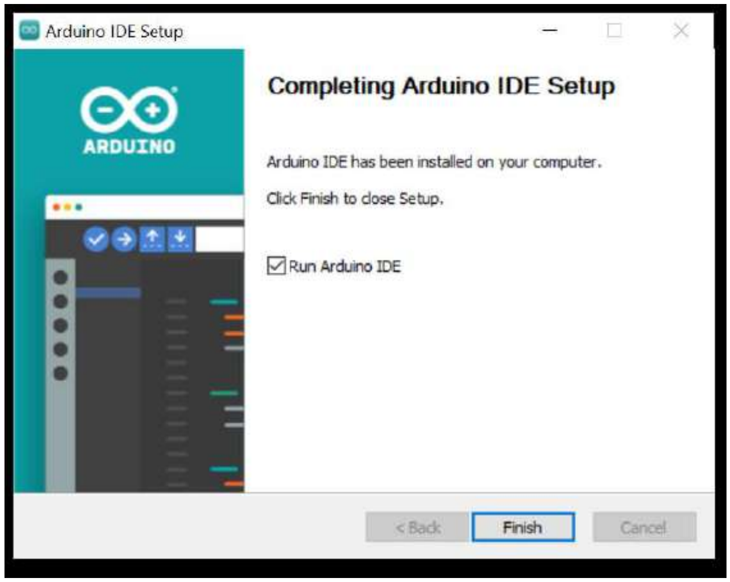


Figure 92: Click on Finish

2. Open Arduino IDE.

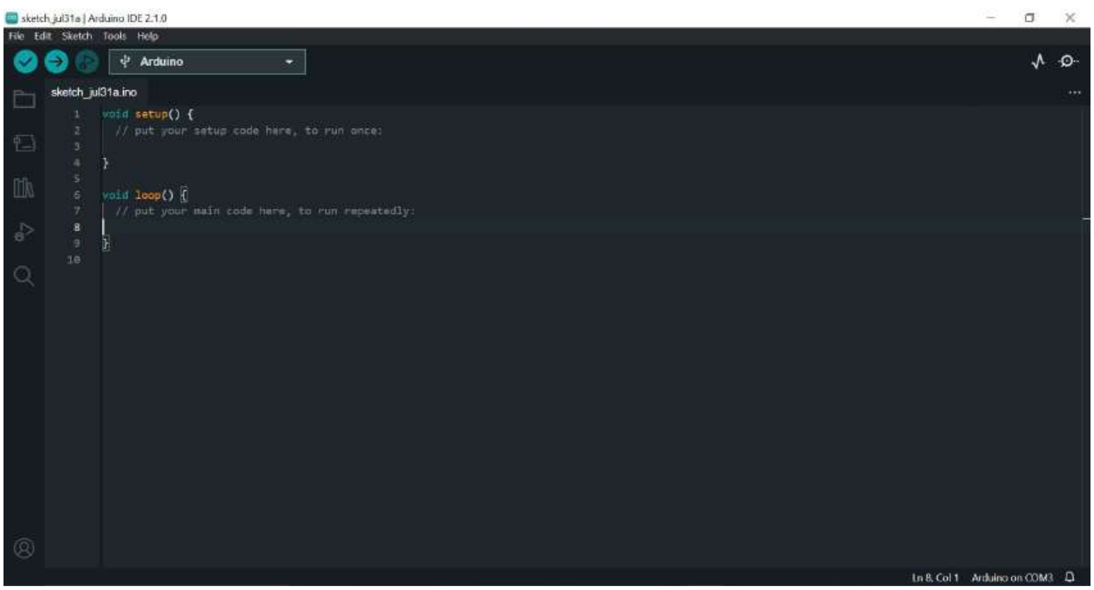


Figure 93: Arduino IDE

3. Connect the Wemos D1 mini to PC using a micro-A-type USB cable and select the connected COM port from the "Tools" menu.

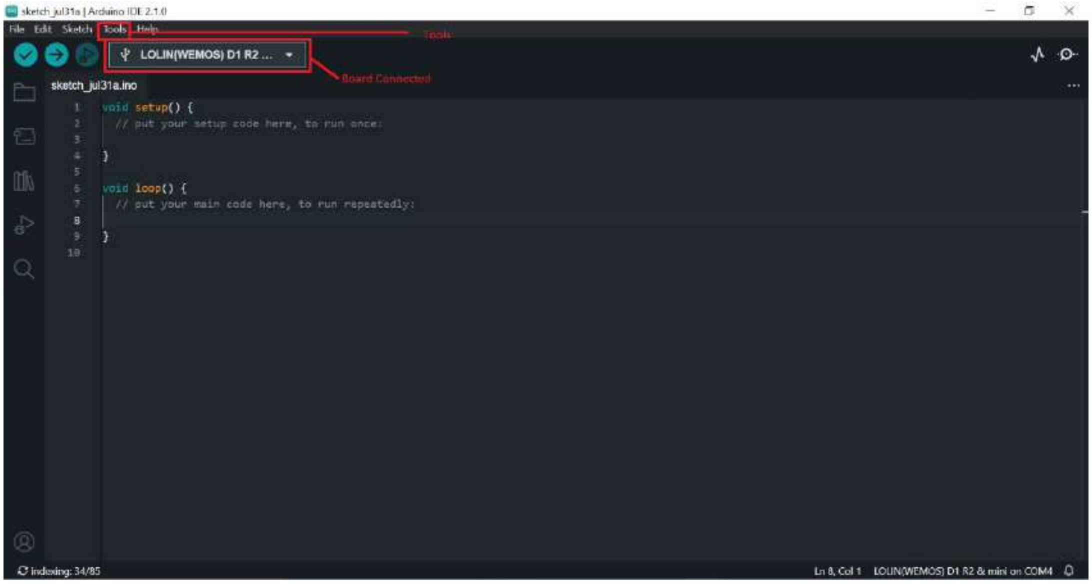


Figure 94: Board Connection and Tools Menu

4. Choose "Preferences" from the "File" menu.

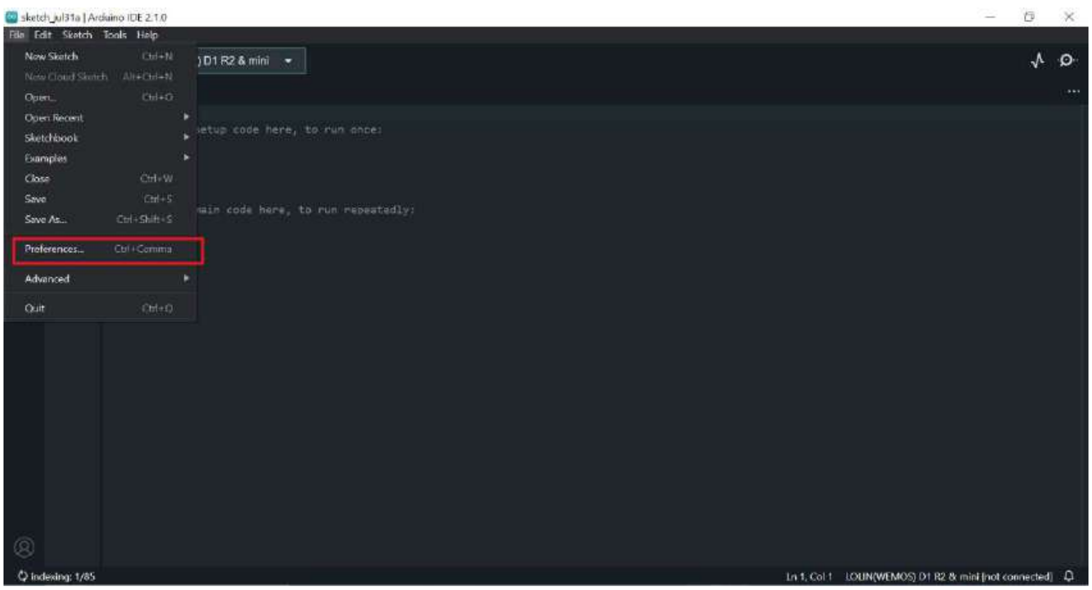


Figure 95: Preferences from File Menu

5. "Additional Boards Manager URLs" option is available in "Preferences" tab. Put the URL **http://arduino.esp8266.com/stable/package_esp8266com_index.json** in the box.
6. To save your changes and dismiss the "Preferences" window, click "OK."

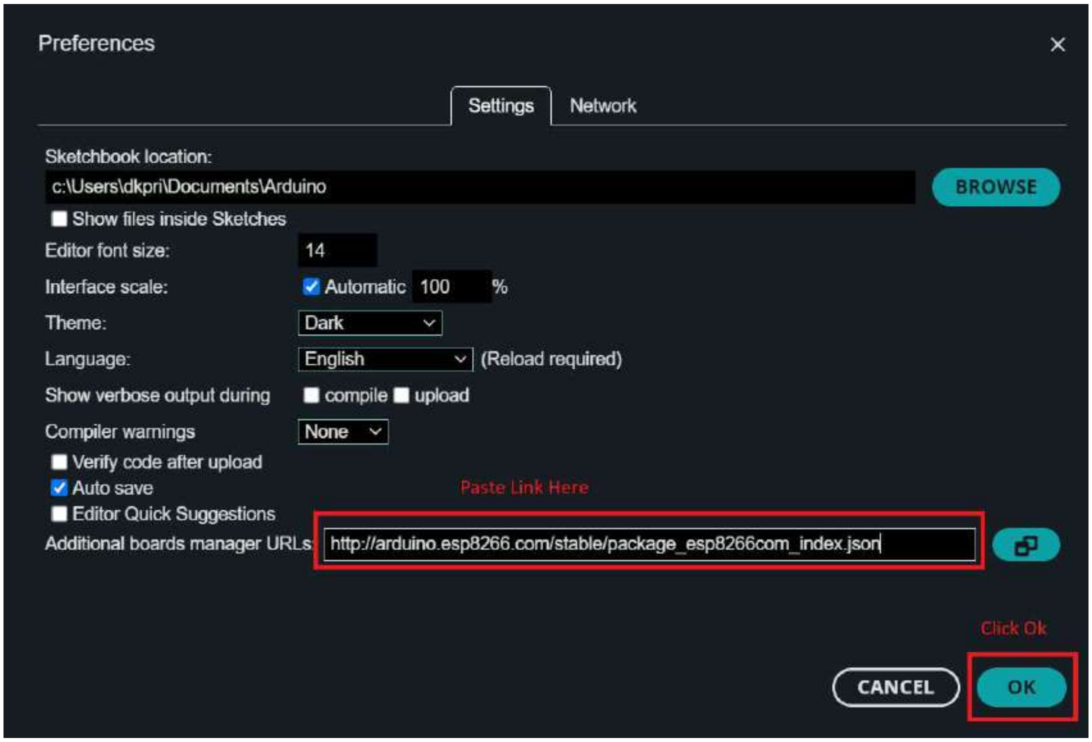


Figure 96: Paste link and Click OK

7. Pick "Boards Manager" from the "Tools" menu's "Board" section.
8. Enter "ESP8266" in the "Boards Manager" window's search field.

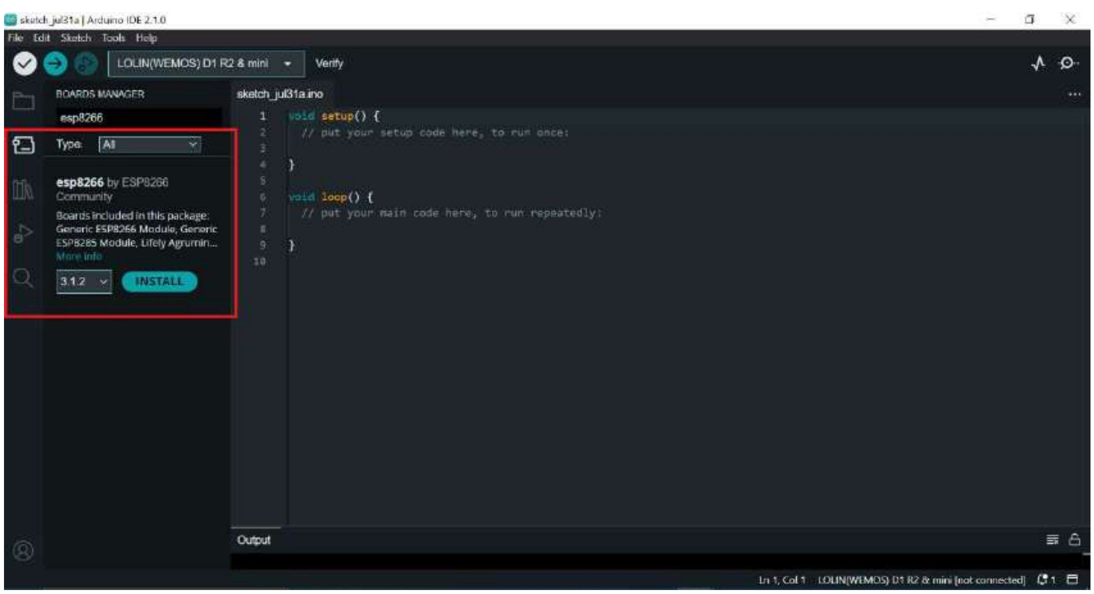


Figure 97: ESP8266 in Board Manager Menu

9. Hold off until the installation is finished. Close the "Boards Manager" window once you're finished.

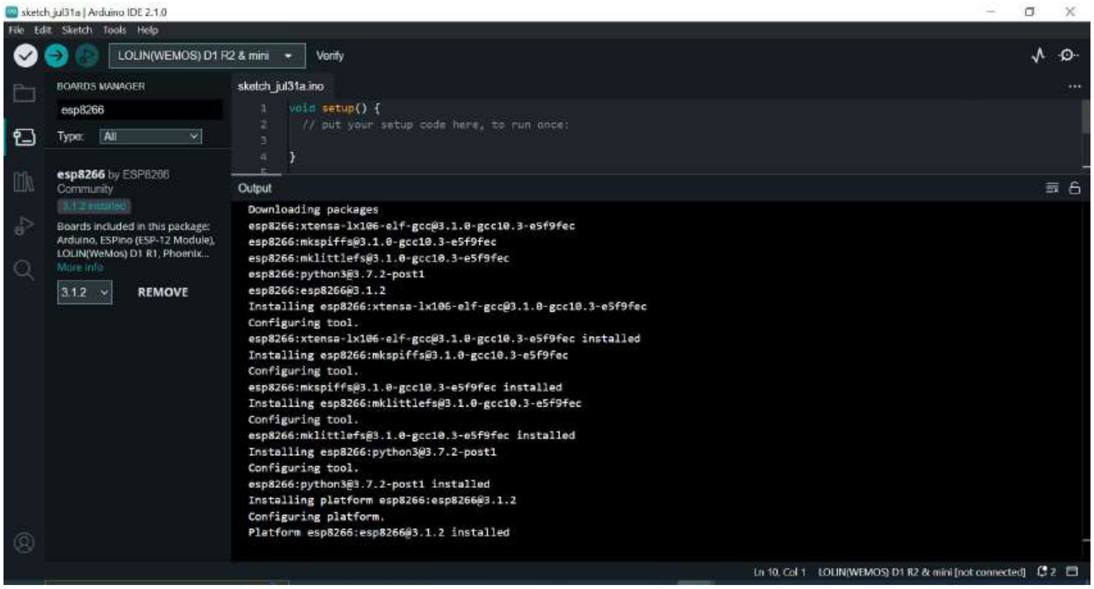


Figure 98: Successfully Installed

10. Return to the "Tools" menu, choose "Board," then scroll down until you find the ESP8266 boards. Choose your exact ESP8266 board from the list; in this example, "WeMos D1 R1" from the list.
11. After choosing the board, you may write code or upload sketches to your ESP8266 board based on your needs.

Code

Sensor with Arduino

```
#include <PZEM004Tv30.h>

PZEM004Tv30 pzem(16, 17);

void setup() {
    Serial.begin(115200);

    // Uncomment to reset the internal energy counter
    // pzem.resetEnergy()
}

void loop() {

    Serial.print("Custom Address:");
    Serial.println(pzem.readAddress(), HEX);

    // Read the data from the sensor
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float freq = pzem.frequency();
    float pf = pzem.pf();

    // Check if the data is valid
    if(isnan(voltage)){
        Serial.println("Error reading voltage");
    }
    else if (isnan(current)) {
        Serial.println("Error reading current");
    }
    else if (isnan(power)) {
        Serial.println("Error reading power");
    }
    else if (isnan(energy)) {
        Serial.println("Error reading energy");
    }
    else if (isnan(freq)) {
        Serial.println("Error reading frequency");
    }
    else if (isnan(pf)) {
        Serial.println("Error reading power factor");
    }
    else {

// Print the values to the Serial console
Serial.print("Voltage: "); Serial.print(voltage);Serial.println("V");
Serial.print("Current: "); Serial.print(current);Serial.println("A");
Serial.print("Power: ");   Serial.print(power);  Serial.println("W");
Serial.print("Energy: ");  Serial.print(energy); Serial.println("kWh");
Serial.print("Freq: ");    Serial.print(freq);   Serial.println("Hz");
Serial.print("PF: ");      Serial.println(pf);


    Serial.println();
    delay(2000);
}
```

```cpp
#include <PZEM004Tv30.h>

PZEM004Tv30 pzem(16, 17);

void setup() {
    Serial.begin(115200);

    // Uncomment to reset the internal energy counter
    // pzem.resetEnergy()
}

void loop() {

    Serial.print("Custom Address:");
    Serial.println(pzem.readAddress(), HEX);

    // Read the data from the sensor
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float freq = pzem.frequency();
    float pf = pzem.pf();

    // Check if the data is valid
    if(isnan(voltage)){
        Serial.println("Error reading voltage");
    } else if (isnan(current)) {
        Serial.println("Error reading current");
    } else if (isnan(power)) {
        Serial.println("Error reading power");
    } else if (isnan(energy)) {
        Serial.println("Error reading energy");
    } else if (isnan(freq)) {
        Serial.println("Error reading frequency");
    } else if (isnan(pf)) {
        Serial.println("Error reading power factor");
    } else {
// Print the values to the Serial console
Serial.print("Voltage: "); Serial.print(voltage);Serial.println("V");
Serial.print("Current: "); Serial.print(current);Serial.println("A");
Serial.print("Power: ");   Serial.print(power);  Serial.println("W");
Serial.print("Energy: ");  Serial.print(energy); Serial.println("kWh");
Serial.print("Freq: ");    Serial.print(freq);   Serial.println("Hz");
Serial.print("PF: ");      Serial.println(pf);
    }
    Serial.println();
    delay(2000);
}
```

Figure 99:Code for PZEM with Arduino

Wi-Fi

```cpp
#include <ESP8266WiFi.h>

void setup() {
  Serial.begin(115200);
  // Connect to WiFi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
```

Figure 100: Wi-Fi Configuration

Webserver

```
#include <ESP8266WebServer.h>

char auth[] = "##############################"; // Replace with your Blynk authentication token
const char* ssid = "Wifi- Name";
const char* password = "passward";

ESP8266WebServer server(80);

void handleRoot() {
String html = "<html><body>";
  html += "<h1>SAKOON</h1>";
  html += "<p>Voltage: <span id=\"voltage\">" + String(voltage) + "</span>V</p>";
  html += "<p>Current: <span id=\"current\">" + String(current) + "</span>A</p>";
  html += "<p>Power: <span id=\"power\">" + String(power) + "</span>W</p>";
  html += "<p>Energy: <span id=\"energy\">" + String(energy) + "</span>Wh</p>";
  html += "<p>Frequency: <span id=\"frequency\">" + String(frequency) + "</span>Hz</p>";
  html += "<p>Power Factor: <span id=\"pf\">" + String(pf) + "</span></p>";
  html += "<p>Message: <span id=\"message\">" + message + "</span></p>";
  html += "</script>";
  html += "</body></html>";
}

void runLocalServer() {
  server.handleRoot();
}
```

Figure 101: Code for ESP8266 Web Server

Blynk Integration

```
#include <BlynkSimpleEsp8266.h>

char auth[] = "##############################";  // Replace with your Blynk authentication token
const char* ssid = "Wifi- Name";
const char* password = "passward";

void handleData() {
  String json = "{";
  json += "\"voltage\": " + String(voltage) + ",";
  json += "\"current\": " + String(current) + ",";
  json += "\"power\": " + String(power) + ",";
  json += "\"energy\": " + String(energy) + ",";
  json += "\"frequency\": " + String(frequency) + ",";
  json += "\"pf\": " + String(pf) + ",";
  json += "\"message\": \"" + String(message) + "\"";
  json += "}";
  // Send data to Blynk app
  Blynk.virtualWrite(V0, voltage);
  Blynk.virtualWrite(V1, current);
  Blynk.virtualWrite(V2, power);
  Blynk.virtualWrite(V3, energy);
  Blynk.virtualWrite(V4, frequency);
  Blynk.virtualWrite(V5, pf);
  Blynk.virtualWrite(V6, message);
}
```

Figure 102: Blynk Integration

Firebase Integration

```
#include <FirebaseESP8266.h>

#define FIREBASE_HOST "https://name-#####-default-rtdb.firebaseio.com/"
#define FIREBASE_AUTH "***********************************************"
const char* ssid = "Wifi- Name";
const char* password = "passward";
FirebaseData firebaseData;

void sendDataToFirebase() {
  float voltage, current, power, energy, frequency, pf;
  voltage = pzem.voltage();
  current = pzem.current();
  power = pzem.power();
  energy = pzem.energy();
  frequency = pzem.frequency();
  pf = pzem.pf();
  // Send data to Firebase
  Firebase.pushFloat(firebaseData, "/voltage", voltage);
  Firebase.pushFloat(firebaseData, "/current", current);
  Firebase.pushFloat(firebaseData, "/power", power);
  Firebase.pushFloat(firebaseData, "/energy", energy);
  Firebase.pushFloat(firebaseData, "/frequency", frequency);
  Firebase.pushFloat(firebaseData, "/pf", pf);
  Firebase.pushString(firebaseData, "/message", message);
}
```

Figure 103: Firebase Integration

Cost Estimation

```
    float ECOST = 30;
    float CPDAY = 24;
    float CPMONTH = 30;
    float energyInKWh = power / 1000;
    float cost = energyInKWh * ECOST;
    float costpday = cost * CPDAY;
    float costpmonth = costpday * CPMONTH;
  Blynk.virtualWrite(V7, String(cost));
  Blynk.virtualWrite(V8, String(costpday)); // Convert costpday to string
  Blynk.virtualWrite(V9, String(costpmonth));
```

Figure 104: Cost Estimation (Real Time, Daily, Monthly)

High Load Detection

```
String message;

if (power >= 1000) {
  message = "Heavy Load Detected";
} else if (power >= 1) {
  message = "Light Load Detected";
} else {
  message = "No Load Detected";
}
```

Figure 105: Code for Heavy Load Detection

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Sakoonv2

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SAKOON: Automating Electric Load of Building

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2023

SAKOON: Automating Electric Load of Building

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A Project Report Submitted to the Department of Computer Engineering for the partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Engineering

Department of Computer Engineering

National University of Technology (NUTECH)

Islamabad, Pakistan

2023

BS CEN **SYED MUSA RAZA NAQVI, MUHAMMAD SOHAIL** **2023**

CERTIFICATE OF APPROVAL

It is certified that the project titled "SAKOON: Automating Electric Load of Building" carried out by SYED MUSA RAZA NAQVI, Reg. No. F19604002, and MUHAMMAD SOHAIL, Reg. No. F19604005 under the supervision of Dr. MUHAMMAD EJAZ KHAN, National University of Technology (NUTECH), Islamabad, is fully adequate in scope and in quality, as a capstone project for the degree of BS of Computer Engineering.

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We sincerely hope that our work on the SAKOON project will contribute meaningfully to the field and stand as a testament to the transformative power of innovative thinking and research, particularly in the sustainable energy sector.

Our deepest appreciation goes to our families for their unwavering affection, prayers, understanding, and backing. Their confidence in our skills has made this academic adventure feasible.

At last, we wish to articulate our aspiration that SAKOON becomes an instrumental asset in the sphere of energy management and conservation, contributing positively towards the creation of a sustainable and energy-conscious future.

DEDICATED

TO

OUR

FAMILY

SUPERVISOR

LOVED ONES

ABSTRACT

"SAKOON: Revolutionizing Energy Management for a Sustainable Future"

Embracing the prowess of cutting-edge technologies, "SAKOON: Automating Electric Load Management" emerges as a game-changer, reshaping our understanding and control of energy utilization. This IoT-enabled platform synergizes the potency of an advanced sensor module with the convenience of an intuitive mobile application, presenting real-time energy consumption details directly to the user. It amalgamates a sophisticated sensor module, a high-performance ESP8266 microcontroller, and user-friendly applications to create a comprehensive and accessible energy monitoring system. The sensor module is tasked with collecting real-time energy consumption data, measuring parameters like voltage, current, power, and energy. This raw data, in the form of analog signals, is then converted into digital data, comprehensible by the microcontroller. The ESP8266 microcontroller utilizes its onboard Wi-Fi capabilities. It receives digital data from the sensor module, processes it, and communicates with mobile and web applications. This process is facilitated by leveraging the TCP/IP and UART communication protocols, allowing seamless and error-free data transmission. The mobile application, compatible with multiple platforms (i.e., Android, IOS) and the web-based dashboard (Industrial Dashboard Control Panel), provides user with a detailed and real-time view of their energy consumption. Data communicated from the microcontroller is rendered in an easily interpretable graphical format, enabling users to make informed energy-saving decisions. Moreover, the system integrates the Blynk platform, enhancing its functionality and user experience. The web server ensures data accessibility in real time, serving web pages to users upon request. SAKOON is more than just a tool; it represents a leap toward sustainable living by empowering users with granular control over their energy usage. Utilizing advanced algorithms and robust communication protocols, SAKOON empowers users to monitor and control energy consumption in real time, fostering an environment of energy consciousness and efficiency. With its innovative web dashboard and seamless integration, SAKOON is more than just an energy management tool - it's a step towards a sustainable future.

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LIST OF ABBREVIATIONS

PZEM……….. Sensor Module (measure current, voltage)

UI………....... User Interface

IoT………...... Internet of Things

SDGs……….. Sustainability Development Goals by United Nations

UN………...... United Nations

TTL………... Transistor-Transistor Logic

UART……… Universal Asynchronous Receiver Transmitter

CSR……….... Corporate Social Responsibility

DR...……….... Demand Response

RTP……….…. Real-Time Pricing

CPP…..…….... Critical Peak Pricing

ToU……….…. Time of use

PPE………..…. Personal Protective Equipment

Chapter 1

INTRODUCTION

1.1 Problem Statement

The high cost of electricity is causing stress among people. Due to rising energy use, depleting resources, and environmental deterioration, the globe is today confronting a severe problem. To address these difficulties, efficient management and energy conservation are essential, but conventional power metering systems cannot provide timely, accurate information on energy use patterns and prices.

Figure 1: News about High Energy Prices

Although digital power meters have advanced, there is still a significant need for an integrated system that combines real-time energy monitoring, precise cost calculation, and user-friendly interfaces for thorough energy management. Furthermore, the absence of specific advice for energy-saving measures and predictive analyses for future energy patterns further exacerbates the issue.

Figure 2: Blackout due to Shortage of Energy

1.2 Background

The significance of effective energy management and conservation has been highlighted by rising energy consumption and worries about resource depletion and environmental impact. Systems for power metering are essential for allowing people and businesses to track and manage their energy use. These technologies let customers get insightful information about patterns of energy use, spot inefficient regions, and make well-informed choices that will lower their energy expenses and environmental impact. Power metering systems have historically depended on simple analog meters that had to be read by people and lacked real-time data-collecting capabilities.

Figure 3: Analog Electric Meter

The development of digital power meters, which provide improved accuracy, automation, and data accessibility, has revolutionized industry. These contemporary power meters offer smooth integration with microcontrollers and software platforms and enable real-time monitoring, analysis, and visualization of electrical data. They are often outfitted with digital communication interfaces.

Figure 4: Digital Electric Meter

Power metering systems now have more possibilities thanks to the development of IoT (Internet of Things) technologies in recent years. IoT-enabled power metering systems take advantage of connectivity and cloud-based platforms to provide interactive user interfaces for simple monitoring and control as well as remote access to energy data. These developments have opened the way for more advanced energy management techniques, allowing users to optimize energy usage, spot chances for energy savings, and save expenditures.

Figure 5: Smart Metering System

The development of SAKOON can improve energy efficiency and save costs. It is intended to enable effective analysis of electrical characteristics, provide users with exact, real-time information about their energy usage, and helps to gain financial independence. This power metering system aims to overcome the drawbacks of conventional metering systems by merging cutting-edge hardware components, durable software, and user-friendly web-based dashboards. It also gives users a potent tool for energy management and monitoring. Furthers help to estimate electricity bills based on data on energy usage and market rates, allowing individuals to save their hard-earned money and cut down on energy waste for the sake of the planet. SAKOON can improve energy management, efficiency, cost savings, as well as environmental sustainability by offering real-time insights, reliable data, and visualization tools.

Figure 6: SAKOON: Save Energy and Money

1.3 Objectives

Effective management and monitoring of electrical power use are essential for development and survival in the modern world. For real-time monitoring, analysis, and the simplification of energy price calculations, a complete power metering system is necessary, which is a low-cost, commercial-grade electric load management system, Works alongside a mobile app to provide real-time information.

Modern hardware and software platforms are used by the system to enable reliable data gathering, processing, and visualization of crucial electrical characteristics. The power metering system allows customers to acquire useful insights into their energy consumption and take proactive steps towards energy saving by merging a strong microcontroller-based platform with a trustworthy energy meter.

Figure 7: Low-cost, commercial-grade electric load management system – Hardware Module

Figure 8: Works alongside mobile app to provide real time information - Software Module

The followings are main objectives to be achieved:

- Create and design a hardware interface that enables reliable data exchange and acquisition between a sensor and a microcontroller that efficiently gathers and processes data, does the required computations, and makes it available for analysis.
- Make a web-based dashboard and a mobile app that is simple to use and offers real-time visualization of key electrical characteristics. Users of the application will be able to efficiently monitor and analyze their energy usage habits thanks to the application's interactive gauges, charts, and graphs that provide data in a visually attractive and instructive way.
- Implement a reliable cost calculation module that makes use of the gathered data on energy use and current energy prices to provide consumers with a precise idea of their power bills. Users will be given the tools they need to utilize this feature to take the required measures to optimize their energy usage and save expenses. The system offers accurate and trustworthy data for use in energy monitoring and analysis.

Figure 9: Industrial Dashboard Control Panel - Software Module

For both residential and commercial customers, the effective adoption of this power metering system will provide several advantages. They will be able to determine energy-intensive appliances or places and make knowledgeable judgments about energy-saving practices thanks to real-time data about their energy consumption. Users' comprehension of their energy consumption patterns will be improved by the incorporation of cutting-edge visualization tools and cost calculation capabilities, which will also provide them the ability to optimize their energy use for optimal efficiency and cost savings.

1.4 Scope

The development of SAKOON can improve energy efficiency and save costs. It is intended to enable effective analysis of electrical characteristics, provide users with exact, real-time information about their energy usage, and helps to gain financial independence. The creation and use of SAKOON, an IoT-based energy monitoring system, opens a wide range of opportunities for thorough energy management and conservation.

Figure 10: Modern concept of Cloud Computing. Both the mobile app and web dashboard using data from cloud

Several important elements may be used to determine the project's scope, including:

- **Hardware Development**: For the system to function, a reliable hardware interface that enables the seamless integration of sensor technologies with microcontrollers for real-time data collection and processing must be designed and developed.
- **Software Implementation**: The project's scope includes developing a specialized mobile app and an online dashboard. They will have intuitive user interfaces and provide essential energy statistics in a comprehensible and aesthetically attractive manner. Through these services, users may track, evaluate, and regulate their energy use in real-time.
- **Cost Estimation**: The scope of the system also includes the incorporation of an accurate cost estimation function. This will be integrated into both the mobile and online platforms and analyze data on energy consumption and current energy costs to forecast future power bills.

- **Real-time Energy Tracking**: The project's scope includes monitoring individual appliances' and the system's overall energy use in real-time. Additionally, there are high energy usage notifications that help consumers spot inefficient equipment or routines. We will provide suggestions for energy-saving measures.
- **Data Security**: It's crucial to ensure user data safety. Part of the scope includes putting strong data security procedures in place to protect against unauthorized access or data leakage.
- **Scalability**: As user acceptance increases or as customers extend their energy monitoring to other appliances or spaces, the power metering system is designed to be scalable and capable of handling growing data loads. The system's architecture places a strong emphasis on interoperability, enabling efficient communication and operation alongside other smart devices and systems, hence improving its use and possible applications.
- **User Training and Support**: Provision of thorough user guides, training, and support, ensuring that users can efficiently use all features and functionalities of the power metering system.

Even though the goal is to build a complete energy monitoring system with all functions, it may be essential to prioritize certain aspects over others due to time, financial, or technological restrictions.

1.5 System Features

The SAKOON system is built with a variety of unique features intended to make tracking energy use easier. It features secure data transfer, an interactive UI, thorough cost estimates, real-time monitoring, and effective hardware integration. It also offers thorough user training and assistance, supported by an effective assessment and feedback system. SAKOON is a potent tool for both individual and business customers looking to increase the efficiency of their energy consumption when these elements are combined.

Figure 11: SAKOON's feature: Realtime, cost eatimation, mobile app, web dashboard.

1.5.1 Real-Time Monitoring

SAKOON provides real-time monitoring of energy usage, allowing users to have instant access to their energy consumption data. This feature aids in making immediate adjustments to energy use and in understanding the patterns of energy consumption.

1.5.2 Friendly and Interactive User Interface (UI)

Both the web-based dashboard and the mobile app for the system have an intuitive UI. Users can rapidly grasp and act on the data.

1.5.3 Cost Estimation

SAKOON features an innovative cost estimation module that calculates an estimate of the energy bill based on current usage rates. This helps users anticipate their expenses and adjust their usage accordingly.

Figure 12: Cost Estimation in Mobile App

1.5.4 Secure Data Transmission

To ensure the safety of user data, SAKOON employs robust security measures. Data transmission between the hardware and software platforms is secured to protect against unauthorized access and potential data breaches.

1.5.5 Efficient Hardware Integration

The system's hardware includes sensors for data collection and a microcontroller for data processing. The hardware components are meticulously integrated to ensure efficient and accurate collection and processing of energy data.

1.6 Synopsis

The story of SAKOON starts with generating electricity, typically from hydroelectric or nuclear power plants. These locations capture and transform nature's untamed force into electrical energy. For instance, hydroelectric facilities spin turbines to produce electricity using the kinetic energy of flowing water. Similarly, nuclear plants utilize nuclear fission to heat water into steam, which again spins turbines to create electrical power.

Figure 13: Water Dam

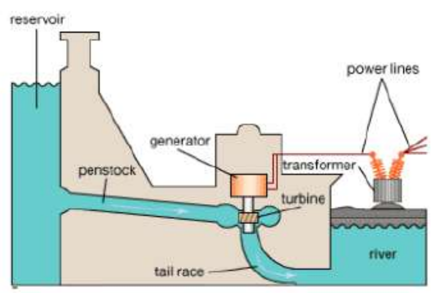

Figure 14: Hydro Plant Working.

Figure 15: Nuclear Plant

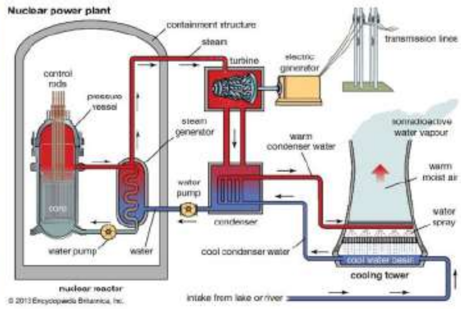

Figure 16: Nuclear Plant Working.

Post-generation, this electrical energy is often at very high voltages, unsuitable for direct consumer use. To facilitate safe transmission over long distances, the voltage is further increased and transmitted through a network of high-tension lines to grid stations. These stations serve as nerve centers in the power distribution network, ensuring electricity reaches different regions as needed.

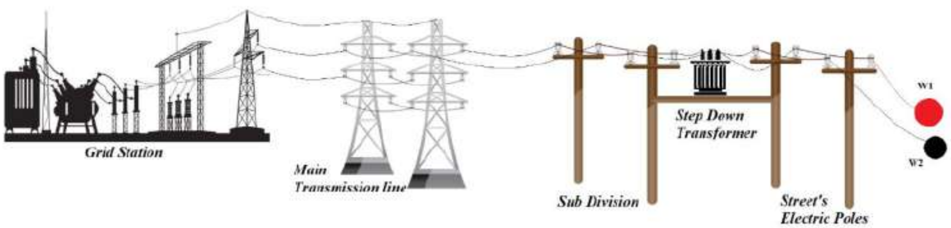

Figure 17: Electricity from Grid Station to Street Poles (cont.)

Upon reaching a specific region, the electricity must be lowered to a safer, usable voltage level. This is where transformers, located at local substations, come into play. They reduce the voltage from the high levels used for long-distance transmission to levels suitable for local distribution, typically around 220 volts in many regions.

Figure 18: Electricity from Street Poles to Homes

From these substations, electricity is distributed via local power lines to homes and businesses. It's here where the power meter enters the picture. Usually located at the point where electrical wiring enters a building, the power meter measures the total amount of electrical energy consumed by that building.

Beyond the meter, the electrical wiring within a home or business distributes power to individual sockets, lights, and appliances. And this is where SAKOON truly shines. Acting as an intelligent gatekeeper at this stage, SAKOON interfaces directly with the power system in a building, continuously monitoring energy consumption at the appliance level.

Figure 19: User Consuming electricity in house after installation of SAKOON

The SAKOON leverages a sophisticated sensor module to measure the electrical power consumed by individual appliances. This data is then processed by a microcontroller and transmitted to a mobile application and web dashboard in real-time. This gives users granular insights into their energy consumption habits, helping them make informed decisions about energy usage, identify wastage, and optimize efficiency.

Figure 20: Industrial Dashboard Control Panel

In essence, SAKOON offers an advanced look into energy usage patterns from the convenience of your phone or computer, presenting a new, contemporary solution for energy management. This technology aims to enable people to regulate their energy use for a sustainable and energy-efficient future, not merely to measure power.

Figure 21: Mobile App showing real time energy consumption and estimated bill.

1.7 Novelty

SAKOON brings a unique blend of technology, accessibility, and user experience to energy management. Its innovation lies in the efficient integration of the sensor module, the powerful ESP8266 microcontroller, and user-friendly applications, all working harmoniously to provide real-time, detailed, and actionable energy consumption data. This IoT-based energy monitoring system offers real-time data access and enables users to understand their energy usage patterns in depth, promoting energy conservation. Moreover, incorporating the Blynk platform and compatibility with a wide array of mobile platforms underscore SAKOON's commitment to user accessibility and convenience. Additionally, the system's capability to calculate and display the energy cost enhances its utility, transforming it from a simple monitoring tool to an essential component of modern, sustainable living.

Figure 22: House from Future

1.8 Application

Figure 23: SAKOON Application (Educational Institute, House, Industry, Corporate)

The SAKOON may be used for a variety of purposes, including:

- **Residential Consumption**: SAKOON enables homeowners to track the energy consumption of their homes in real-time. To reduce their energy costs, they may be able to detect energy-guzzling equipment or times of excessive energy.
- **Government and Municipalities**: To monitor and regulate their energy usage, local governments might employ SAKOON in public buildings or facilities more effectively. Additionally, this could support their attempts to live more sustainably and ecologically.
- **Utility Companies**: SAKOON might be used by energy suppliers to provide their clients with extensive information about their energy usage, encourage energy-saving habits, or develop dynamic pricing schemes based on real-time data on energy use.
- **Research and Development**: SAKOON might be used by scientists for experiments or research on energy use, conservation, or efficiency.
- **Smart Cities**: SAKOON might be widely implemented throughout city infrastructure as part of the smart city project to enable real-time energy monitoring, allowing more effective resource utilization.
- **Energy Consultants**: SAKOON may be used by energy auditors or consultants to provide their customers with accurate and thorough evaluations of their energy use, enabling them to suggest practical energy-saving strategies.

1.9 Industrial Applications

1.9.1 Industrial Significance: Bridging the Energy Management Gap

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The SAKOON system is a ground-breaking invention that has the potential to completely change the way energy management is approached in the industrial sector. The timing of this is crucial as businesses everywhere struggle with inflated energy bills and a pressing need to decrease their carbon footprints. SAKOON offers an intelligent solution that helps companies streamline energy usage, improve efficiency, and contribute to global sustainability goals.

As a critical energy monitoring and management system, SAKOON utilizes advanced sensor technology and IoT integration to provide real-time energy consumption data. This granular view of energy usage patterns can be a game-changer for industries, empowering them to identify and rectify energy inefficiencies, plan maintenance schedules, and predict future energy requirements.

1.9.2 SAKOON: Driving Energy Efficiency and Cost Savings

The crux of SAKOON's industrial significance lies in its potential to deliver substantial cost savings. By providing precise insights into energy consumption, SAKOON enables businesses to take proactive measures in mitigating energy wastage. This, in turn, translates into significant reductions in energy bills, creating substantial cost savings that can be channeled back into core business operations. This potential for cost savings places SAKOON as a vital tool for businesses seeking to enhance their financial efficiency and competitiveness.

Figure 24: Conceptual Representation of Industrial cost saving

1.9.3 Sustainability and CSR: Enhancing Industry Reputation

Moreover, as industries become increasingly conscious of their role in environmental conservation, SAKOON stands out as a tool that aligns with their corporate social responsibility (CSR) goals. By facilitating a reduction in energy usage, industries can significantly lower their carbon emissions, contributing positively to the global fight against climate change. The adoption of SAKOON can therefore enhance a company's reputation as a responsible, environmentally conscious entity, a trait increasingly valued by consumers, investors, and stakeholders.

1.9.4 Anticipating the Future: The Role of SAKOON

Looking ahead, the relevance and importance of SAKOON in the industrial landscape are only set to grow. As energy costs continue to rise and global sustainability goals become ever more stringent, the need for effective energy management systems like SAKOON will be paramount. In addition, as industries increasingly turn to digitalization and automation, SAKOON's compatibility with IoT and other digital technologies makes it a vital part of this futuristic industrial landscape.

Figure 25: Industry 4.O

In essence, SAKOON is not just a response to the current energy challenges facing industries; it is a strategic tool for industries to prepare for and shape their future.

1.10 SAKOON Contribution for United Nation's SDGs

SAKOON's innovative energy management system offers valuable contributions to multiple United Nations Sustainable Development Goals (SDGs). It aligns with these global objectives by driving sustainable change and promoting responsible energy usage, ultimately fostering a more sustainable future.

1.10.1 SDG 9: Industry, Innovation, and Infrastructure

As an innovative solution in the energy sector, SAKOON reinforces SDG 9 by leveraging technology for sustainability. It optimizes energy usage in industrial operations, contributing to sustainable and resilient infrastructures.

Figure 26: Industry, Innovation, and Infrastructure – SDG 9

1.10.2 SDG 11: Sustainable Cities and Communities

SAKOON supports SDG 11 by encouraging sustainable energy practices within households, contributing to the creation of sustainable and resilient communities. It aids in the development of 'smart cities' that manage resources efficiently.

Figure 27: Sustainable Cities and Communities – SDG 11

Overall, SAKOON's energy management solution not only enhances energy efficiency but also strongly aligns with the global sustainability goals set by the United Nations. By promoting responsible energy consumption and contributing to the development of sustainable communities, SAKOON helps shape a more sustainable and resilient future.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a thorough review of the relevant literature related to power metering systems is provided. The review addresses key areas such as hardware/component selection, circuit design for voltage and current measurement, application development, calculation and estimation of usage and cost, as well as remote monitoring of electrical appliances.

2.2 Hardware/Component Selection

In a study conducted by Barman et al. (2018)[1], they introduced an IoT-based smart energy meter that measures and controls energy consumption using ESP 8266, a Wi-Fi module. The energy data collected by this meter is then uploaded to a cloud platform for easy accessibility by consumers and producers. This approach exemplifies the possibilities of incorporating IoT technology into power metering systems, which aligns with the aims of the SAKOON system.

2.3 Circuit Design for Voltage and Current Measurement

Preethi and Harish (2016)[2] highlighted the design and implementation of a Smart Energy Meter (SEM) to address the issue of power theft. They underscored the role of the SEM in conserving energy resources by mitigating power theft, especially in countries like India where it is a prominent issue. Their work provides valuable insights into circuit design for measuring voltage and current.

2.4 Blynk App Development

"IoT Based Electricity Energy Meter using ESP32 & Blynk" is an application that displays Voltage, Current, Power, and total unit consumed in kWh on the Blynk Application Dashboard. This provides an example of how user-friendly and real-time data visualization can be achieved on a mobile application.

2.5 Calculation and Estimation of Usage and Cost

A study by Rauf et al. (2016)[3] highlights the importance of enabling end users to understand the major characteristics of their energy consumption during peak and off-peak hours. This understanding can help utilities maintain load demand in extreme conditions, leading to a more reliable system with improved overall efficiency.

2.6 Remote Monitoring of Electrical Appliances

In a paper by Tedla et al. (2021)[4], they present an interoperable automation system that leverages IoT technology for remote control and monitoring of electrical appliances connected to the power supply system. Transducers within the socket outlets collect critical information regarding the status of the electrical network.

2.7 Detail Review

2.7.1 IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid

The modern world revolves around electricity, an energy source that powers the engines of our civilization. Its importance is beyond argument, central to industrial and economic development, shaping our societies, and defining our lifestyles. The demand for electrical power is ubiquitous across households, industries, institutions, and public facilities. However, the current systems for power distribution in numerous countries have far from optimal configurations.

These setups involve service lines that are directly connected to consumer meters without a comprehensive and sophisticated system for load management. The consequences of these flawed systems are manifold and severe. For instance, they contribute to substantial line losses that stem from outdated transmission and distribution networks, leading to significant energy wastage. Additionally, they result in a lack of consumer control and awareness regarding power demand and energy consumption.

Traditional metering systems that are predominantly in use pose significant limitations. Notably, these systems lack the capability for internal power quality measurement. Such a deficiency leads to severe problems, mainly when dealing with power factor issues. Supply companies often cannot respond promptly to these issues due to the meter's inability to provide real-time data, resulting in delayed reactions, often spanning a month-long period. These issues become even more problematic at the consumer end, especially in domestic sectors. In these contexts, systems for measuring power factors or quality levels are virtually non-existent, furthering the gaps in inefficient energy usage and management.

One of the most severe implications of these shortcomings in power management systems is power theft, a prevalent issue that significantly undermines the efficiency of energy distribution. It is an illicit action that brings enormous losses in terms of revenue for power companies and the broader economy. Power theft is rampant in regions where open-wire connections are standard. Given the constraints of existing metering systems, effectively addressing this problem becomes a significant challenge. As such, there is an urgent need for comprehensive measures to mitigate power theft, thereby reducing its adverse impact on economies and making power distribution systems more robust and secure.

In recent years, home automation has begun to challenge conventional energy management and usage modes. This relatively new concept has been receiving significant attention in the engineering field. The objective of this innovative system is to allow users to monitor and control home appliances remotely via the Internet. Although promising and already offering certain conveniences, this technology does not fully address the need for effective load management systems and real-time power quality measurements. To address these pressing concerns, this research proposes a solution in the form of an IoT-based energy meter. This innovative device seeks to overcome the limitations of conventional meters. The intelligent metering kit proposed here is designed to aid traditional single-phase energy meters. It calculates power values by measuring the load side's voltage, current, and power factor. The calculated power values are then uploaded to an online database. This digital integration significantly improves the accessibility of power usage data for consumers, allowing them to understand better and manage their energy consumption.

A dedicated Android-based application has been developed for end-user control. This application provides a user-friendly platform for consumers to observe resultant values, remotely switch loads, and pay electricity bills. It thus offers more than just convenience; it empowers consumers by granting them more control over their energy usage and bills. This system also facilitates real-time load and power factor monitoring, which has immense potential for enhancing energy consumption efficiency.

Another key feature of this IoT-based energy meter is its innovative billing method. The system incorporates online banking, further simplifying consumers' ability to manage their electricity expenses. The ability to pay electricity bills through the app reduces the hassle for consumers and minimizes the operational expenses of power companies in terms of meter reading and bill delivery.

This suggested system has wide-ranging and perhaps revolutionary ramifications. It introduces a much-needed improvement to power management systems, representing a substantial step forward from the existing situation. The system could substantially mitigate power theft and optimize energy use by improving consumer control and providing real-time data on power quality. It does not just offer a more efficient way to manage energy usage; it potentially revolutionizes energy distribution and consumption.

However, it raises fresh issues and problems, just like any new technology. To improve the system, evaluate its applicability in various situations, and investigate possible integration techniques with the current infrastructure, further study is required. This study asks fascinating concerns about what the future of power management could entail in the IoT era and offers a roadmap for further research in this field.

In conclusion, the proposed IoT-based energy meter represents an innovative and promising solution for improving power management systems. It addresses many issues in conventional metering systems and introduces new capabilities. The potential of this system is enormous, but realizing this potential will require substantial further work and research. This research provides an exciting starting point for this journey towards more intelligent and efficient power management systems.

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2.7.2 Design and implementation of smart energy meter

The literature review in this research paper delves into the design and implementation of a prepaid electricity connection via an intelligent energy meter system. The study explores the potential drawbacks of post-paid electricity connections. It offers an alternative solution: a prepaid system that prompts users to replenish their electricity meters commensurate with the desired electricity usage.

The notion of a prepaid electricity connection isn't new, with several preceding studies tackling similar themes. Notably, Li, X. et al. (2019), in their research titled "Design and Implementation of a Smart Meter and Its Data Transmission System Based on LoRa Technology[5]," underlined the merits of a smart meter system. This subject find resonance in this study. The paper "A Prepaid Energy Meter using GSM" by Arasu, V.T., et al. (2015)[6] examined the application of prepaid meters to discourage wasteful electricity usage extensively.

The main objective is to develop a prototype intelligent energy meter designed to facilitate energy management. The meter is designed to discontinue power supply upon detecting a low or zero balance, a feature intended to foster judicious electricity usage. The energy meter's modus operandi, which involves reading consumption values that are then displayed on an LCD screen along with the current balance, is elucidated in this paper.
Presenting real-time consumption data and balance information aligns with existing literature. For instance, the study by Duquennoy S. et al. (2013) titled "Leveraging IP for IoT: Benefits and Challenges[7]" investigated similar intelligent metering systems and their capacity to provide real-time consumption information to users.

The proposed intelligent energy meter's novelty in this paper lies in its utilization of a digital energy meter that gauge's electricity consumption and transmits pulses proportional to the energy used. An additional feature is an EEPROM memory for balance storage, a crucial function during power outages that prevent data loss.

The paper is organized into two critical parts: hardware and software components. The hardware component involves wiring a keypad, LCD screen, consumption unit, and digital energy meter to the Arduino board. Conversely, the software component includes the coding solutions in the Arduino IDE, a platform lauded for its usefulness in such projects, as Margolis, M. (2011)[8] highlighted in the book "Arduino Cookbook."

The research includes functional block diagrams, mathematical calculations, and physical implementations for the proposed hardware solution. The meter is depicted as generating a frequency of impulses proportional to the consumed power, an efficient way to communicate energy usage to consumers.

Digital energy meters form the core of the hardware solution. These meters produce pulses proportional to the energy consumed, signified by a blinking LED. This mode of operation aligns with the findings of Sharma V. et al. (2018) in the paper "Smart Metering for Next Generation of Sustainable Energy Systems[9]," which detailed the operation of digital energy meters.

The research paper presents a modern approach to managing electricity consumption using an innovative energy metering system that operates on a prepaid basis. The proposed system encourages mindful electricity usage, averting overconsumption and efficiently managing and controlling energy costs.

The paper overviews the intelligent energy metering system's design and implementation, focusing on hardware and software solutions. The system consists of a digital energy meter, an Arduino Uno board, a 16x2 I2C LCD screen, a 4x4 keypad, and a solid-state relay. All are assembled strategically to realize a practical and functional system.

The Arduino Uno board is employed to count and process the digital energy meter's pulses, effectively translating energy consumption into understandable data for the user. Information regarding energy consumption and remaining credit is displayed on the LCD screen, and the keypad allows the user to recharge the system's balance as necessary. The solid-state relay is used for switching the electricity connection based on the balance available in the system.

The paper includes detailed mathematical calculations demonstrating how the system calculates energy consumption. A 1000 imp/kWh pulse rate energy meter is used in the calculations, with a 75-watt bulb connected to the energy meter serving as the load for demonstration purposes. Through these calculations, the research illustrates how the system converts energy consumed into financial cost, informing the user of their spending on electricity.

Regarding software, the paper discusses using the Arduino IDE for pulse detection from the digital meter and consumption calculations. The system employs interruptions to monitor consumption levels and react accordingly when the balance is low. If the system's balance is not recharged in time, the system cuts off the energy supply to the connected unit, preventing overuse. The system also stores balance values in EEPROM to preserve data during power outages.

The research paper outlines an effective and efficient solution for managing electricity usage. The prepaid system, combined with the visual display of consumption and cost, promotes responsible energy usage. The system is well-designed, and its real-time notifications add value by warning users of low balance, giving them time to recharge the system. With the prototype successfully built and tested, the paper is a promising step toward intelligent, cost-effective energy management solutions.

Furthermore, the user-friendly design allows users to recharge their electricity balance and view their consumption details easily. Assembling all components into a single system demonstrates the feasibility of such a system for mass production and usage. The results shown in the paper could have significant implications for consumers and energy providers, providing a practical and innovative solution for energy management.

The literature review discloses that the research paper is a fusion of established notions and novel suggestions regarding prepaid electricity connection and innovative meter systems. It expands upon the concepts of real-time data representation, energy consumption tracking, and prepaid electricity metering while introducing new elements such as EEPROM balance storage. The research stands on the foundation of previous studies while attempting to advance the field of smart energy meters and management.

2.7.3 Domestic Electrical Load Management Using Smart Grid

The ongoing technological revolution in the energy sector, characterized by the evolution of Smart Grid technologies, offers significant boundless opportunities to enhance energy efficiency and reliability. These progressive solutions, aimed at modernizing conventional power grids, employ sophisticated components, including real-time sensor technology for power flow adaptation, Phase Measurement Units (PMUs), and Phasor Data Concentrators (PDCs). By leveraging these advanced tools, grid capacity, and productivity are substantially enhanced, with resilience fortified through improved phase or power flow measurement capabilities.

In the complex web of a Smart Grid system, interconnected transmission components such as load stations and substations are vital players. Their interconnectedness, reinforced by Smart Grid tools, including intelligent sensors, PMUs, and robust communication components, significantly heightens system reliability and power quality. However, more than these hardware enhancements are needed to harness a Smart Grid's potential fully. Instead, it requires complementing hardware infrastructure with innovative Information and Communication Technologies (ICTs), such as tailored protocols and advanced wireless networks. The creation of a communication link between customers and utilities is made possible by integrating ICTs into the grid ecosystem, enabling prompt and effective bi-directional communication.

This strategy not only keeps the lines of communication open between the parties but also gives customers and utilities the capacity to make data-driven choices about energy supply and usage. One practical manifestation of this bidirectional communication is the widespread adoption of smart energy meters. These devices offer a compelling illustration of how Smart Grid technologies have begun to transform the energy landscape. Providing two-way communication that monitors power flow in real time, smart meters give consumers unprecedented control over their energy use. In instances of local distribution generation, smart meters can even guide excess power back into the national grid. This unique feature presents a win-win scenario, benefiting energy suppliers and users by ensuring the most efficient use of available power. With the increasing prevalence of smart meters, it's hard to overlook the role of Advanced Metering Infrastructure (AMI) in driving this technological shift. AMI presents a quantum leap over older systems such as Advanced Meter Reading (AMR), offering capabilities that extend beyond basic consumption tracking. Features such as automatic billing, intricate data logging, and various user-friendly incentives make AMI a linchpin in pursuing an energy-efficient future.

In parallel with the progress on the consumption side, Smart Grid technologies are also making strides in the way we manage renewable energy sources. Consider the example of solar PV systems. The intermittent nature of these sources necessitates using intelligent storage solutions that seamlessly align supply with demand. Commonly used storage devices include batteries, capacitors, and mechanical flywheels. Despite their somewhat high expense, batteries frequently serve as the preferred choice for extended storage owing to their adaptability and diverse applications. Progress in the durability of battery technology also significantly contributes to reducing the overall system expenses, making batteries an increasingly appealing option for sustaining long-term energy reserves.

To further understand the impact of Smart Grid technologies, we must delve into domestic load management. Here, loads are typically classified into three types: baseline, regular, and burst. Baseline loads encompass applications such as lighting, fans, television, and internet modems, which operate as per necessity and can be utilized at any time. Although persistent, these loads do not constitute a significant part of the total load. Regular loads, on the other hand, comprise refrigeration, cooling, and heating loads. These are more variable, tend to fluctuate with weather conditions and account for roughly 15-20% of the total domestic load.

Lastly, busted loads, which are anticipated to operate for specific periods, such as during cooking, heating, washing, drying, ironing, and cleaning. To improve energy efficiency, it's essential to prioritize managing baseline loads for seamless system operation and employ energy-efficient devices for the regular load. Implementing these strategies can increase the system efficiency, saving an estimated 10-30% of total domestic electrical power. One of the key strategies to achieve such efficiency is integrating diverse ICT techniques with demand-side load management techniques. While most people traditionally focus on the generation side, demand-side energy efficiency offers immense potential. However, it requires considerable effort and innovation to fully harness this potential and make the energy system more reliable and efficient.

Reducing the existing load through energy-efficient alternatives can significantly decrease the problem of load shedding faced by countries like Pakistan. Utilities can help increase grid efficiency by focusing on demand-side management, even though they do not directly control the consumer load. Such management involves monitoring, planning, and implementing various techniques to ensure the smooth operation of the system.

With the strategic implementation of these demand-side management strategies, researchers estimate that CO_2 emissions equivalent to those from 16 million cars could be mitigated if the power grid becomes at least 10% more efficient than the existing system. These estimates underscore the environmental significance of these efforts, pointing towards a sustainable energy future.

In conclusion, the transition to Smart Grid, effective load management strategies, and comprehensive ICT integration hold immense promise. This progression paves the way for an era of unparalleled energy reliability, sustainability, and efficiency, emphasizing technological innovation's transformative role in shaping our energy future. As we continually refine and advance these technologies, we incrementally approach this envisioned future of enhanced sustainability and efficiency in energy utilization.

2.7.4 Development of an Internet of Things based Electrical Load Management System

The research article[10] outlines a novel strategy for overcoming the difficulties of contemporary power supply systems. The authors' solution advanced the development of intelligent home systems, which allow remote control and monitoring of electrical appliances utilizing Internet of Things (IoT) technology. The investigation's key findings should be analyzed and condensed in this review.

Understanding the conditions of this investigation's execution is crucial to appreciating its significance. The World Energy Council predicts that in 2040 the power demand will significantly increase. This is mainly due to industries like heating, manufacturing, and transportation shifting towards electricity as their primary energy source. Over a century old, current power supply system's lack transparency and transparent information about appliance energy consumption. Moreover, present remote appliance monitoring and control technologies are often too complex or unaffordable for many consumers. These challenges necessitate an innovative and practical solution, which is precisely what the authors propose.

The IoT-based automation system proposed in the paper capitalizes on the transformative potential of IoT technology to provide controllability, interconnectedness, and reliability. It integrates several elements, including transducers, NodeMCU microcontroller, Wi-Fi transceivers, Raspberry Pi, RFID tags, and an HD night vision camera, to gather essential data about the operation and status of electrical appliances. This data encompasses AC consumption, appliance status, and RFID tag information, offering a comprehensive overview of the system's operations.

The system's brain is the NodeMCU microcontroller, which has an integrated Wi-Fi transceiver. Data from each socket outlet is processed and sent to the Raspberry Pi computer via the central processing units microcontroller. This information and a live video feed from an integrated HD night vision camera enable the power supply system to be observed in real-time.

Each socket outlet in the system has an RC522 RFID module, a non-intrusive current sensor, and a solid-state relay. The RFID module recognizes tagged appliances and communicates their connection status to the microcontroller. Each RFID transponder assigned to an appliance carries a unique alphanumeric code, which aids in identification.

The proposed automation system excels in identifying various power quality issues frequently encountered in electrical networks. By offering a clear view of daily electrical energy usage, it encourages consumers to adopt more efficient energy consumption habits, thereby contributing to energy conservation.

The researchers' meticulous attention to detail extends to calibrating the sensors integrated within the IoT system. Before their integration, the sensors are calibrated using active loads with differing ratings. A digital multimeter (DMM) measures the load's actual current and voltage consumption. At the same time, the Root Mean Square (RMS) value of the sensor's output is calculated and recorded for each load. A subsequent statistical analysis generates a trendline equation of the sensor readings, which aids in developing a C++ function that allows the NodeMCU to convert sensor readings into amperes accurately.

Next, the authors delve into the design of the communication infrastructure. The OSI network model provides the foundation for a data transmission system capable of accommodating the complex requirements of an IoT automation system. The authors analyze and compare a range of wireless protocols, assessing their frequency, data transmission rate, range, power consumption, openness/decency, and module cost.

The authors chose Wi-Fi for the system due to its high data rates, small coverage area, and less complex integration, given the built-in Wi-Fi transceivers in the NodeMCU and the Raspberry Pi. This decision reflects careful consideration of the technical specifications and compatibility with existing system components.

Furthermore, the authors discuss the selection of a suitable application layer protocol for the OSI network model, a critical component responsible for identifying communication partners, resource availability determination, and communication synchronization. The authors consider several messaging protocols crafted specifically for IoT systems, including CoAP, XMPP, MQTT, AMQP, and DDS protocols.

The MQTT protocol was chosen for its suitability in handling sizeable wireless sensor networks managed by a single server. Based on the Publish/Subscribe model, the MQTT architecture involves three elements: the Publisher, Broker, and Subscriber. The broker implemented in the proposed system is MOSQUITTO, a lightweight and open-source message broker that uses the MQTT protocol.

The depth and breadth of the authors' research are highlighted in this section, emphasizing their careful selection and implementation of the communication infrastructure in the automation system. This thoughtful approach, along with its intricate system of interconnected components, enhances the reliability and efficiency of its IoT system.

In conclusion, the interoperable automation system leveraging IoT for remote control and monitoring presents a strong case for modernizing power supply systems. It offers a comprehensive, affordable solution for remote appliance management and promotes energy conservation, thereby addressing many current challenges in power supply systems. Future research should optimize this system for various scenarios and enhance its energy efficiency and user-friendliness. The presented paper thus constitutes a significant contribution to IoT and power supply systems, offering an innovative solution to revolutionize how we monitor and control our electrical appliances.

2.7.5 Multi-Agent Systems for Resource Allocation and Scheduling in a Smart Grid

From the beginning of humanity, energy has been a fundamental need, especially in modern society. This paper[11] highlight the pivotal transition from pollutant-laden, non-renewable fossil fuels to purer, renewable energy alternatives is not just an environmentally conscious choice but a vital necessity for the well-being of our planet. Given the challenges of climate change and unsustainable energy usage, a clear and robust global initiative is unfolding toward more environmentally friendly energy options.

The accelerating pace of energy consumption further compounds this urgency. With expanding economies and exponential technological advancements, the global thirst for energy intensifies. It's a complex predicament; juxtaposed with the environmental threats posed by our energy sources, our need for energy to drive progress makes it critical for us to explore renewable energy options and devise inventive strategies for efficient and sustainable energy utilization.

Traditionally, high-capacity systems depend on the Supervisory Control and Data Acquisition (SCADA) system. The SCADA system, a centralized platform, was pivotal for making intelligent decisions in the energy sector. However, the centralized nature of SCADA systems meant that many computational and decision-making responsibilities were placed on the central processor. This often led to inefficiencies, especially when the system processed vast real-time data.

The limitations of the SCADA system paved the way for the emergence of Distributed Control Systems (DCS). Instead of relying on a single centralized system, DCS distributed the responsibilities among smaller controllers. Such a setup proved to be versatile, more reliable, and more secure. From an economic standpoint, DCS became a cost-effective alternative to traditional centralized systems. This innovative approach to energy management provided the foundation for the evolution of "Smart Grids (SGs)."

Smart Grids are a testament to technological advancement in the energy sector. These grids are not just systems for energy distribution; they are comprehensive platforms that leverage advanced sensing, superior control mechanisms, and state-of-the-art communication technologies. The shift from conventional to intelligent grids marks a substantial paradigm shift in the energy industry. Unlike their predecessors, intelligent grids emphasize real-time monitoring, foster continuous dialogue between energy providers and consumers, and, most importantly, prioritize using renewable energy sources.

The energy landscape of SGs is diverse, harnessing power from the sun, wind, and underground heat. The beauty of smart grids is their ability to tap into multiple energy sources, offering unparalleled reliability. Moreover, decentralizing power systems, a defining feature of SGs, has democratized energy generation. Today, consumers are not just passive recipients of energy; they can generate their energy and feed the excess back into the grid. However, the journey of intelligent grids is full of challenges. The fact that SGs largely depend on consumers for investment in energy-generation infrastructure has been a topic of debate and criticism.

Enter Multi-Agent Systems (MAS). These systems, defined by their autonomous intelligent agents, can collaboratively solve complex problems, offering a novel solution to the challenges faced by smart grids. MAS has demonstrated immense potential in streamlining power system operations. Their versatility is evident from their wide range of applications, from power market modeling to network protection and troubleshooting.

Integrating MAS into smart grids has catalyzed the development of sophisticated tools like Intelligent Energy Electronic Devices (IEDs), which are crucial in managing power flow and ensuring optimal equipment functioning. MAS's real-time energy management capabilities ensure that energy grids remain secure and that faults are handled efficiently. Their applications also permeate realms like energy scheduling, pricing, and marketing. Recent innovations have also highlighted the potential role of MAS in seamlessly integrating SGs with electric vehicles and building energy systems.

However, as with any transformative technology, the broader implementation of MAS is fraught with challenges. The coordination between various agents in a MAS, ensuring the security of these systems, and equitable distribution of tasks are hurdling that researchers and engineers are striving to overcome. These challenges are not just technological; they intertwine with regulatory, environmental, and economic considerations that redefine SG technology.

One can only discuss modern energy management using home power generation systems. In the wake of significant power outages, these decentralized energy generation units have emerged as more than alternatives; they are becoming mainstays that supplement the existing power infrastructure. Such advancements underscore the need for intelligent management systems that ensure energy efficiency, optimize demand profiles, prevent energy losses, and are cost-effective. Integrating machine learning and artificial intelligence into these systems will further empower them to troubleshoot, diagnose, and rectify network issues.

In conclusion, the fusion of MAS with smart grids signifies a promising future in energy management. The path is riddled with challenges, but the potential of MAS in revolutionizing how we produce, distribute, and consume energy is enormous. As global communities collectively work toward a sustainable future, MAS stands at the forefront, ready to reshape the energy landscape. This comprehensive exploration underlines the importance of ongoing research aimed at surmounting the challenges faced by MAS. Overcoming these challenges is not just about optimizing the performance of MAS in intelligent grids; it is about fully unlocking their potential to redefine energy management for a sustainable tomorrow.

2.7.6 Integrating Smart Energy Management System with Internet of Things and Cloud Computing for Efficient Demand Side Management in Smart Grids

This paper[12] highlight the emerging challenges of high energy demand and increased energy costs necessitate intelligent strategies for tracking, controlling, and conserving energy. Demand-side management emerges as a crucial strategy in averting significant supply disruptions and enhancing energy efficiency. This perspective is reinforced by Palensky and Dietrich's study, which underlines the crucial role of demand-side management in energy conservation. The study implies that with the proper implementation of demand-side management, energy efficiency can be substantially improved while avoiding the adverse effects of supply disruptions (Palensky & Dietrich, 2011)[13].

An integral part of demand-side management is an intelligent energy management system that can help cut expenses, fulfill energy requirements, formulate customers' energy consumption patterns, and respond to energy-saving algorithms and directives. Moreover, the Internet of Things (IoT) has shown immense potential in effectively managing energy consumption across various industrial, commercial, and residential sectors. Liang et al. (2019)[14] illuminate the contributions of IoT to energy efficiency in their work. Their emphasis on the significant contribution of IoT to enhancing energy efficiency aligns with the central concepts of this study.

Integrating an energy controller with an IoT middleware module can result in efficient demand-side management. The controller, installed with numerous sensors and actuators, can collect data on energy consumption from each intelligent device. Faria and Vale (2018) provide insights into using energy controllers for optimizing energy consumption, specifically concerning air conditioning systems. They also discuss the role of IoT middleware in collecting and analyzing energy data, which informs the proposed system's architecture.

By focusing on air conditioning systems, which contribute significantly to electricity consumption, particularly in regions like Pakistan, the energy conservation potential of the system is validated. This intelligent combination of the IoT, demand-side management, and innovative energy management systems facilitate real-time monitoring, allows better control over the air conditioning systems, and contributes to cost savings, environmental benefits, and prolonged equipment life. When tested and implemented in four buildings, the proposed system demonstrated substantial energy savings ranging from 15% to 49%, underlining the system's significant benefits.

In conclusion, the reviewed literature offers valuable insights into developing an intelligent energy management system. The integration of demand-side management principles, intelligent energy management systems, IoT applications in energy management, and the incorporation of energy controllers and IoT middleware significantly guide the design and implementation of this project. The continuous review and analysis of literature in this field will further shape the direction and outcomes of this project.

2.7.7 IOT Based Smart Grid Monitoring Using Arduino Controller

The research encapsulates the conversion of load energy consumption readings over the internet, eliminating human involvement in power maintenance. Utilizing the Internet of Things (IoT), allowing the connecting of standard devices makes this feasible. These devices may be monitored and analyzed remotely to bridge the gap between the actual world and computer-based systems. The importance of IoT keeps expanding as the market experiences an exponential rise in wireless devices (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014)[15].

The proposed system allows the user to monitor energy consumption in watts through a webpage by providing a channel id for the load. The webpage uses THINGSPEAK analytics to analyze energy usage, which delivers visualization of the energy use metrics. These insights have been further validated by Patel and Patel (2015)[16], who discuss the role of analytics in transforming raw energy data into actionable information.

The system uses an Arduino microcontroller, a testament to its flexibility and robustness, essential for handling real-time energy data (Banzi & Shiloh, 2014)[17]. In this system, the Wi-Fi unit conducts IoT operations by transmitting the energy data of the load to the webpage, which can then be accessed through the device's channel id. This mechanism demonstrates the utility of Wi-Fi communication in real-time energy data transmission, as underscored by Hussein et al. (2017)[18].

The concept of consumer-driven management by providing real-time energy usage data. This way, consumers can make informed decisions and adopt energy-saving practices. Earlier research by Strengers (2013)[19] shows the positive impact of similar initiatives, where consumer awareness of their energy use patterns leads to more efficient usage.

Electricity is increasingly demanded in the contemporary global environment for various uses, including agriculture, industry, home usage, healthcare, etc. The difficulty of managing power maintenance and demand has increased, therefore. Power use must be reduced as much as feasible. The proposed system presents a technical twist to conventional energy meters using IoT technology.

Additionally, it addresses problems like electrical theft, which costs capital. The main goals that may be accomplished for a better system are monitoring, optimizing power use, and decreasing power waste. The suggested system aims to support the effective and sustainable use of energy resources. Capitalizing on IoT technology, it aims to improve the accuracy and efficiency of energy consumption data, reducing power wastage (Pérez-Lombard, Ortiz, & Pout, 2008)[20].

In conclusion, the research literature strongly supports employing IoT and analytics to address energy consumption issues. The use of Arduino microcontrollers, Wi-Fi communication, and real-time energy data analysis, coupled with the principles of consumer-driven management, contribute significantly to optimizing power usage and reducing power wastage. IoT technology in energy meters presents an innovative approach to dealing with increasing power demand and the need for efficient energy consumption.

2.7.8 Optimal Energy Management System of IoT-Enabled Large Building Considering Electric Vehicle Scheduling, Distributed Resources, and Demand Response Schemes

Energy management in large buildings constitutes a complex, multifaceted problem. With sprawling infrastructure and diverse energy demands, these buildings often fall beyond the scope of traditional energy management methods. Consequently, innovative and technology-driven solutions are required to meet these requirements efficiently and sustainably. As such, an integrative system encompassing solar Photovoltaics (PVs), energy storage systems, and electric vehicles is emerging as a significant contender in pursuing more sophisticated methods.

Solar PVs have long been recognized for their benefits, primarily their contribution to a greener environment and cost-effectiveness. In the face of escalating concerns over climate change and the associated need for more sustainable energy solutions, the importance of renewable energy resources like solar PVs cannot be overstated (Hernandez, Bird, & Adler, 2012)[21]. However, their role in large buildings' energy portfolios has gained prominence recently. Solar PVs provide a compelling solution for these buildings as they can be installed on rooftops, utilizing otherwise wasted space. Furthermore, the energy produced can be used directly, reducing the need for transmission and, consequently, energy losses (Alstone, Gershenson, & Kammen, 2015)[22]. Integrating solar PVs in significant buildings' energy systems is becoming an increasingly significant field of research and development as renewable energy technology quickens.

The energy management systems of significant buildings become even more complicated and provide new opportunities when they include energy storage devices and electric cars. Batteries and other energy storage devices enable storing extra energy produced while demand is low for later use. The resilience and efficiency of the energy system are improved by the capacity to balance supply and demand in real-time (Budischak et al., 2013)[23]. Similarly, when connected to the grid, electric vehicles can function as movable energy storage units, providing a flexible resource to aid demand response strategies (Pearre et al., 2011)[24]. However, integrating these elements requires careful management and coordination to maximize their potential benefits.

In this context, the role of demand response (DR) strategies, like real-time pricing (RTP), critical peak pricing (CPP), and time of use (ToU), is pivotal. DR strategies can significantly increase energy efficiency by providing consumers with price incentives to reduce or shift their electricity use during peak periods, thereby aligning demand more closely with supply (Borenstein, Jaske, & Rosenfeld, 2002)[25]. While the potential of these strategies is well established, their dynamic nature and impact on operational costs are often overlooked aspects that deserve further investigation. In the paper under discussion, these dynamic DR schemes have been incorporated into the model, offering a more comprehensive approach to energy management.

To handle the complexity and multifaceted nature of this integrative system, linear programming (LP) has been utilized. As a mathematical method, LP has found extensive use in resource allocation and decision-making problems across various fields, including energy management. It provides a rigorous and systematic approach to optimizing the system, considering its constraints and objectives (Dantzig, 2002)[26]. The proposed system can be accurately modeled and optimized by formulating the energy management problem as a linear program.

The results obtained from the model indicate that the RTP scheme achieves the highest savings (58%) compared to CPP and ToU. This finding aligns with previous research, suggesting that by reflecting the real-time electricity production costs, RTP can encourage more cost-effective and efficient electricity consumption (Borenstein, 2005)[27]. However, this research also brings attention to the dynamic nature of RTP, adding a novel perspective to understanding these strategies.

The suggested solution further highlights the model's efficiency by reducing operating expenses and greenhouse gas (GHG) emissions. Numerous research has confirmed the link between using renewable energy and reducing GHG emissions .The proposed model aligns with this trend by integrating renewable energy resources and adopting DR strategies, further strengthening its potential.

However, achieving the efficient operation of such a complex system requires robust enabling technologies. In this regard, the Internet of Things (IoT) is necessary. With many sensors, actuators, and other storage and protective components, IoT brings intelligence and interactivity to the energy management system. It provides end-users with detailed real-time information, empowering them to make more informed decisions regarding their energy consumption (Sisinni, Saifullah, Han, Jennehag, & Gidlund, 2018)[28].

Beyond large buildings, the versatility of IoT extends to various domains, including industries, healthcare centers, and smart cities. The ability to gather, evaluate, and analyze data from multiple devices enables more effective and sustainable energy usage. This data-driven method allows the creation of more specialized and efficient energy-saving programs by offering insightful data on end-user energy usage behavior.

In conclusion, an integrated approach to energy management, encompassing renewable energy sources, dynamic DR strategies, and IoT technologies, offers a promising solution for large buildings. The study's findings show the possibility for lower operating expenses, greenhouse gas emissions, and higher energy efficiency. But this system has some limitations, including the legal issues surrounding the adoption and execution of DR strategies, assembling various technologies, cash, and others. As a result, detailed research is required. Future work should enhance these systems' performance and scalability and evaluate their application and influence in the real world. These interconnected systems will become crucial in helping us meet our energy and environmental objectives as knowledge and technology advance.

Chapter 3

METHDOLOGY

3.1 Research and Planning

The initial stage of this project was an extensive study of the power metering systems currently available on the market, customer requirements, and the capabilities of existing technologies. Current technologies' capabilities, advantages, and disadvantages were assessed, identifying any areas the SAKOON system could enhance.

This necessitated understanding the technical specifications and standards in the power metering industry. The SAKOON system's design and development stages were influenced by the knowledge gained during this stage, which helped to ensure that the SAKOON system would be well-suited to its target audience and capable of addressing identified gaps in the present landscape of energy metering systems.

3.1.1 Market Research

A detailed market study of current energy metering systems was conducted before the design and development process began. The existing technologies, their functionality, user feedback, and pricing structures were analyzed. Focus was given to the features they provide, such as real-time monitoring, device integration capabilities, mobile or online interfaces, and energy-saving techniques.

Figure 28: Energy Meter

Figure 29: Acuvim II

Figure 30: Electricity Management System

Some of the products with their features are listed below:

Table 1: Related Products with their Features

FEATURES	DEVICES		
	Energy Meter	***Electricity Management System***	***Acuvim II***
Real Time	Yes	Yes	Yes
Integration with Mobile App/Web Dashboard	The platform is not accessible via a web-based or mobile app.	The platform is currently accessible via a web-based dashboard and mobile application. But will be available when user is on same Wi-Fi.	The platform is currently accessible via a web-based dashboard and does not yet extend to a mobile application.
Load Management Technique	Does not support any suggestion regarding load management	Notify the user for manual load management or automatically shut down everything connected with the device	Help user to analyzing Industrial Dashboard for manual load management,
Cost Estimation	No	No	No

3.1.2 Evaluation of User Needs

Understanding the requirements of potential users was a critical component of the research process. User surveys, interviews, and market trend analyses were all part of this evaluation. The aim was to understand the issues users face with current systems, their expectations, and the additions they would find most beneficial. This process illuminated what an ideal power metering system would need to meet user requirements.

Table 2: User Need Analysis

Method of Evaluation	Key Findings	User Expectations	Beneficial Additions
User Surveys	Users struggle with inaccurate readings in current systems	Users expect real-time accurate readings	A feature to monitor energy usage trends over time
Interviews	Users face difficulty in comprehending complex meter readings	Users expect an easy-to-understand, user-friendly interface	An intuitive dashboard with simplified metrics and visualizations
Market Trend Analysis	Current systems lack efficient energy usage predictions	Users expect predictive analysis for future energy planning	A feature that uses AI to predict future energy consumption based on past trends

3.1.3 Technology Evaluation

A thorough evaluation of the existing technologies was conducted, identifying their advantages, drawbacks, and the level of user demand satisfaction. This included analysis of hardware components such as sensors and microcontrollers, software platforms such as mobile applications and web dashboards, and data analysis tools like real-time monitoring and cost estimation.

The following table gives a technology evaluation:

Table 3: Technology Evaluation

Technology Type	Examples	Advantages	Drawbacks
Hardware Components	Sensors, Microcontrollers	Accurate data collection, automation	Limited processing capabilities, physical wear, and tear
Software Platforms	Mobile Apps, Web Dashboards	User-friendly, remote access	Dependent on device compatibility and internet connection
Data Analysis Tools	Real-time monitoring, Cost estimation	Enables immediate action, financial management	Accuracy dependent on data quality, need constant updates

3.1.4 Analysis of Gaps

After the market research, user needs, and technological evaluations, a gap analysis was carried out to identify opportunities for the SAKOON system. This analysis revealed where existing products fall short in terms of meeting user needs, system functionality, or technical capabilities. The goal of this analysis was to identify unique market niches where SAKOON could provide value. The following gaps are identified after researching products in the market and interacting with users:

Table 4: Gap Analysis

User Needs	Current Market Solutions	Identified Gaps	Potential Value Provided by SAKOON
Real-time energy tracking	Only some systems provide real-time tracking	Inconsistent and not universally available	SAKOON can provide consistent real-time energy tracking
User-friendly interface	Complex interfaces, not user-friendly	Users require easier interaction with the system	SAKOON can provide a simple and intuitive interface
Cost-effective solutions	High-end solutions are expensive	Affordable solutions with high functionality are lacking	SAKOON can offer high functionality at a competitive price

3.1.5 Understanding Technical Standards and Requirements

A comprehensive understanding of technical requirements and industry standards was essential to ensure that the system designed would comply with all relevant regulations and perform safely and effectively. This included an overview of data security policies, national and international standards for power metering systems, and any regulations controlling the use and transmission of energy data.

Table 5: Technical Requirement and Industrial Standard

Technical Requirements and Industry Standards	SAKOON's Compliance
Data Security Policies	SAKOON is designed with robust data protection measures to secure user data
National and International Power Metering Standards	SAKOON complies with all relevant national and international standards for power metering systems

3.2 System Design

Based on the results of the research, the SAKOON system was designed, including its hardware components, software platforms, and data analytics capabilities. This phase involved creating detailed schematics of the hardware interface, outlining software functionality, and defining the techniques that would be used for data analysis.

3.2.1 Hardware Design

The hardware, a key component of the SAKOON system, is mainly comprised of sensors and microcontrollers.

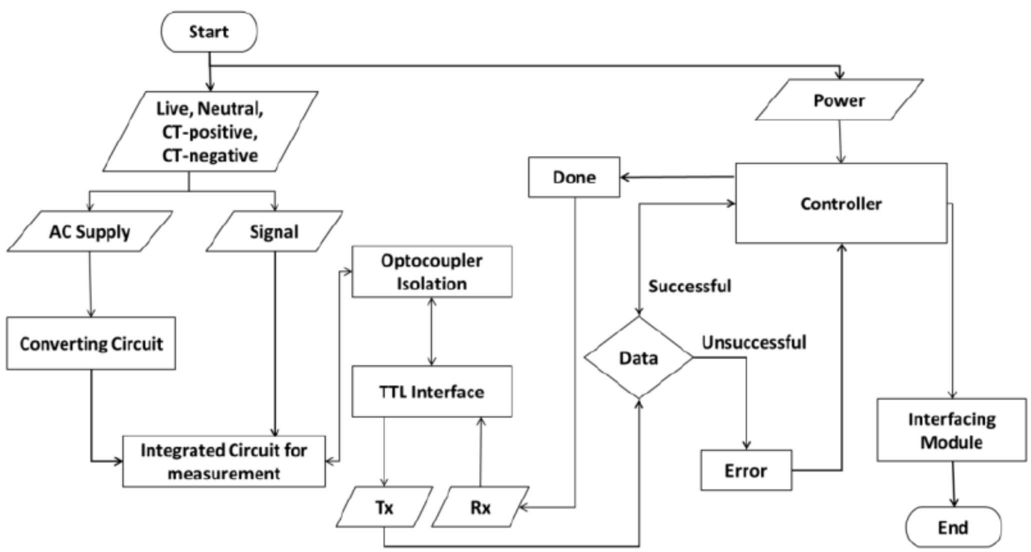

Figure 31: Flowchart for overall working of Hardware

1. **Sensor Design:** The sensors were used to measure important readings like voltage and current with features like precision, dependability, and lower power consumption.

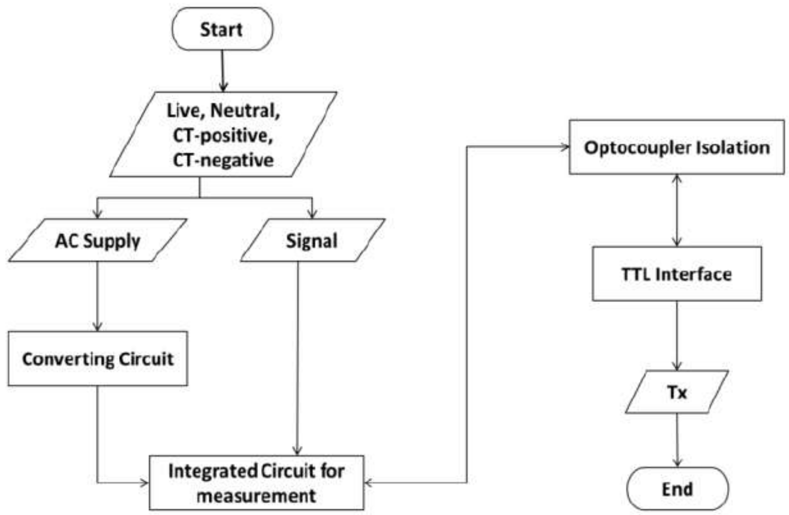

Figure 32: Flowchart foe working of Sensor Module

2. **Microcontroller Design:** The microcontroller analyses the information gathered by the sensors. The microcontroller's design took several factors into account, including processing speed, memory capacity, power requirements, and an effective communication protocol.

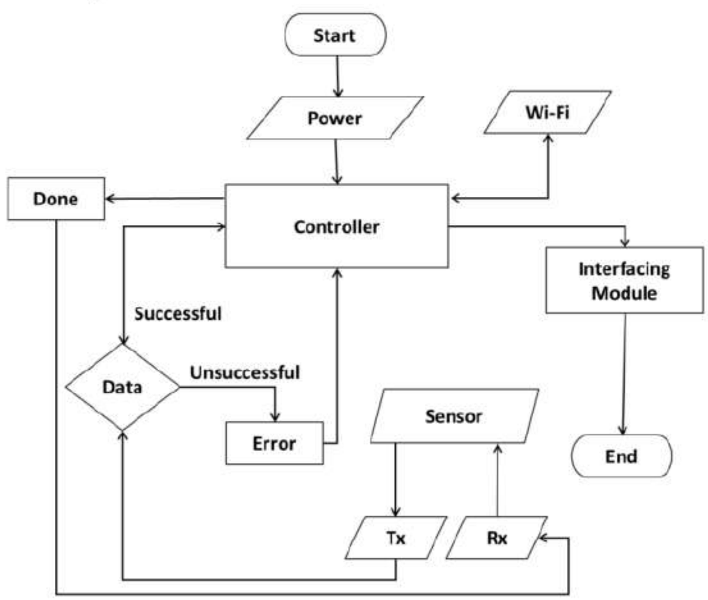

Figure 33: Flowchart for working of Microcontroller.

3.2.2 Software Design

The software platforms of the SAKOON system included a web-based dashboard and a user-friendly mobile app. Both platforms were designed to provide users with real-time access to critical energy statistics in a visually appealing and approachable manner.

Figure 34: Mobile Appliction (In Development Phase)

2. **Web Dashboard Design:** Users can monitor their energy usage from any internet-connected device via the web-based dashboard. Its functionality is like the mobile app's but may include additional features designed for a larger screen, such as in-depth energy reporting and analytics.

Figure 35: Web Dashboard UI (Under Development)

3.2.3 Design of Data Analytics

The data analytics capabilities of the system were designed to provide users with meaningful insights. This required defining the techniques and algorithms for analyzing the collected energy data, including real-time monitoring, predictive analysis, cost estimation, and formulation of energy-saving measure recommendations. These functions were designed to operate seamlessly and provide valuable insights.

3.2.4 System Architecture

Based on the designs of the hardware components, software platforms, and data analytics capabilities, a detailed system architecture was developed. This architecture provided a comprehensive overview of the SAKOON system's functionality by outlining the interactions between each component and the user.

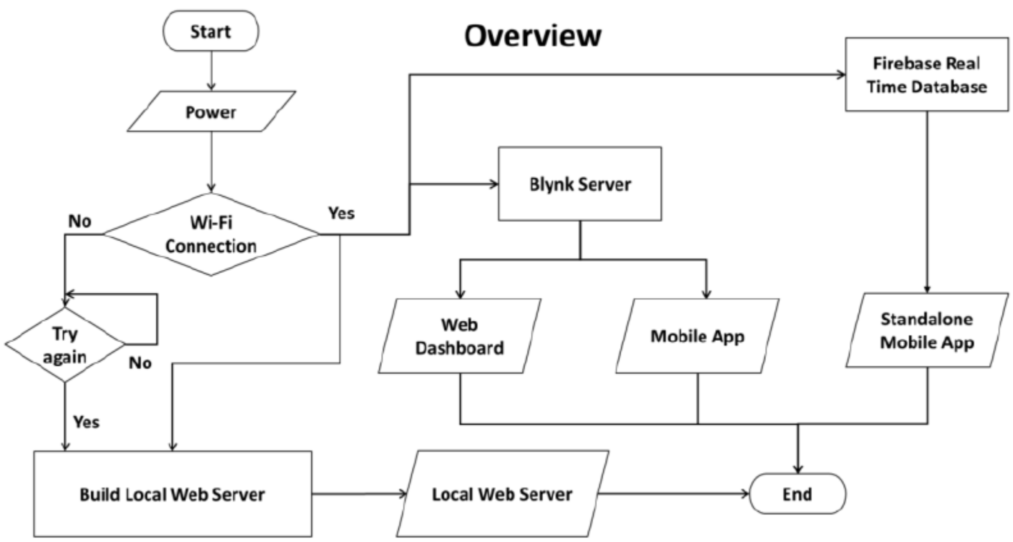

Figure 36:Flowchart overall system working.

3.3 Hardware Development

The assembling of the hardware components marked the beginning of the development phase. A sensor and a microprocessor were included in the hardware for data collection and processing, respectively. These elements were carefully integrated, providing the precise and effective gathering and processing of energy data.

3.3.1 Sensor Unit

One of the earliest phases in the hardware development process was the sensor module's assembly. These sensors were created to precisely monitor a variety of power usage-related characteristics. The sensors were carefully chosen to be strong, dependable, and accurate. To avoid any data errors, their integration into the system was done carefully.

Figure 37: Sensor Module - PZEM 004t

3.3.2 Integration of Microcontrollers

The microprocessor, acting as the system's brain, was integrated after the sensors were put together. The microcontroller's purpose was to quickly and effectively process the data gathered by the sensors so that it was prepared for analysis. The microcontroller was carefully chosen for its function and carefully integrated with the rest of the equipment.

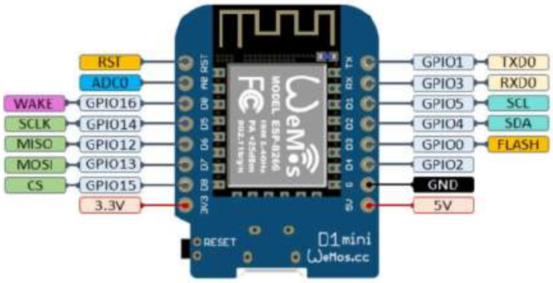

Figure 38: Microcontroller - Wemos D1 mini

3.3.3 Hardware testing

In-depth hardware testing was done once the sensors and microcontroller were put together and integrated. To assure the system's dependability and accuracy in gathering and processing energy data, intensive testing was done. Before going on to the software development phase, any problems or malfunctions discovered during the testing phase were swiftly fixed to guarantee the hardware components functioned as intended.

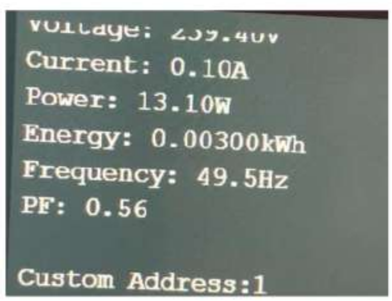

Figure 39: Hardware Testing on Serial Monitor

3.3.4 Final Assembly

The final assembly of the whole system was carried out after the successful conclusion of the testing on each hardware component. For everything to work together, all hardware components had to be integrated. To ensure that the hardware was prepared for the next phase of software development and data processing, the complete system underwent another round of extensive testing after final assembly.

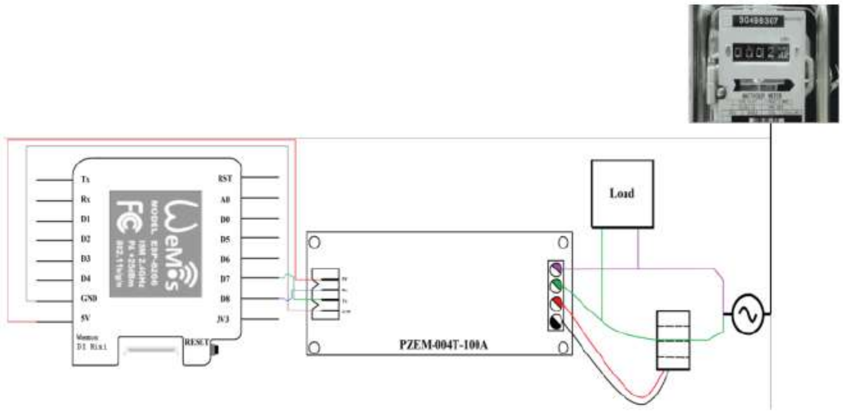

Figure 40: Hardware Final Assembly

3.4 Software Development

After the hardware components had been developed and tested successfully, the software development phase was started. A mobile application and a web-based dashboard were the two main platforms that needed to be designed and developed throughout this project. A cost estimation module was also developed; it was intended to calculate energy costs based on usage and market prices. The software's user-friendliness and data display in an aesthetically pleasing and understandable style were key design considerations.

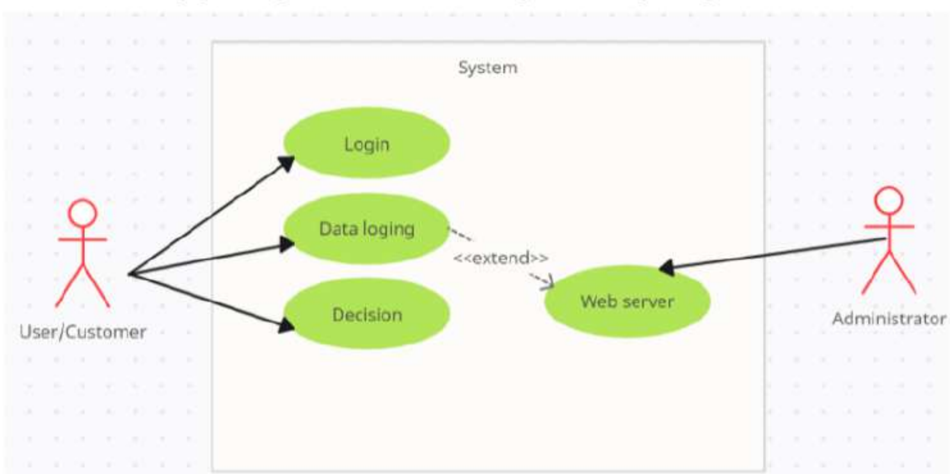

Figure 41: Use Case Diagram

3.4.1 Development of Mobile Applications

Software development includes app development which customers to obtain real-time energy information on their smartphones. It was created to provide customers with interactive GUI, charts, and other visual aids so they could readily comprehend their energy consumption. Before being released, the mobile application underwent extensive testing to verify its usability, performance, and usefulness.

It was decided to use the Agile software development technique. The iterative creation and testing of software in smaller, more manageable portions is a common practice in the field of software engineering, known as agile. This makes it possible for the team to react to modifications and new needs throughout the development process swiftly and efficiently.

Here is a more thorough explanation of the Agile software development process:

3.4.1.1 Adoption of the Agile Methodology

The flexibility, reactivity to change, and customer satisfaction emphasis of the agile approach define it. The development team adopted an iterative method for the SAKOON project, with each iteration including a unique set of tasks.

3.4.1.2 User Story Creation

User story creation was the first step in the Agile development process. These were succinct, straightforward explanations of a feature or function from the viewpoint of the user. The team used user stories to assist them in staying focused on the requirements and experiences of the end user throughout the development process.

3.4.1.3 Iterative Development and Testing

The group broke up the software development process into several iterations, commonly known as sprints. The team determined the user stories and tasks to be accomplished during each sprint at the planning meeting that preceded each sprint. The features were then created by the team and tested throughout that sprint.

3.4.1.4 Adding a Real-Time Database

During the software development phase, a real-time database was incorporated. The online and mobile apps accessed this database to give users the most recent statistics on energy use. It held the data gathered by the hardware in real-time.

3.4.1.5 Networking

A networking component was also a part of the software, which made it easier to move data from the hardware to the software platforms and from those platforms to the database.

3.4.1.6 Continual Criticism and Adjustments

Input from stakeholders (supervisor, co-supervisor, and faculty) and end users was often asked while using the Agile approach. This feedback was used to adjust the program while it was being produced, rather than waiting till the project was finished to make important modifications.

Table 6: Agile Development

Development Stage	Description
Adoption of the Agile Methodology	The Agile methodology was chosen for its flexibility, ability to react quickly to changes, and emphasis on customer satisfaction. This method involves iterative development, with each iteration having a unique set of tasks.
User Story Creation	User stories, simple and concise descriptions of a feature from a user's perspective, were created. These helped to keep the focus on the end-user's requirements and experiences during the development process.
Iterative Development and Testing	The development process was broken down into multiple iterations, or sprints. The user stories and tasks to be completed in each sprint were determined during the preceding planning meeting. The team then developed and tested the features within each sprint.
Addition of a Real-Time Database	A real-time database was integrated during the software development process. The web and mobile applications utilized this database to provide users with up-to-date energy usage statistics. It stored the data collected by the hardware in real time.
Networking	A networking component was included in the software to facilitate the transfer of data from the hardware to the software platforms, and from those platforms to the database.
Continuous Feedback and Adjustments	Throughout the Agile process, feedback from stakeholders (including supervisors and faculty) and end users was frequently sought. This feedback was used to adjust the program during its development, rather than waiting until after its completion.

3.4.2 Creation of Web-Based Dashboards

A web-based dashboard was created concurrently with the mobile application. Users of this platform will be able to check their energy use from any internet-connected device. The dashboard offered visualizations of energy statistics and consumption trends, just as the mobile application did. The style was made to provide a thorough view of energy reporting and analytics that would be appropriate for a bigger screen. To guarantee its faultless functioning, security, and user-friendliness, the dashboard completed several testing phases.

3.4.3 Development of the Cost Estimation Module

The cost computation module was a key component of the SAKOON system. This module was created to make use of the energy data gathered and, using the current energy pricing, to provide users with an estimate of their energy expenses. This module's correctness was crucial; thus, it was carefully created and tested to guarantee its accuracy and dependability.

3.5 Testing and Debugging of Software

To assure the program's dependability, performance, and security, intensive testing and debugging procedures were implemented after the construction of the software components. Before going on to the system integration phase, any found faults or performance problems were swiftly fixed to guarantee the software components worked as intended.

3.5.1 White Box Testing

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As part of the software testing process, white box testing—also referred to as transparent box testing or structural testing—was used. This method focused on analyzing the logic and internal structure of the code. White Box testing is applied on certain software components to ensure that the code was working as intended. This included evaluating database interfaces, validating the proper data flow throughout the system, and testing conditional and loop logic.

3.5.2 Black Box Testing

This method did not consider the internal code structure while evaluating the software's functioning. It evaluated if the program complied with the criteria, reacted appropriately to inputs, managed errors, and produced the desired results.

3.5.3 User Interface and Experience Design

The design of the user interface and user experience received considerable consideration throughout the software development process. The platforms were intended to be simple to use and comprehend. User input was valued and utilized to hone and enhance the mobile applications and web-based dashboard's overall user interface and user experience.

3.6 Hardware and software integration

The project steps red the integration phase once each hardware and software development step were finished. This key phase filled the gap between sensor-based data gathering and software platform-based data visualization and analysis.

After completing this phase, the SAKOON system was able to collect real-time data on energy use, analyze it, store it in a real-time database, and show it on the software platforms for in-depth study and intuitive visualization.

3.6.1 Using the Microcontroller to Program

The microcontroller's programming was the main effort at this point. To allow the microcontroller to comprehend sensor outputs, precisely analyze the collected data, and securely communicate it to the authorized software platforms, the team created a new software code.

3.6.2 Establishing a Network Connection

A solid network connection was created to enable the real-time data flow from hardware to software. The team made sure the microcontroller could communicate data reliably using the appropriate networking protocols, enabling the mobile app and online dashboard to provide real-time energy use statistics.

3.6.3 Integrating a Real-Time Database

The system's integration with a real-time database was the project's main objective. The microcontroller-processed data was kept in this database and made available to the software platforms as required. It made sure that both history and current data were accessible to the software platforms, allowing for in-depth data analysis and visualization.

3.6.4 Data Integrity Verification

Rigid testing procedures were implemented to preserve data integrity throughout the data transmission process. These tests made sure that the software platforms correctly represented the sensor- and microcontroller-processed data. To maintain the system's accuracy and dependability, discrepancies found throughout this testing were thoroughly investigated and fixed.

3.6.5 Ensuring a Stable and Reliable Connection

The success of the system depended heavily on the hardware and software components having a strong and dependable connection. To verify the dependability and stability of the data connection, which is essential for real-time data updates on the software platforms, the team put rigorous connectivity standards into place and exhaustively tested the system under various circumstances.

3.6.6 Coordination of Hardware and Software Activities

The synchronization of the activities of the hardware and software components was a crucial component of the integration process. This synchronization made it possible to create schedules for data collection, processing, and visualization that ran without interruption and efficiently.

3.7 Testing and Debugging

After integration, it underwent a thorough testing and debugging process. This phase's goal was to make the system deliver accurate and trustworthy data on energy use and operate as planned. With the ability to provide accurate and practical energy usage statistics to end users, the SAKOON was made robust, dependable, and deployment ready.

3.7.1 System testing

A thorough system testing procedure was performed on the constructed system. This included looking at the system rather than simply its parts. It evaluated the cohesion and performance of the fully integrated system, confirming that the hardware and software parts communicated effectively and consistently carried out their intended functions.

3.7.2 Performance Testing

Performance testing was done to evaluate the SAKOON's effectiveness and dependability under different loads and situations. By doing this, the system was guaranteed to function flawlessly under normal operating conditions as well as under adverse circumstances or excessive loads.

3.7.3 Functional Testing

Functional testing ensured that the system was operating in accordance with the functional specifications. The SAKOON's features and functions were all put to the test to make sure they worked as planned and behaved as predicted.

3.7.4 Testing Network Connectivity

Considering the crucial part that network connection plays in the SAKOON's real-time data transmission. Testing of network connectivity was done. This evaluated the system's real-time data capabilities and assured smooth and continuous data movement between the hardware elements and the software platforms.

3.7.5 Debugging

A crucial step in the testing procedure was the debugging phase. It involves locating, isolating, and fixing any problems that were discovered during the testing phases. If a problem was found, it was initially investigated to ascertain its root cause before a fix was applied. The system was retested after these adjustments to be sure the problem had been entirely fixed.

3.7.6 User Acceptance Testing

The system was tested with actual users in the real-world. To ensure that the system has good UX and meets all the requirements of the end user. Feedback from this testing phase was very helpful in identifying possible areas for development and how the user interacts with the system.

Chapter 4

TECHNICAL CONCEPT AND TOOLS

4.1 Power Electronics

Power electronics deals with the study and design of electronic circuits and systems that convert and control the flow of electrical energy. This branch of electronics revolves around the transformation of electric power into a form that can be conveniently used. The technology utilizes solid-state electronics for the control and conversion of electric power. Power electronics played a pivotal role, primarily implemented through the PZEM sensor module, responsible for measuring energy parameters.

4.1.1 Current and Voltage Measurement

The sensor module uses a combination of a current transformer and a voltage divider circuit for current and voltage measurements.

- **Current Measurement:** The current transformer, an integral part of the sensor module, is used to measure the current. The transformer works on the principle of electromagnetic induction. When primary coil changes its current, a proportional current is induced in the secondary coil, providing a safe and isolated measurement.

Figure 42: Current Transformer - for current measurement

- **Voltage Measurement:** A voltage divider circuit serves to measure voltage. It is made up of two resistors that are series-connected to divide the input voltage (V_{in}) between them. The midpoint voltage (V_{out}), which is a scaled-down representation of the input voltage, is then measured.

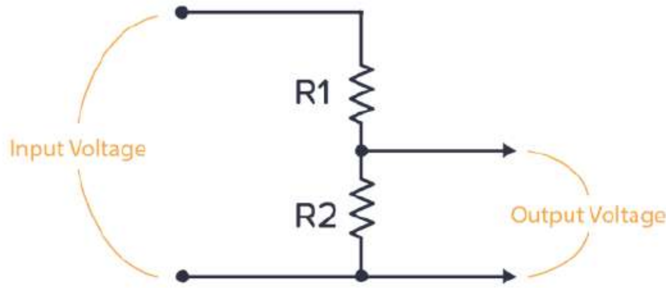

Figure 43: Voltage Divider Circuit

The formulas for current (I) and voltage (V) measurement are as follows:

$$I = N * I_{secondary}$$

$$V_{out} = V_{in} * \frac{R_2}{R_1 + R_2}$$

- N is the turn ratio of the transformer and R1 and R2 are the resistances in the voltage divider circuit.

4.1.2 Power and Energy Calculation

The power consumption (P) can be calculated using Voltage and Current, mathematically:

$$P = V * I$$

- Voltage and current together make up power.

Power over time is expressed as the integral of the energy used (E), expressed in kilowatt-hours (kWh), mathematically:

$$E = \int P(t)dt$$

- where P(t) is the power consumed at time t.

In practical terms, for discrete measurements, energy is commonly approximated as:

$$E_{kwh} = \frac{P * t_{hrs}}{1000}$$

- where P is the power measured.

Using measured and calculated values, the user can keep an eye on energy consumption in real-time, thereby facilitating more effective energy management.

4.2 Internet of Things-IoT

The Internet of Things-IoT is an advanced technology that has woven itself into various aspects of our daily lives. It's like a giant invisible web that connects everything from our daily household items to complex industrial machinery. This network isn't just limited to computers or humans; it even connects animals and other physical objects, allowing them to communicate data seamlessly across this intricate network, all without the need for direct human-to-computer or human-to-human interaction. IoT is crucial to the SAKOON system's overall operation. It was used to connect several devices, principally the energy meter and the microcontroller, into a network. This network of linked devices gathers important information about energy use and then disseminates it online.

The main node in this Internet of Things network is the microcontroller in the SAKOON system. It is linked to the energy meter, which provides real-time data collection and processing on energy use. The web-based dashboard and mobile application get this processed data once it has been sent over the Internet.

By using IoT, SAKOON can offer end users real-time data logging (energy consumption), enabling the users to monitor their consumption and take the necessary actions to manage it more effectively. The system will become even more adaptable and UI friendly because of the openings for future improvements like automation and control over appliances that consume a lot of energy.

Figure 44: IoT - Internet of Things

4.3 Microcontroller Communication

The SAKOON system relies on TCP/IP and UART protocols for accurate data transmission. TCP/IP serves as the digital postmaster, maintaining a steady internet connection. UART creates a crucial channel for communication between the sensor module and the microcontroller, acting as a translator and encoding/decoding information. The synergistic collaboration between these protocols forms the foundation for the system's seamless functioning.

4.3.1 The Microcontroller's Function and Architecture

The microcontroller serves as the CPU of a smart system, collecting data and performing analysis to make decisions and execute. Wemos D1 mini ESP8266 microcontroller is renowned for its outstanding capabilities and small design, and built-in WIFI that will work with other IoT platforms and devices, particularly in situations where power and space are limited.

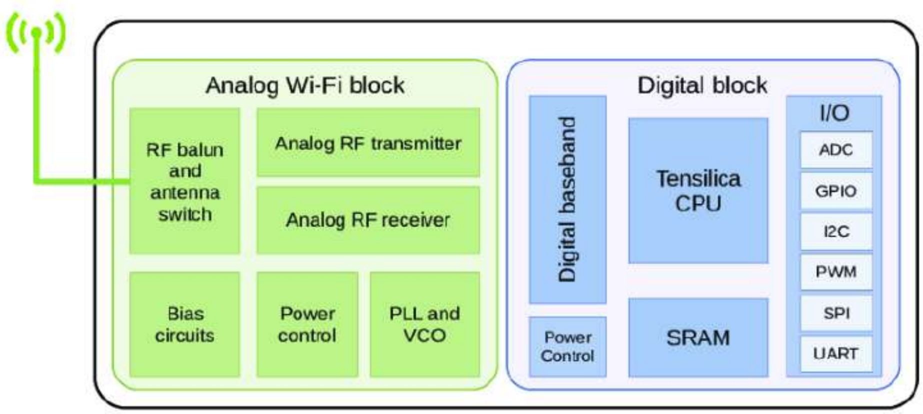

Figure 45: ESP8266 Architecture

Features

- Mini
- Fast
- Portable
- Built in Wi-Fi
- Open-Source Libraries available

4.3.2 TCP/IP Network Stack Integration

The SAKOON operates using the ESP8266 microcontroller's TCP/IP network stack. After establishing a secure communication route through a mobile app and web-based dashboard, the system sends and receives data over the Internet. Each internet-connected device's unique IP address enables precise identification and communication across the complex internet network. Data is divided into packets for internet transmission, with each one being individually routed to the destination IP address. So, in essence, the IP is a key component of the internet's design and the functionality of our IoT-based SAKOON, guaranteeing that data packets arrive at their intended locations accurately and on time.

Figure 46: TCP/IP

1. The TCP/IP network stack's integration ensures that the SAKOON system can reliably and accurately communicate over the internet. This is critical to real-time monitoring of energy consumption and real-time control of connected devices, which are central features of the SAKOON system.
2. The postal address system is analogous to the Internet Protocol (IP). It gives each internet-connected device a distinct address (IP address), ensuring that data packets are accurately routed across the intricate internet network. The IP makes sure the data packets arrive at their intended location.

The inclusion of the TCP/IP network stack guarantees the accuracy and dependability of internet communication for the SAKOON system.

4.3.3 UART

Sensors, modems, and other microcontrollers may all be communicated via the Universal Asynchronous Receiver Transmitter (UART) communication protocol. A peripheral interface unit (PIU) is a physical circuit that controls asynchronous serial communication (one bit at a time). The system relies on the UART protocol to make it possible for the ESP8266 microcontroller and the sensor module to communicate with one another. The UART protocol serves as a communication bridge between these two essential system parts, enabling the precise and effective transmission of data.

The following actions are necessary for UART to function:

- Receiving parallel data from the microcontroller, the transmitting UART device converts it to serial format before sending it. The serial data is received by the receiving UART device, which then transforms it back to parallel format and sends it on to the sensor module.
- A clock signal is not necessary for this asynchronous serial connection, made possible by the UART protocol, to synchronize the outgoing bits from the broadcasting UART to the arriving bits on the receiving UART. Instead, the baud rate—the pace at which data is sent and received—must be agreed upon by both devices.

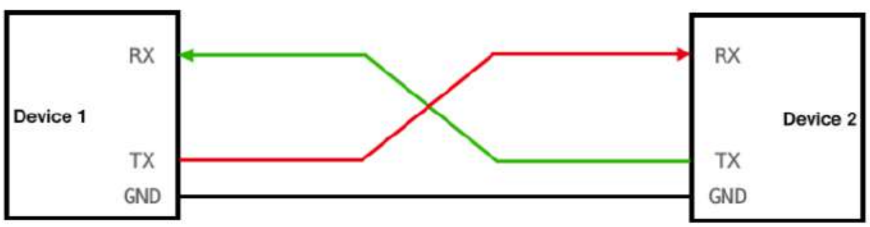

Figure 47:UART Asynchronous Communication

UART plays a crucial role in systems like SAKOON, where precise and real-time energy data collection is essential. The usefulness and dependability of the whole system are considerably improved by UART, which guarantees the accurate and effective bit-by-bit transfer of data through a serial port.

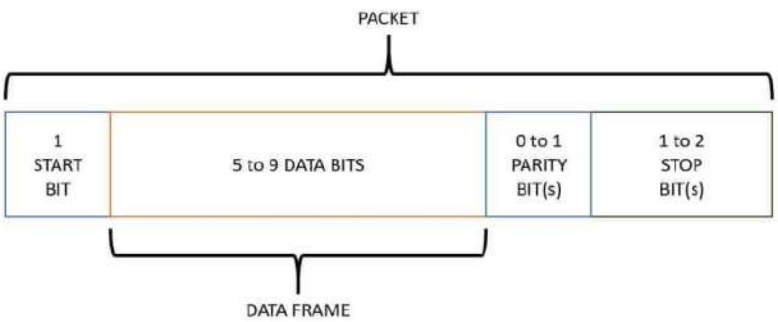

Figure 48: UART Data Packet

4.4 Sensor Module

The sensor module enables precise measurements of energy use and makes it easier to communicate with the microcontroller.

Figure 49: Sensor Module

4.4.1 Measurement of Current and Voltage

The SAKOON makes use of the PZEM sensor module. used to determine how much energy is used by electrical devices that are linked. The current transformer in this sensor module measures the current passing through the circuit. The voltage across the circuit is measured simultaneously using a voltage divider circuit.

4.4.2 Analogue to digital conversion

The values of the current and voltage are analog measurements. These values must be transformed into digital signals for the microcontroller to handle them. An analog-to-digital converter included inside the sensor module makes this conversion easier. The microcontroller can now handle and process these numbers since they have been transformed into digital signals.

4.4.3 Calculation of Power and Energy

The microcontroller may then determine the power by multiplying the current and voltage using the digital data for current and voltage. Additionally, by integrating the power over time, the microcontroller determines the energy usage in kilowatt-hours (kWh).

$$Cost = Energy_{kWh}\ X\ Tariff$$

- Where tariff is defined by government or electricity supplier

4.4.4 TTL Protocol communication

The TTL (Transistor-Transistor Logic) protocol facilitates communication between the sensor module and the microcontroller. The interaction and information exchange between the sensor module and the microcontroller is made possible by this digital logic protocol, which aids in the efficient running of the system.

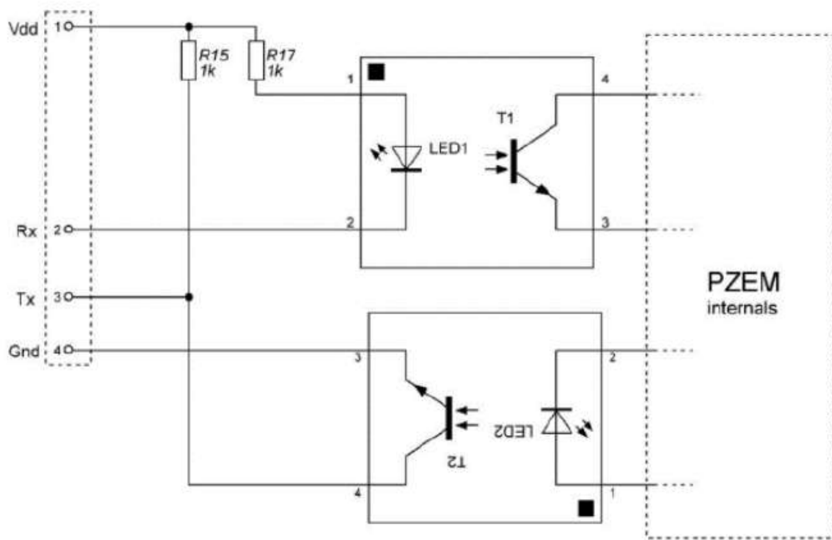

Figure 50: TTL Protocol in PZEM

4.5 App Development

The process of creating computer programs for usage on mobile devices like smartwatches, tablets, and smartphones is referred to as app development. To transfer desktop computer capability to portable devices, mobile applications are created. They provide users services that are comparable to those obtained on PCs.

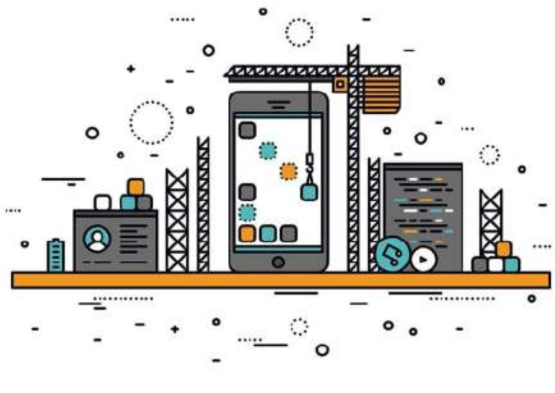

Figure 51: Development of app

4.5.1 Design of App Interface

The app's visual design, which includes the layout, typography, color schemes, buttons, and icons, is involved here. To promote customer happiness and engagement, the interface design must be simple to use, intuitive, and visually appealing.

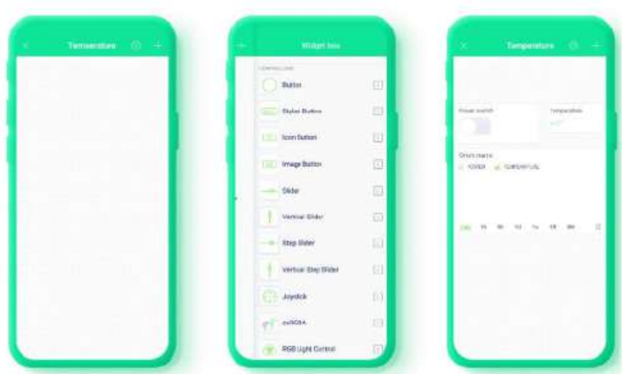

Figure 52: App Interface

4.5.2 Real-time Functionality

Instantaneous results are provided by real-time applications, which analyze and report data as it is generated. With SAKOON, this feature enables customers to keep an eye on their energy use as it occurs.

4.5.3 Support for Multiple Platforms

A bigger audience may be reached by an app if it is compatible with several mobile operating systems like Android and iOS. This entails creating an app that works effortlessly on a variety of platforms and devices via design and code.

Figure 53: Android Platform

Figure 54: IOS Platform

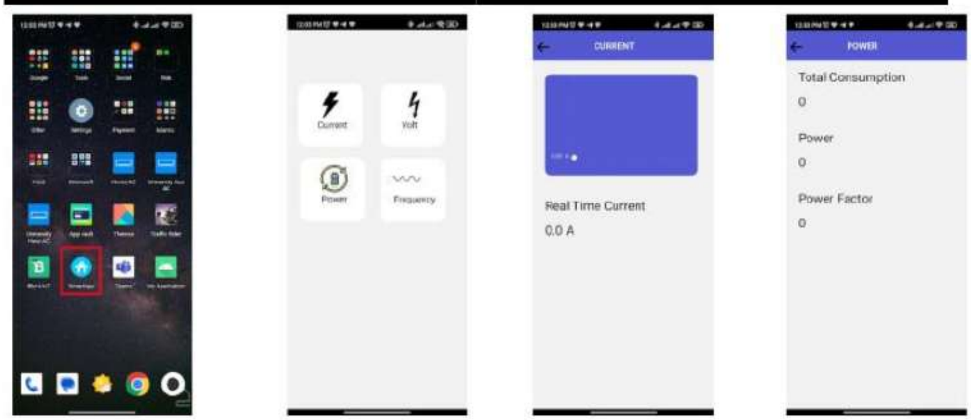

Figure 55: Stand-alone Android App

4.6 Integration with Blynk

A platform called Blynk enables mobile device control of microcontrollers like

Arduino and Raspberry Pi. This IoT platform makes it easier to interface these devices with mobile apps and link them to the internet.

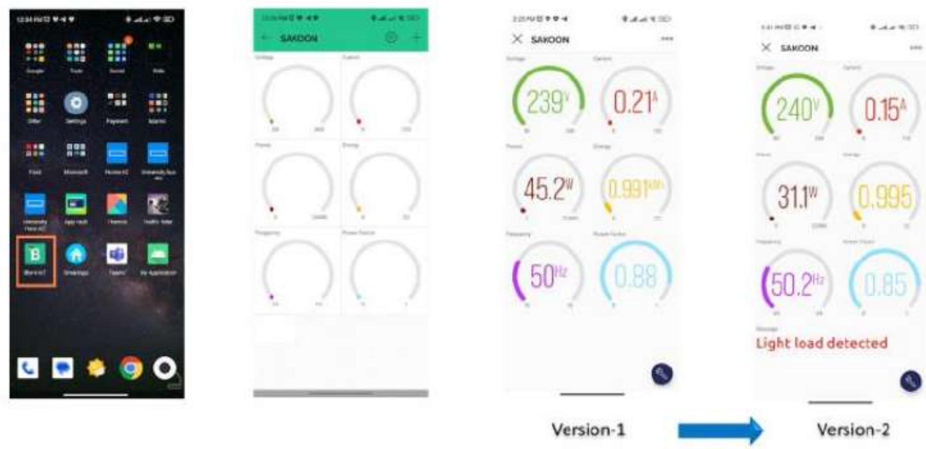

Figure 56: Blynk Integration Android Platform

Figure 57: Blynk Integration IOS Platform

4.6.1 Blynk in App Development

To make the integration of IoT capability in mobile applications easier, Blynk offers a collection of tools and APIs. It aids programmers in designing user interfaces, managing hardware, reading sensor data, and writing firmware.

4.6.2 Communication between a microcontroller and Blynk

Blynk offers libraries that provide internet-based communication between the mobile app and the microcontroller. These libraries make ensuring that data transfers go smoothly, making real-time monitoring possible.

4.7 Interfacing with Web Dashboard

The process of building a web-based interface for a dashboard that consumers can use to engage with their data. It is often used for data processing and visualization.

- Data Visualization: Information is graphically represented in data visualization. It offers a simple means of comprehending patterns, outliers, and trends in data.

Figure 58: Data Visualization Industrial Dashboard

- Web-Based Accessibility: Data may be viewed using any internet-connected device and from any location using web-based dashboards, giving customers ease and flexibility.

4.8 Web Server

A web server is a device that stores, manages, and sends users' online page.

Figure 59: Local Web Server

- Serving Web Pages: Providing Web Pages Web servers take care of user requests and provide the correct web pages. They manage the HTTP protocol that is required for the transmission of online pages.
- Serving Real-Time Data: Web servers often deal with real-time data in the IoT setting. Then, they transfer it to the user's device after receiving the data from IoT devices and processing it if required.

Chapter 5

DESIGN AND DEVELOPMENT

Several parts interact to create a working system. The SAKOON is no different; it synthesizes many technologies that successfully manage and monitor energy. One must manage the design and development of a system like SAKOON efficiently to guarantee its efficient operation. Tools, including algorithms, flowcharts, block diagrams, and circuit diagrams, are helpful in this situation. These tools act as the framework, enabling a systematic way to visualize, comprehend, and effectively carry out the complex activities that regulate the system.

The algorithm serves as the cornerstone for every job the system completes. The algorithms choreograph the dance of information flowing continuously throughout the system, from data collecting to data processing and transfer. They establish the guidelines, the operating procedures, and the sequence in which the various duties are carried out. Essentially, algorithms convert the project's goals into directions that the hardware and software can understand and carry out. Algorithms allow a complete and effective execution of the system's operations by providing a step-by-step method, but this is sometimes insufficient, particularly in a complicated system like SAKOON.

One needs a tool to visualize these algorithms, observe the events they order, and understand their effects on the system. In this situation, flowcharts are helpful. They provide a visual depiction of the algorithms, making the algorithm's operating flow obvious. Flowcharts in the SAKOON outline the data acquisition, processing, and transmission processes. They make it possible for efficient deployment by providing a clear roadmap of the many tasks needed.

We now reach circuit diagrams. These schematics serve as the SAKOON's electrical connections' building blocks. They provide the information required for the system's physical realization. The SAKOON's creator depends on circuit schematics to assemble the hardware the way a builder would while constructing a structure. They clearly explain the connections between the electronic parts, such as the sensor, microcontroller, and communication modules. This accurate illustration helps ensure that every component is properly positioned and connected, allowing impeccable assembly.
Algorithms, flowcharts, block diagrams, and circuit diagrams are not simply extras but essential components in creating a system like SAKOON. They provide a systematic approach to comprehending, creating, and putting into practice complicated systems. These tools enable developers to traverse the system's complexity, ensuring that each component performs as intended and the system accomplishes its goals. They also encourage clarity, make troubleshooting more accessible, and provide a solid reference for future improvements or revisions. Therefore, knowledge of and proficiency with these tools is essential for the SAKOON project's success.

However, just comprehending and using algorithms is insufficient.

5.1 Algorithm

At its essence, an algorithm is a step-by-step process used to solve problems or accomplish objectives. Algorithms are a collection of instructions that direct a system's functioning in computer science and electronics. Algorithms in the project might be seen as the master planners, controlling the flow and modification of data to get the intended result—real-time energy monitoring.

For instance, an algorithm is created to specify how the microcontroller should interact with the sensor when to request data, how to interpret the receiving data, and where to properly store it to gather data from the sensor module. When followed, this algorithm's carefully organized set of directives ensures precise and effective data collection.

Similarly, specialized algorithms are created for data processing and transmission via the Internet. These algorithms describe how to transform the sensor's raw data into helpful energy values, format the data for transmission, and transfer the information over the Internet to the Blynk platform and the web server. Each of these algorithms fills a specific jigsaw piece, and when combined, they create the SAKOON system's operational backbone, allowing it to run smoothly and serve its intended purpose.

5.1.1 Algorithm for Connecting the PZEM-004T Sensor Module

1. **Preparation:** Make sure the load's power source is shut off before you do anything else. This ensures security during the connection procedure.

Figure 60: Shutdown Dower Source before starting.

2. **Wiring Live Wire:** Determine the live wire supplied to the load (often red or brown in color). Connect this live wire to the PZEM-004T sensor module's first terminal.

Figure 61: Detection of live wire using tester.

3. **Wiring Neutral Wire:** Next, locate the neutral wire (often blue or black in color). This neutral wire should be connected to the sensor module's second terminal.

Figure 62: Detection of neutral wire using electric detector.

4. **Current Transformer (CT) Connection:** Pass the live wire from step two to CT. Make sure the CT's arrows are pointing in the direction of the load.

Figure 63: Live Wire Through CT connected to Load.

5. **Connect CT to Sensor Module:** Find the two wires from the CT, which are typically red and black. They should be connected to the third and fourth sensor module terminals. The CT is not polarity sensitive. Thus, it doesn't matter which wire connects to which terminal.

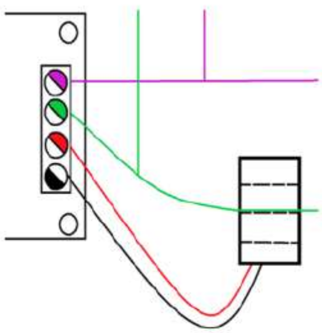

Figure 64: CT Connection with PZEM Schematics

Figure 65: CT Connection with PZEM

6. **Verify Connections Again:** Verify all connections once more before turning on the power. Make sure each connection is safe and that no bare wire is visible.
7. **Powering Up:** Restart the power source. Now that the sensor module is properly attached, it should be able to detect energy use.

Figure 66: Power on the System

Remember: When working with electricity, takfe these precautions:

Even if the algorithm offers a step-by-step tutorial for attaching the PZEM-004T sensor module, it's critical to stress the significance of safety precautions while dealing with electricity. No matter the size of the project, from modest home DIY endeavors to large-scale industrial installations, electricity offers serious risks, such as electrocution, fire, and equipment damage.
The following are important safety measures to follow:

- **Always Disconnect Power:** Before beginning any electrical work, always make sure the power supply is unplugged. The first and most important safety guideline is this one. Disconnecting a gadget completely from the power supply is preferable to just turning it off.

Figure 67: Disconnect Electricity

- **Use Insulated Tools:** Always use insulated handle tools while working with electrical cables. Insulation prevents energy from entering your body via the gadget.

Figure 68: Insulated Tools

- **Protective Gear:** Wear appropriate safety equipment, such as rubber gloves and boots, to lower your chance of receiving an electric shock. Your eyes may be shielded from sparks or debris by wearing safety glasses.

Figure 69: PPE

- **Avoid Water:** Unless you are properly educated, you should never operate on electrical systems or equipment in damp environments. Electric shock danger is increased by water's ability to carry electricity.

Figure 70: Do not touch electricity with wet hands.

- **Verify Connections:** Check to make sure all connections are securely fastened and that no naked wires are visible. Sparks from loose connections may start electrical fires.

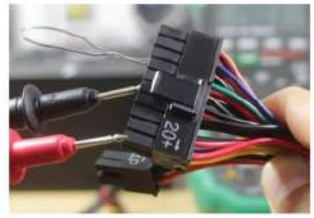

Figure 71: Verify Connection

- **Understanding the System:** Be certain that you have a thorough understanding of the system you will be using before starting work. A detailed understanding of the system helps you to foresee potential issues and take the necessary safeguards.

Figure 72: Deep Understanding

- **Consult a Professional**: Beginner in the field of electricity is at greater risk. So, always consult your senior or professional to start working. It is safer and often more economical to do tasks correctly the first time.

Figure 73: Consult a Professional

5.1.2 Algorithm for Connecting PZEM-004T to Wemos D1 Mini:

1. For safety reasons, first, turn off the PZEM-004T and the Wemos D1 mini. Never attempt to connect powered devices.
2. Locate the PZEM-004T module's power supply pins. These are commonly identified as ground (GND) and 5V (for power). Similarly, locate the Wemos D1 mini's GND and 5V pins.
3. Use a connecting wire to join the PZEM-004T's 5V pin to the Wemos D1 mini's 5V pin. The Wemos D1 mini powers the PZEM-004T module through this wire.
4. Using a different connecting wire, attach the GND pin of the PZEM-004T to the GND pin of the Wemos D1 mini. A ground connection is required to complete the circuit and enable electricity to flow.
5. Identify the PZEM-004T module's TX (transmit) and RX (receive) pins. These pins enable data transfer between the microcontroller and the sensor module.
6. Find the Wemos D1 mini's digital pins. We are utilizing D7 (for RX) and D8 (for TX) for this project. The PZEM-004T module's RX and TX pins will be connected to these pins.
7. Connect the D8 pin of the Wemos D1 mini to the TX pin of the PZEM-004T module. To the Wemos D1 mini in this configuration, the PZEM-004T module transfers data; remember that TX stands for "transmit."
8. Similarly, connect the D7 pin of the Wemos D1 mini to the RX pin of the PZEM-004T module. The PZEM-004T module will receive data from the Wemos D1 mini since the letter RX stands for "receive."
9. Make sure all connections are secure and accurate by checking them twice. The PZEM-004T sensor module and the Wemos D1 small are now attached and prepared for use.

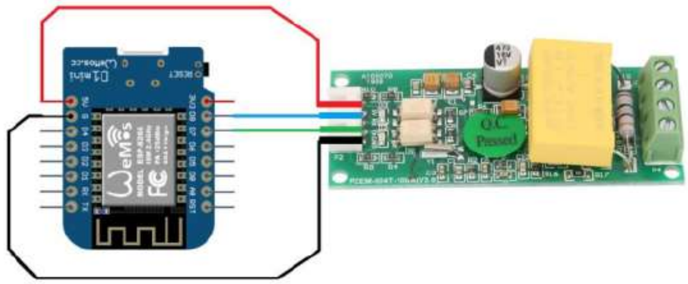

Figure 74: Sensor Connection with Controller

Remember: Always maintain safety while dealing with electricity; never forget that. Before making any connections or changes, always turn the system off. Inadequate connections might endanger your safety or do irreversible harm to your gadgets. Carefully read the Datasheet of the sensor and microcontroller to avoid any loss.

5.1.3 Algorithm for Data Acquisition

1. **Start with the initial setup:** Turn on the system, including the PZEM-004T sensor module and Wemos D1 small. Make sure that every connection is made correctly according to the prior method.
2. **Initialize the sensor module:** Run the command to initialize the PZEM-004T sensor module on the Wemos D1 mini to start the sensor module. This usually entails loading the proper library for PZEM-004T and configuring the TX and RX pins (in the project, D8 and D7, respectively).
3. **Start the acquisition loop:** This ongoing procedure will operate if the machine is switched on. Start a loop in the program that keeps looking for fresh information from the sensor module.
4. **Request data:** The first step in this loop is to request the current measurement data to the PZEM-004T sensor module.
5. **Check for data:** After submitting the request, see whether the sensor module has sent any data by checking for it. It could be essential to wait briefly before the data is released since there might be a little delay.

6. **Read data:** Once data is available, read it onto the Wemos D1 mini into an appropriate variable. If the sensor delivers many readings simultaneously, this might be a more complicated data structure or a single value for current or voltage.
7. **Validate data:** Verify the validity of the data retrieved from the sensor module. This might include looking for numbers outside the expected range or ensuring the checksum matches the data.
8. **Data processing:** Now that we have accurate data, process it as necessary. Calculations, such as calculating power from current and voltage or unit conversions, may be necessary.

Note: The specific instructions and functions used in implementing this method depend on the programming language used; in our case, that is Arduino IDE. The PZEM-004T sensor module and the Wemos D1 micro libraries, which include but are not limited to PZEM and ESP8266, are also essential. To maintain a smooth development process and efficient problem-solving, it is always advantageous and highly advised to refer to the appropriate library documentation when building and debugging your product.

5.1.4 Data Processing and Calculation Flowchart

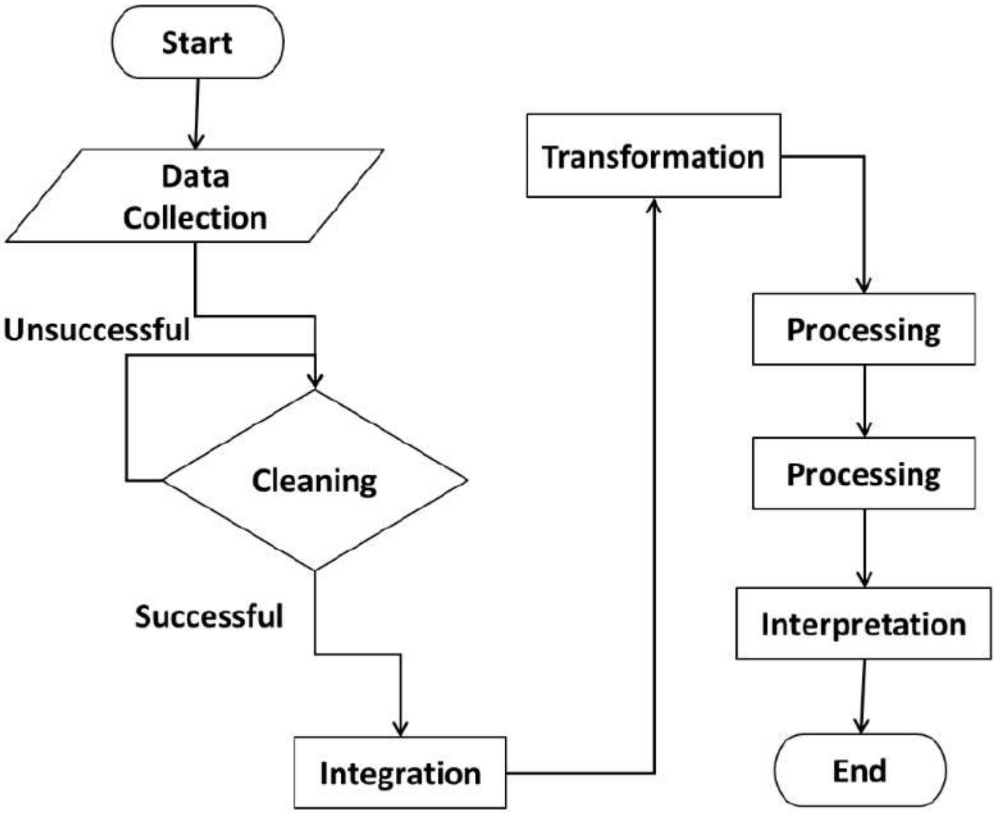

Figure 75: Data Processing Flowchart

5.1.5 Data Transmission Algorithm

The Data Transmission Algorithm is a critical component of the SAKOON, enabling seamless transmission of computed energy usage data from the hardware system to the server and, eventually, to the user interface. This algorithm follows sequential steps for an effective and efficient data transmission process.

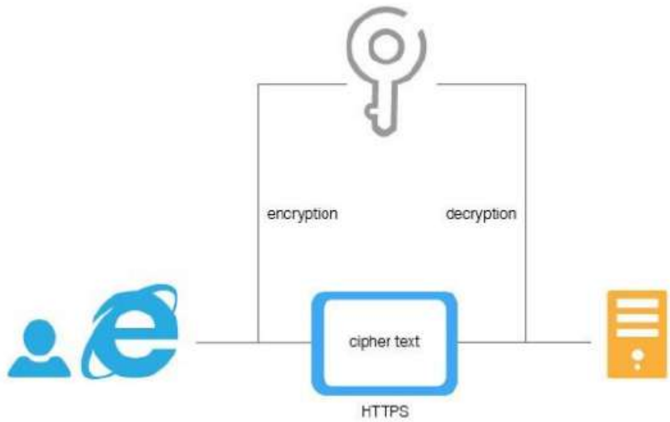

Figure 76: HTTP Protocol

1. **Data Serialization**: The computed data, including measurements of voltage, current, power, and energy usage, is serialized into a format suitable for network transmission. The data serialization ensures that it retains its structure and integrity during transmission.
2. **Packet Formation**: The serialized data is then encapsulated into data packets. These packets include the serialized data and essential metadata such as timestamps, device IDs, and checksums for error detection.
3. **Data Transmission to Server**: The prepared data packets are sent from the SAKOON hardware system to the server via a predefined communication protocol like MQTT, HTTP, or CoAP, depending on the requirements. We are using HTTP protocol for the SAKOON.
4. **Server-Side Data Reception and Decoding**: Upon receiving the data packets, the server decodes the packets and extracts the serialized data. The decoding process reverses the serialization process, converting the serialized data to its original format.
5. **Data Storage on Server**: The decoded data is stored in the server's database. Data is categorized and organized according to different parameters, like device ID and time, to facilitate easy retrieval in the future.
6. **Data Retrieval for User Interface**: When a user requests data on their user interface, the server retrieves the corresponding data from the database and prepares it for transmission to the user interface.

7. **Transmission to User Interface**: The retrieved data is then transmitted to the users' platform (Mobile application or Web dashboard), presented in a user-friendly format. Depending on the user interface design, this could include graphs, charts, or tables showing energy usage data.
8. **Data Presentation**: The transmitted data is displayed on the desired platform (Mobile application or Web dashboard). It may include visual aids, such as consumption patterns, that help users understand their energy consumption patterns.

The SAKOON Data Transmission Algorithm is the backbone of the real-time energy monitoring capability of the SAKOON system, ensuring users have access to accurate and up-to-date information about their energy consumption.

5.2 Libraries

5.2.1 PZEM

The PZEM-004T v3.0 is a current and energy monitor manufactured by Peacefair. This monitor is designed to provide accurate measurements for power systems, and it has become quite popular among hobbyists and professionals alike due to its affordable price and high accuracy. The PZEM004Tv30.h library is an essential tool for working with the PZEM-004T v3.0 energy monitor in the Arduino environment. The library provides a high-level interface to the hardware, making it possible to interact with the device without needing to handle low-level details like serial communication or data interpretation.

The library provides several methods to access real-time data about a power system. These include voltage (Volts), current (Amperes), power (Watts), energy (Watt-hours), frequency (Hertz), and power factor. These values are crucial for many energy-related applications, such as energy monitoring systems, home automation, and renewable energy projects.

The primary purpose of this library is to facilitate the easy collection and processing of data from the PZEM-004T v3.0. It does so by establishing communication between the device and an Arduino board using a serial connection, typically through hardware or software serial ports. Once communication has been established, the library provides straightforward methods for requesting and retrieving the various measurements that the device can produce.

Additionally, the PZEM004Tv30 library also supports commands for resetting energy totals, setting device addresses for multiple sensor networks, and modifying the device's baud rate. These additional features provide flexibility and control when integrating the PZEM-004T v3.0 into a broader system.

Another crucial feature of this library is its support for error handling. The PZEM-004T v3.0 communicates using a protocol that includes error checking. This library handles the verification of received data, ensuring that the values read from the device are accurate. In case of errors, the library provides a method to check the error code, helping the user to identify and fix issues.

The library also provides an object-oriented interface, which makes it easy to manage multiple PZEM-004T v3.0 devices in a single application. Each device can be represented by an instance of the PZEM004Tv30 class, and each instance maintains its state, making it possible to work with multiple devices in a straightforward way.

In conclusion, the PZEM004Tv30.h library is an indispensable tool for anyone working with the PZEM-004T v3.0 energy monitor in the Arduino platform. It abstracts away the complexities of interfacing with the device, providing a simple and user-friendly way to collect and process energy data. By using this library, developers and hobbyists can quickly build projects involving energy monitoring and control, contributing to more efficient and sustainable use of energy.

5.2.2 ESP8266 Wi-Fi

The Arduino platform needs the ESP8266 Wi-Fi library to use the ESP8266's Wi-Fi. With the library, it is easier to drive the Wi-Fi of ESP8266, which requires a deep knowledge of the embedded system so programmers may quickly interface with the built-in Wi-Fi capability of the ESP8266.

Developers may concentrate on more crucial application logic than the minute details of the Wi-Fi connection since the ESP8266 Wi-Fi library lessens the complexity of managing the built-in Wi-Fi capability. Most IoT projects using the ESP8266 chip use this library as the primary structural support.

This library is equipped to handle Wi-Fi connections on the ESP8266, whether it involves creating a new network (AP mode), joining an existing Wi-Fi network (STA mode), or operating both concurrently (STA+AP mode). It also gives users the liberty to control connection settings, including the network's SSID and password.

Moreover, the ESP8266WiFi library can scan for accessible Wi-Fi networks, a useful feature when locating networks within the ESP8266's range or pulling specific information about a network, like signal strength (RSSI), encryption type, and channel.

The library also aids in the IP configuration of the ESP8266. It supports assigning static IP addresses, subnet masks, and gateway addresses to the ESP8266, an essential feature when the ESP8266 needs to be reachable at a fixed IP address consistently. Another key capability of the ESP8266WiFi library is managing TCP/IP protocols. This includes initiating connections, sending data, and terminating them. Additionally, it supports both unsecured and secured (SSL) connections, enhancing its use in projects requiring secure data transfer.

The library also supports DNS (a protocol within the TCP/IP suite) which provides domain name like "www.sakoon.com" into an Internet Protocol (IP) address like "10.4.18.73" that computers utilize for network communication. The ESP8266WiFi library even includes Wi-Fi multi-functionality, a more effective method for handling Wi-Fi connections. Wi-Fi multi enables the ESP8266 to connect to the strongest Wi-Fi from a list of recognized networks, negating the need for active user intervention in the connection process.

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Furthermore, the library backs WPS (Wi-Fi Protected Setup), a network security standard aiming to make home network protection user-friendly. The ESP8266WiFi library has a wide range of features that ease user for developing IoT applications using the ESP8266 module. It empowers developers to concentrate on the intricacies of their projects by handling the complex aspects of managing Wi-Fi connections. Numerous IoT applications, from intelligent household appliances to industrial monitoring systems, have been developed due to their versatility, affordability, and popularity.

5.2.3 Blynk ESP8266

The BlynkSimpleEsp8266.h library is a part of the Blynk platform, which gives programmers the resources they need to create Internet of Things (IoT) applications. The ESP8266 Wi-Fi module may be used to construct IoT applications more easily using Blynk platform. By making it easier to connect ESP8266-based devices to the Blynk Cloud or a local Blynk server, this library makes it possible to remotely manage and monitor these devices using the Blynk app. The BlynkSimpleEsp8266.h library gives developers a high-level interface so they can concentrate on building IoT apps rather than having to learn about the more complex details of network connection and data exchange.

The Blynk server connection, Blynk account authentication, data transmission to the Blynk app, and command reception from the Blynk app are all supported by the library. Furthermore, it takes care of the periodic heartbeats required to maintain the connection to the Blynk server and offers immediate reconnection if the connection is lost.

One of the key features of the BlynkSimpleEsp8266.h library is its use of "virtual pins", a concept that extends the physical input/output pins of the ESP8266. These virtual pins allow developers to exchange almost any data between the Blynk app and their hardware. Data sent to these virtual pins from the Blynk app can trigger events in the ESP8266 program, and data written to these pins in the ESP8266 program can be displayed or used in the Blynk app.

In conclusion, the BlynkSimpleEsp8266.h library is a powerful tool that simplifies the process of connecting ESP8266-based IoT devices to the Blynk platform. By handling the lower-level details of the Blynk protocol, it enables developers to focus on creating innovative applications for AI detection and other IoT scenarios.

5.2.4 Firebase ESP8266

Firebase is a comprehensive mobile development platform from Google, which provides a suite of cloud-based tools, including a real-time database, authentication services, storage, and hosting. Firebase ESP8266 client is a library developed for Arduino projects to interface with Firebase services seamlessly.

Its main feature is authentication, database, cloud, Realtime database which simplify integration of Firebase's cloud services with Internet of Things (IoT) projects that use the ESP8266 Wi-Fi module. The Firebase ESP8266 library provides an API (Application Programming Interface) for communicating with Firebase's services. This includes making requests to Firebase's Real-time Database, a NoSQL cloud database that syncs data across all clients in real time. Firebase Real-time Database enables you to build collaborative and live-updating applications without managing complex synchronization code.

In IoT applications where the ESP8266 is used to collect or produce data that has to be saved or accessed across different devices, this might be very helpful, Firebase Cloud Messaging (FCM) is a free service that lets you send messages and alerts to your devices. For instance, you may alert a mobile device when an event is detected by a sensor connected to the ESP8266.

Additionally, by using Firebase's login service, which can provide users safe access to your Firebase resources and recognize people across multiple devices, the library streamlines the login process. This library makes it simple to work with JSON data, which is the main standard for storing and transmitting data in Firebase. It offers a collection of JSON encoding and decoding methods to make sending and receiving complicated data structures to and from Firebase easier.

The Firebase ESP8266 library is a modern ease for developers creating IoT applications with ESP8266 and Firebase. It includes set of functions that simplify interacting with Firebase's cloud-based services, thus enabling developers to focus on building their applications without getting caught up in the intricacies of network programming and data synchronization.

5.3 Firebase

5.3.1 Introduction

Firebase was produced by Google, is intended to facilitate the creation and expansion of online and mobile apps. It functions as a Backend-as-a-Service (BaaS), freeing developers from the burden of overseeing server infrastructure so they can concentrate on creating better user experiences. It's crucial to remember that Firebase is more than simply a database; it's a group of services that can handle most server-side tasks. This vast platform has revolutionized the way developers create and maintain apps.

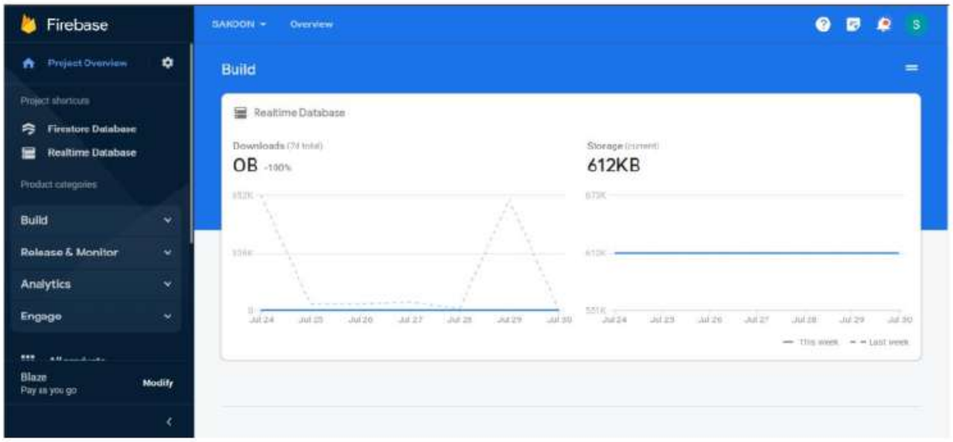


Figure 77: Real-Time Database Firebase

The Real-time Database, a NoSQL database that lets you store and sync data amongst your users in real-time, is Firebase's initial standout feature. Because of this, it's a great option for real-time applications like chat apps, gaming, and collaboration tools. The usage of WebSocket, which is quicker and more effective than conventional HTTP queries for data transfer, is one of the Firebase Real-time Database's distinctive features. By storing data on the client side and synchronizing it with the server once the connection is restored, the Real-time Database may also function when a connection is lost.

Additionally, Firebase offers more recent and scalable NoSQL cloud database created to store, sync, and query data for mobile, web, and Internet of Things applications. Although Fire store offers more advanced querying capabilities, transaction features, and hierarchical data structures, it retains its predecessor's real-time aspect. Data may be organized by developers into collections and documents that can be effectively queried even at scale.

Firebase Authentication, which supports several sign-in methods, including email and password, phone, and well-known federated identity providers like Google, Facebook, Twitter, and GitHub, is another crucial feature. By offering a simple secure sign-in capability to incorporate into your app, this service removes the need for developers to construct their own authentication system.

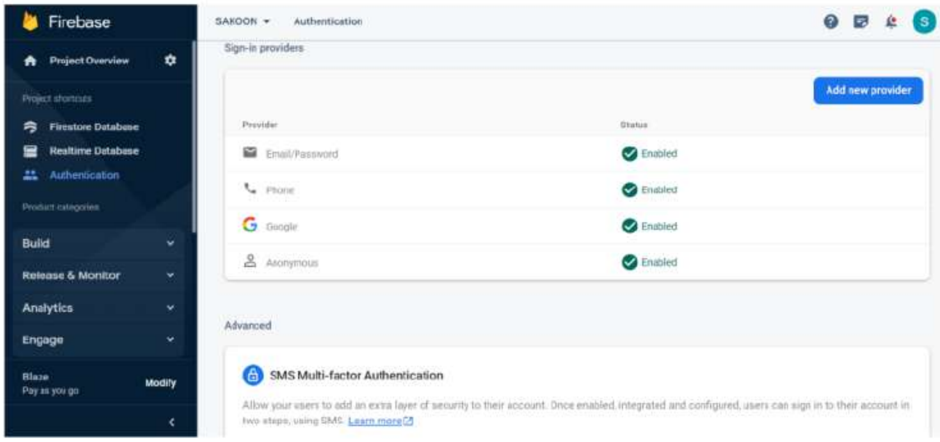


Figure 78: Authentication Firebase

A potent tool for sending messages and alerts to clients on many platforms, such as Android, iOS, and the web, is Firebase Cloud Messaging (FCM). It may be used for a variety of things, such as broadcasting alerts to huge audiences or delivering direct messages to specific devices. FCM is very useful since it doesn't need any special client-side code to receive messages.

A scalable and secure cloud file storage option is offered by Firebase's Storage service. It supports the archiving of user-generated material from mobile applications, including images and videos. Due to Google Cloud Storage's support, Firebase Storage can grow to handle petabytes of data. Firebase Storage files are immediately accessible over HTTP, making it easier to integrate them into your program.

Firebase Hosting provides dynamic and static web hosting that is quick and safe. It is perfect for using a single command to distribute static and web content to a global content delivery network (CDN). The deployment is simple and effective by Firebase Hosting's SSL security, availability of a worldwide CDN.

Along with Firebase Test Lab for iOS and Android, Firebase Crash Reporting, Firebase Performance Monitoring, Firebase Predictions, and Firebase App Indexing, Firebase also offers other tools for app development. These technologies provide insights about app use and user behavior in addition to aiding in the quality improvement of the application.

In conclusion, Firebase is a strong, user-friendly platform that can manage server-side activities to significantly speed up application development. Because of the variety of services it offers, including real-time databases, authentication, storage, messaging, hosting, and testing, developers can concentrate on creating cutting-edge, user-centered apps. Its cross-platform compatibility makes it a fantastic option for developers who want to support various operating systems. The use of Firebase in the construction of strong apps is crucial. It significantly increases productivity and efficiency.

5.3.2 SAKOON – Real time Data base

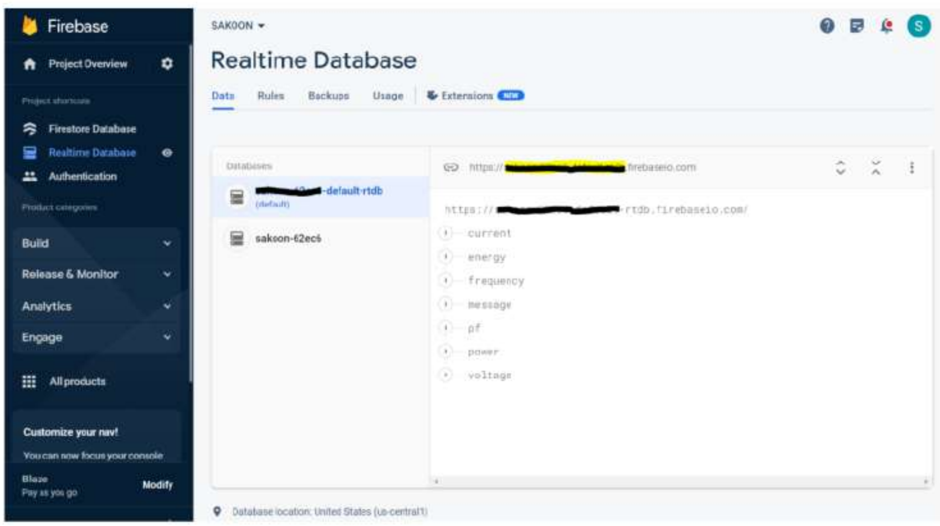


Figure 79: SAKOON Realtime Database on Firebase

Figure 80: Readings on Firebase

Chapter 6

CONCLUSION

The literature review provides an essential foundation for developing SAKOON, a project at the intersection of energy management, IoT technologies, circuit design, and user application development. Each component - IoT integration, circuit design, user-friendly data visualization, and remote monitoring - plays a crucial role in the successful execution and overall effectiveness of the project. The insights gathered through reviewing existing literature help understand the current situation and identify potential opportunities and challenges that may arise in the project's lifecycle.

Firstly, integrating IoT technologies within the project signifies a shift towards more sophisticated, connected, and real-time energy management systems. IoT allows for enhanced automation and control, which is vital in modern energy management. With IoT, energy usage data from various appliances can be collected, processed, and transmitted in real-time, enabling more efficient energy use and improved decision-making processes (Sisinni et al., 2018). However, IoT integration in energy management has limitations and challenges, including data security, privacy, and interoperability of various IoT devices. Understanding these challenges and developing effective strategies is essential for successfully implementing IoT in SAKOON.

Secondly, circuit design for voltage and current measurements is fundamental to any energy management system. Accurate voltage and current measurements enable precise energy consumption readings, which form the basis for monitoring and controlling energy usage. Several factors, such as the choice of measurement devices, the accuracy of these devices, and the methods employed for data collection and transmission, significantly impact the system's effectiveness (Lin, Lee, & Huang, 2013). The literature provides numerous circuit design methodologies and techniques, each with advantages and disadvantages. Therefore, careful consideration must be given to selecting and implementing these methods in the context of SAKOON.

The third critical aspect is the development of user-friendly data visualization. In the era of big data, effective data visualization is essential for presenting complex datasets in an understandable and accessible way. Creating an interactive UI-user interface can help users to visualize his/her energy usage patterns and make informed decisions to optimize their energy consumption (Few, 2009). However, creating an effective data visualization requires a deep understanding of the target users, their needs, and their abilities. It balances functionality and simplicity, providing users with the necessary information without overwhelming them. As such, user interface design principles, usability testing, and user feedback are critical in this project phase.

Lastly, remote monitoring of electrical equipment gives end customers even more convenience and control. With this capability, consumers may use their smartphones or other connected devices to monitor and manage their appliances whenever and wherever they are. This provides users with greater flexibility and allows for more efficient use of energy, as appliances can be switched off or their operation modified remotely based on real-time energy consumption data (Pal, Funilkul, Charoenkitkarn, & Kanthamanon, 20.18). Despite its benefits, remote monitoring brings new challenges, particularly regarding data security and privacy. Ensuring secure data transmission and protecting users' privacy is paramount for successfully implementing this feature.

The development of SAKOON involves a comprehensive understanding and careful integration of various components, each with its own set of opportunities and challenges. The literature review is a valuable guide, providing insights into existing methodologies, potential hurdles, and best practices. It helps shape the project's direction and design, ensuring that SAKOON is not only technologically advanced but also user-friendly, secure, and effective in achieving its goal of improved energy management. As the project progresses, continuous literature review and analysis will be integral to adapting to the evolving technology landscape and user expectations, ensuring the project's ongoing relevance and success.

We have detailed the different phases of the SAKOON power metering system, from the initial conception to the final implementation and testing. The core vision of SAKOON was to design an IoT-based power metering system that would facilitate better power usage monitoring, enable cost-effective energy utilization, and contribute to global sustainability efforts. We can conclude that the project has successfully fulfilled these objectives.

In the global drive towards energy efficiency and sustainability, the SAKOON system contributes significantly to the industrial sector. Industries are one of the largest energy consumers; therefore, even minor improvements in energy efficiency can have a considerable impact. By providing real-time monitoring and visual analytics of energy consumption data, SAKOON aids industries in identifying inefficiencies, assessing power quality, and optimizing energy use. This, in turn, reduces energy costs and improves overall productivity. Furthermore, by leveraging IoT technology, SAKOON enables remote monitoring, thus simplifying energy management and contributing to Industry 4.0.

The value of SAKOON extends beyond industries, offering significant advantages to utilities and individual consumers. For utilities, SAKOON provides a powerful tool for demand response strategies, enabling peak load management and reducing strain on the power grid. The system empowers individual consumers with real-time energy consumption information and cost estimates, leading to better energy usage habits and savings on energy bills.

Globally, SAKOON aligns with multiple United Nations Sustainable Development Goals (SDGs), by mitigating the need for additional power generation infrastructure, SAKOON contributes to Goal 9: Industry, Innovation, and Infrastructure, Goal 11: Sustainable Cities and Communities. Through this project, we have demonstrated how multidisciplinary collaboration, innovative use of technology, and user-centered design can lead to solutions that address global challenges.

The SAKOON power metering system represents a significant advancement in energy management, benefiting multiple stakeholders, from industries and utilities to individual consumers. Moreover, the project showcases the pivotal role of innovative technological solutions in realizing sustainable development goals. As we move towards an IoT-dominated future, projects like SAKOON serve as a guiding beacon, illuminating the path to sustainable, efficient, and responsible energy consumption.

APPENDICES

APPENDIX A

PZEM-004T V3.0 User Manual

Overview

This document describes the specification of the PZEM-004T AC communication module, the module is mainly used for measuring AC voltage, current, active power, frequency, power factor and active energy, the module is without display function, the data is read through the TTL interface.

PZEM-004T-10A: Measuring Range 10A (Built-in Shunt)

PZEM-004T-100A: Measuring Range 100A (external transformer)

1. Function description

1.1 Voltage

1.1.1 Measuring range:80～260V

1.1.2 Resolution: 0.1V

1.1.3 Measurement accuracy: 0.5%

1.2 Current

1.2.1 Measuring range: 0～10A（PZEM-004T-10A）； 0～100A（PZEM-004T-100A）

1.2.2 Starting measure current: 0.01A（PZEM-004T-10A）； 0. 02A（PZEM-004T-100A）

1.2.3 Resolution: 0.001A

1.2.4 Measurement accuracy: 0.5%

1.3 Active power

1.3.1 Measuring range: 0～2.3kW（PZEM-004T-10A）； 0～23kW（PZEM-004T-100A）

1.3.2 Starting measure power: 0.4W

1.3.3 Resolution: 0.1W

1.3.4 Display format:

＜1000W, it display one decimal, such as: 999.9W

≥1000W, it display only integer, such as: 1000W

1.3.5 Measurement accuracy: 0.5%

1.4 Power factor

1.4.1 Measuring range: 0.00～1.00

1.4.2 Resolution: 0.01

1.4.3 Measurement accuracy: 1%

1.5 Frequency

1.5.1 Measuring range: 45Hz～65Hz

1.5.2 Resolution: 0.1Hz

1.5.3 Measurement accuracy: 0.5%

1.6 Active energy

1.6.1 Measuring range: 0～9999.99kWh

1.6.2 Resolution: 1Wh

1.6.3 Measurement accuracy: 0.5%

1.6.4 Display format:

＜10kWh, the display unit is Wh(1kWh=1000Wh), such as: 9999Wh

⩾10kWh, the display unit is kWh, such as: 9999.99kWh

1.6.5 Reset energy: use software to reset.

1.7 Over power alarm

Active power threshold can be set, when the measured active power exceeds the threshold, it can alarm

1.8 Communication interface

RS485 interface。

2 Communication protocol

2.1 Physical layer protocol

Physical layer use UART to RS485 communication interface

Baud rate is 9600, 8 data bits, 1 stop bit, no parity

2.2 Application layer protocol

The application layer use the Modbus-RTU protocol to communicate. At present, it only supports function codes such as 0x03 (Read Holding Register), 0x04 (Read Input Register), 0x06 (Write Single Register), 0x41 (Calibration), 0x42 (Reset energy).etc.

0x41 function code is only for internal use (address can be only 0xF8), used for factory calibration and return to factory maintenance occasions, after the function code to increase 16-bit password, the default password is 0x3721

The address range of the slave is 0x01 ~ 0xF7. The address 0x00 is used as the broadcast address, the slave does not need to reply the master. The address 0xF8 is used as the general address, this address can be only used in single-slave environment and can be used for calibration etc.operation.

2.3 Read the measurement result

The command format of the master reads the measurement result is(total of 8 bytes):

Slave Address + 0x04 + Register Address High Byte + Register Address Low Byte + Number of Registers High Byte + Number of Registers Low Byte + CRC Check High Byte + CRC Check Low Byte.

The command format of the reply from the slave is divided into two kinds:

Correct Reply: Slave Address + 0x04 + Number of Bytes + Register 1 Data High Byte + Register 1 Data Low Byte + ... + CRC Check High Byte + CRC Check Low Byte

Error Reply: Slave address + 0x84 + Abnormal code + CRC check high byte + CRC check low byte

Abnormal code analyzed as following (the same below)

- 0x01,Illegal function
- 0x02,Illegal address
- 0x03,Illegal data
- 0x04,Slave error

The register of the measurement results is arranged as the following table

Register address	Description	Resolution
0x0000	Voltage value	1LSB correspond to 0.1V
0x0001	Current value low 16 bits	1LSB correspond to 0.001A
0x0002	Current value high 16 bits	
0x0003	Power value low 16 bits	1LSB correspond to 0.1W
0x0004	Power value high 16 bits	
0x0005	Energy value low 16 bits	1LSB correspond to 1Wh
0x0006	Energy value high 16 bits	
0x0007	Frequency value	1LSB correspond to 0.1Hz
0x0008	Power factor value	1LSB correspond to 0.01
0x0009	Alarm status	0xFFFF is alarm, 0x0000is not alarm

For example, the master sends the following command (CRC check code is replaced by 0xHH and 0xLL, the same below)

0x01 + 0x04 + 0x00 + 0x00 + 0x00 + 0x0A + 0xHH + 0xLL

Indicates that the master needs to read 10 registers with slave address 0x01 and the start address of the register is 0x0000

The correct reply from the slave is as following:

0x01 + 0x04 + 0x14 + 0x08 + 0x98 + 0x03 + 0xE8+0x00 + 0x00 +0x08 + 0x98+ 0x00 + 0x00 + 0x00 + 0x00 + 0x00 + 0x00 + 0x01 + 0xF4 + 0x00 + 0x64 + 0x00 + 0x00 + 0xHH + 0xLL

The above data shows

- Voltage is 0x0898, converted to decimal is 2200, display 220.0V
- Current is 0x000003E8, converted to decimal is 1000, display 1.000A
- Power is 0x00000898, converted to decimal is 2200, display 220.0W
- Energy is 0x00000000, converted to decimal is 0, display 0Wh
- Frequency is 0x01F4, converted to decimal is 500, display 50.0Hz
- Power factor is 0x0064, converted to decimal is 100, display 1.00
- Alarm status is 0x0000, indicates that the current power is lower than the alarm power threshold

2.4 Read and modify the slave parameters

At present,it only supports reading and modifying slave address and power alarm threshold

The register is arranged as the following table

Register address	Description	Resolution
0x0001	Power alarm threshold	1LSB correspond to 1W
0x0002	Modbus-RTU address	The range is 0x0001~0x00F7

The command format of the master to read the slave parameters and read the measurement results are same(descrybed in details in Section 2.3), only need to change the function code from 0x04 to 0x03.

The command format of the master to modify the slave parameters is (total of 8 bytes):

Slave Address + 0x06 + Register Address High Byte + Register Address Low Byte + Register Value High Byte + Register Value Low Byte + CRC Check High Byte + CRC Check Low Byte.

The command format of the reply from the slave is divided into two kinds:

Correct Response: Slave Address + 0x06 + Number of Bytes + Register Address Low Byte + Register Value High Byte + Register Value Low Byte + CRC Check High Byte + CRC Check Low Byte.

Error Reply: Slave address + 0x86 + Abnormal code + CRC check high byte + CRC check low byte.

For example, the master sets the slave's power alarm threshold:

0x01 + 0x06 + 0x00 + 0x01 + 0x08 + 0xFC + 0xHH + 0xLL

Indicates that the master needs to set the 0x0001 register (power alarm threshold) to 0x08FC (2300W).

Set up correctly, the slave return to the data which is sent from the master.

For example, the master sets the address of the slave

0x01 + 0x06 + 0x00 + 0x02 + 0x00 + 0x05 + 0xHH + 0xLL

Indicates that the master needs to set the 0x0002 register (Modbus-RTU address) to 0x0005

Set up correctly, the slave return to the data which is sent from the master.

2.5 Reset energy

The command format of the master to reset the slave's **energy** is (total 4 bytes):

Slave address + 0x42 + CRC check high byte + CRC check low byte.

Correct reply: slave address + 0x42 + CRC check high byte + CRC check low byte.

Error Reply: Slave address + 0xC2 + Abnormal code + CRC check high byte + CRC check low byte

2.6 Calibration

The command format of the master to calibrate the slave is (total 6 bytes):

0xF8 + 0x41 + 0x37 + 0x21 + CRC check high byte + CRC check low byte.

Correct reply: 0xF8 + 0x41 + 0x37 + 0x21 + CRC check high byte + CRC check low byte.

Error Reply: 0xF8 + 0xC1 + Abnormal code + CRC check high byte + CRC check low byte.

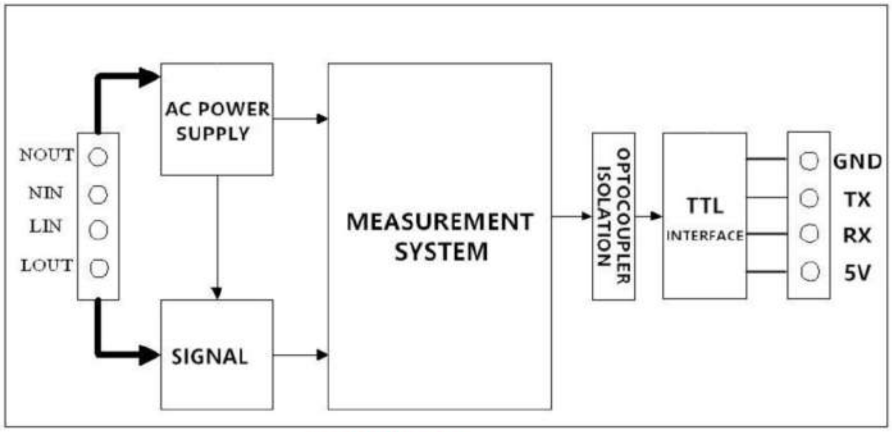
It should be noted that the calibration takes 3 to 4 seconds, after the master sends the command, if the calibration is successful, it will take 3 ~ 4 seconds to receive the response from the slave.

2.7 CRC check

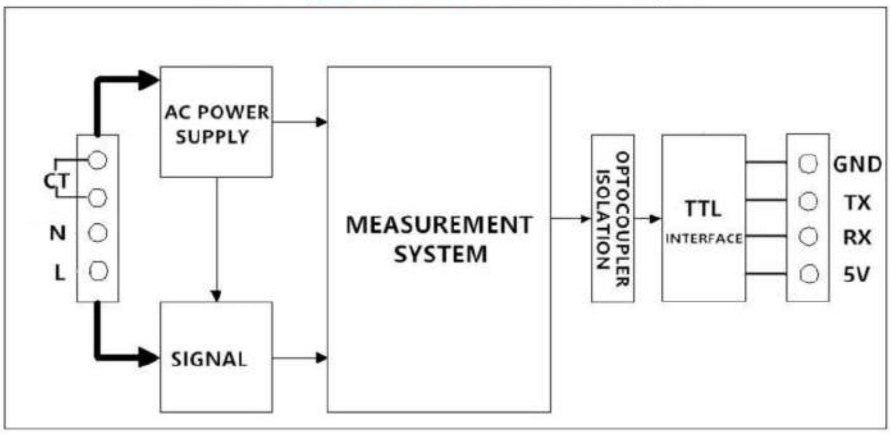
CRC check use 16bits format, occupy two bytes, the generator polynomial is X16 + X15 + X2 +1, the polynomial value used for calculation is 0xA001.

The value of the CRC check is a frame data divide all results of checking all the bytes except the CRC check value.

3 Functional block diagram

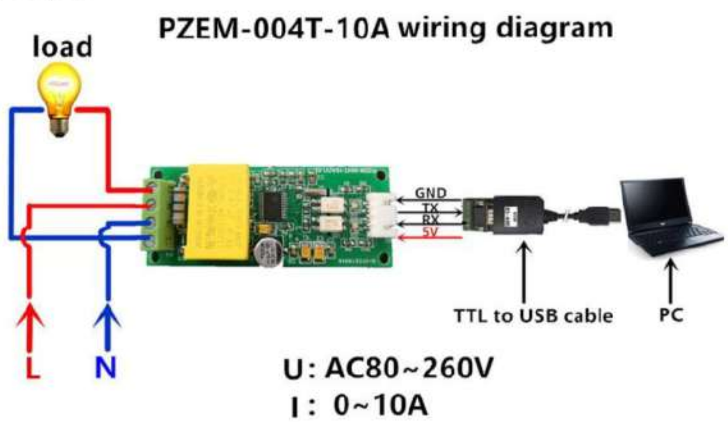


Picture 3.1 PZEM-004T-10A Functional block diagram

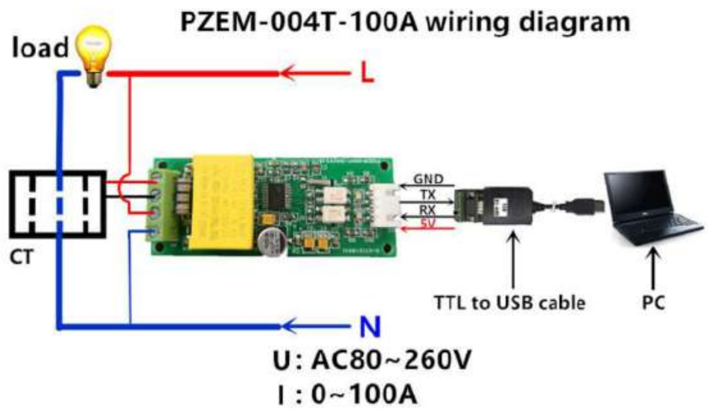


Picture 3.2 PZEM-004T-100A Functional block diagram

4 Wiring diagram



Picture 4.1 PZEM-004T-10A wiring diagram



Picture 4.2 PZEM-004T-100A wiring diagram

5 Other instructions

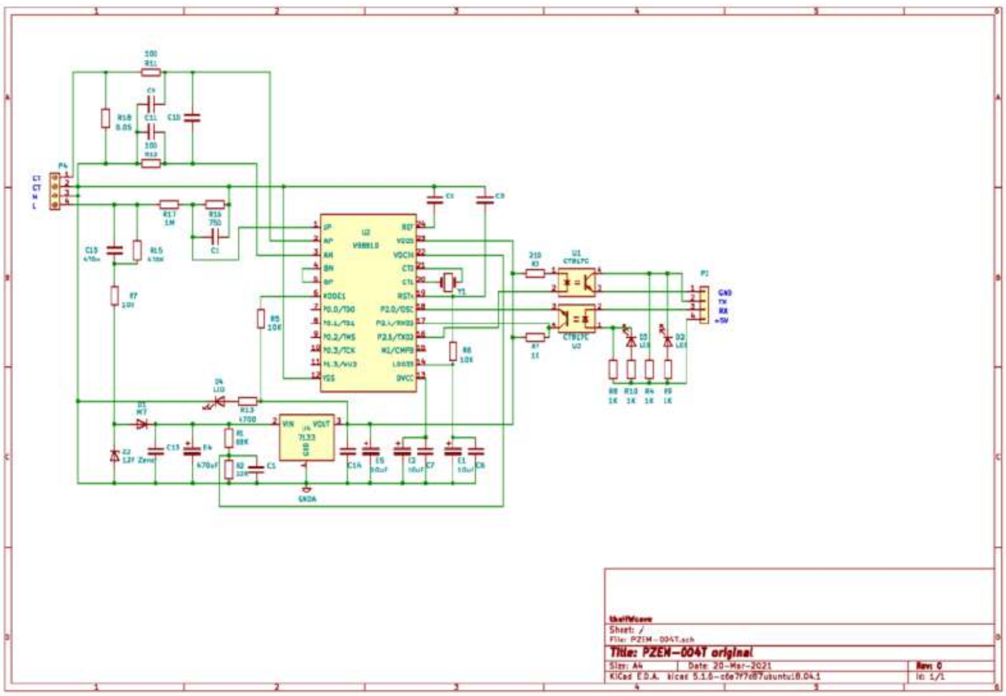
5.1The TTL interface of this module is a passive interface, it requires external 5V power supply, which means, when communicating, all four ports must be connected (5V, RX, TX, GND), otherwise it cannot communicate.

5.2 Working temperature

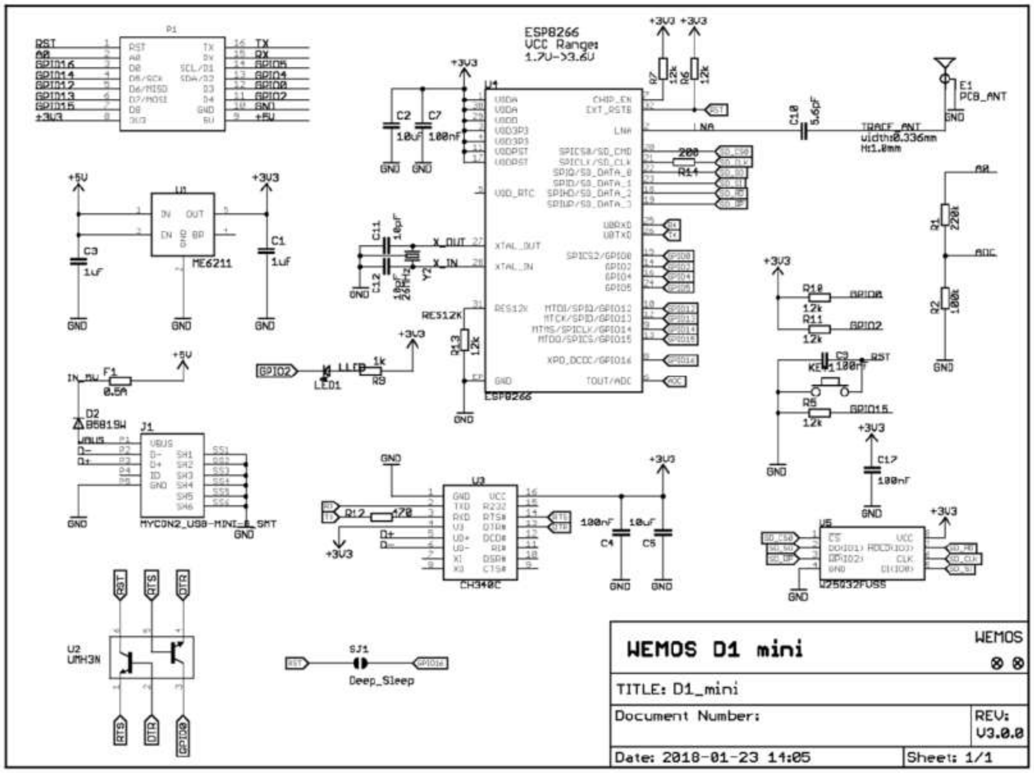
-20'C ~ +60'C。

APPENDIX B

PZEM Schematics



Microcontroller Schematics



APPENDIX C

Figure 81: Project Standee

Figure 82: Project Brochure Page 1

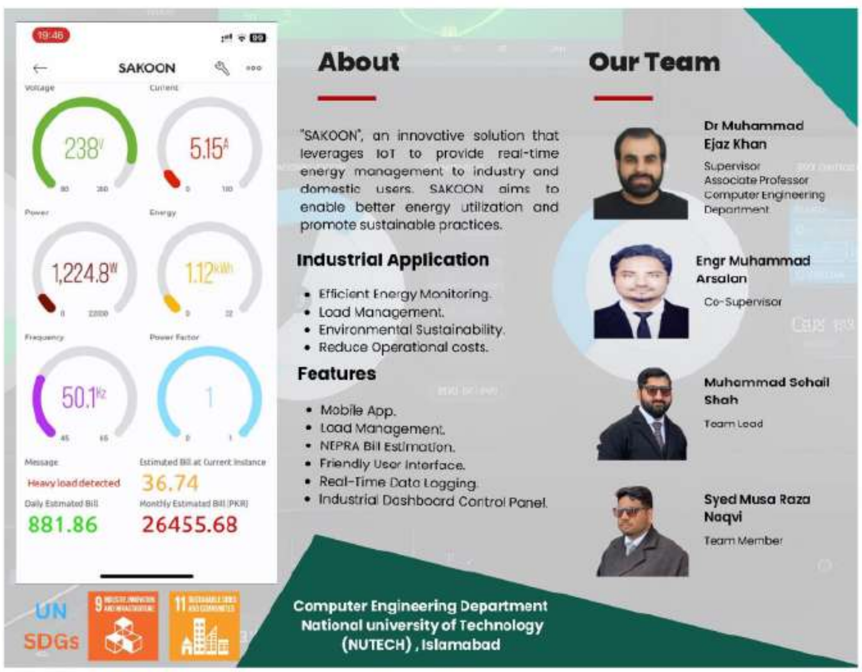


Figure 83: Project Brochure Page 2

APPENDIX D

Market Research Survey

SAKOON: Revolutionizing energy management with real-time data, fostering a sustainable future. Unleash the power of smart, green living with SAKOON's intelligent energy solutions.

We sincerely appreciate your valuable participation in this survey. Your time and insights have been immensely beneficial to us. Thank you for helping us make a difference!

1. How many units did you consume last month?

Mark only one.

- ◯ <100
- ◯ Greater than 100 less than 300
- ◯ Greater than 300

2. Are you satisfied with your energy consumption?

Mark only one.

- ◯ Yes
- ◯ No

3. Are you using any device for Load Management?

Mark only one.

- ◯ Yes
- ◯ No

4. If the previous answer was yes: are you satisfied with the device?

Mark only one.

- Yes
- No

5. Will you buy our proposed device?

Mark only one.

- Yes
- No
- Maybe

APPENDIX E

BUSSINESS CANVAS

Team or Company Name: SAKOON Powered by RASS

The Business Model Canvas

Date: 07/25/23

[X] Primary Canvas
[ ] Alternative Canvas

Key Partners
- **IoT device manufacturers:** These are the partners who provide the necessary hardware components such as the microcontroller and sensor modules.
- **Energy suppliers:** Collaborations with energy suppliers can help RASS offer comprehensive solutions that integrate energy provision and management.

Key Activities
- **Development and maintenance of the IoT energy management system:** This is the core activity, involving everything from hardware setup to software development and updates.
- Customer service and technical support

Key Resources
- **IoT devices:** The microcontroller and sensor module are key hardware components of the system.
- **Mobile and web platforms:** These are the interfaces through which customers interact with the system.

Value Proposition
- **Real-time Energy Oversight:** Enables customers to control energy use and conserve power through real-time monitoring.
- **Intuitive User Interface:** Offers easy interaction with energy data through user-friendly mobile and web platforms.

Customer Relationships
- **Direct and interactive:** Customers can interact directly with SAKOON through the mobile app and web platform.
- **Regular updates:** Keeping customers informed and engaged through newsletters, blog posts, and social media.

Channels
- **Direct online sales:** Customers can buy the product directly from the SAKOON website.
- **App stores:** The mobile app is available for download on iOS and Android app stores.

Customer Segments
- **Residential households:** Homeowners who are keen to manage and potentially reduce their energy consumption.
- **Educational Institutions:** Schools, colleges, universities, and other educational institutes that can significantly benefit from tracking and optimizing their substantial energy usage.
- **Industries:** Various sectors of the industry can leverage real-time energy management for their heavy machinery and vast plants.

Cost Structure
- **IoT hardware manufacturing and maintenance:** This includes the costs associated with producing and maintaining the IoT devices.
- **Software development and updates:** Costs related to the development, testing, and updating of the mobile and web platforms.
- **Cloud services:** Expenses for cloud storage and computing services.
- **Marketing and sales:** Costs for marketing activities and managing the sales process.

Revenue Streams
- **Sales of IoT devices:** Revenue is generated from the sale of the IoT energy management system.
- **Subscription fees:** Customers might pay subscription fees for access to premium features on the mobile app.
- **Data analysis and reporting services:** Offering advanced data analysis and customized reports as additional services can also generate revenue.

Source: www.businessmodelgeneration.com

Team or Company Name: SAKOON Powered by RASS

The Business Model Canvas

Date: 07/25/23

[ ] Primary Canvas
[X] Alternative Canvas

Key Partners
- **Cloud service providers:** These partners provide the storage and computing capabilities necessary for data processing and storing large volumes of energy data.
- **Mobile app development partners:** Partnerships with experienced app developers can ensure the creation of a user-friendly mobile interface.

Key Activities
- Data analysis and reporting
- Marketing and Sales.
- Relationship management with key partners

Key Resources
- **Technical expertise:** Human resources with skills in IoT technology, software development, data analysis, and energy management.
- **Mobile and Web** platforms.

Value Proposition
- **Personalized Alerts:** Allows users to set custom alerts for specific conditions, ensuring prompt actions.
- **Cost Efficiency:** Promotes substantial savings over time by fostering better energy management.

Customer Relationships
- **24/7 customer service and technical support:** Providing round-the-clock support to help resolve any issues promptly.

Channels
- **Partner channels:** Collaborations with IoT device manufacturers and energy suppliers can also serve as distribution channels.

Customer Segments
- **Small to Medium-sized Businesses:** Firms that are exploring ways to monitor their real-time energy use and uncover potential energy-saving opportunities.
- **Large Corporations:** Bigger entities with extensive energy usage, where even minor improvements in energy management can translate to substantial cost savings.

Cost Structure
- **Customer Service and Technical Support:** Resources required to provide customer support, including personnel and infrastructure costs.

Revenue Streams
- **Partner commissions and referrals:** Revenue may also come from collaborations with partners, for example through commission on referred sales.
- **Government Entities:** As a part of the energy conservation initiatives, these bodies could greatly benefit from real-time energy management systems.

Source: www.businessmodelgeneration.com

BUSSINESS PLAN

A comprehensive business plan for the SAKOON energy management system involves defining the company's mission, outlining the market strategy, setting financial goals, and describing the organizational structure.

Here is a high-level business plan for SAKOON:

- **Executive Summary:** SAKOON is a cutting-edge energy management system designed to provide consumers with real-time energy usage data and cost estimation. By promoting better energy consumption habits, SAKOON aims to contribute towards a sustainable and energy-efficient future.

Figure 84: SAKOON: an initiative towards future

- **Company Description:** RASS is a tech startup focused on revolutionizing how consumers interact with their energy usage. Our main product, "SAKOON," leverages IoT technology and data analytics to provide users with actionable insights about their energy consumption.

- **Market Analysis:** The global energy management system market is growing due to increasing energy costs and environmental concerns. The primary target market for SAKOON includes households and small to medium sized businesses looking to save energy and reduce costs. Our secondary market includes energy companies interested in better load management and personalized customer service. However, with the B2B model, we are ready to serve the industry.

Figure 85: Market Analysis

- **Organization and Management:** SAKOON Energy Solutions will be led by a management team experienced in tech startups, energy solutions, and business development. The company will also employ a skilled team of software engineers, data analysts, and marketing professionals.

- **Service or Product Line:** The SAKOON offers features such as real-time energy monitoring, cost estimation, and personalized energy-saving recommendations. The system provides a mobile application for domestic or small businesses and a web-based dashboard with industrial control panel for the industry with interactive UI.

- **Marketing and Sales Plan**: The marketing plan will emphasize digital channels like social media, SEO, and content marketing. Sales will be mostly online, including direct-to-consumer and B2B options for energy firms.

Figure 86: SEO

- **Request for money:** The startup will seek seed money from venture capitalists, angel investors, and government grants encouraging energy-efficient activities. The money will go toward product development, marketing, and operating expenses.

Figure 87: Request for finance

- **Financial Projections:** SAKOON expects to achieve profitability within the first three years of operation. The financial projection includes increasing revenue as the product gains market penetration, and operating expenses decrease as a percentage of sales.

Figure 88: Profit

- **Exit Strategy:** The company's long-term plan could involve an acquisition by a larger technology or energy company or possibly an IPO if market conditions are favorable.

ANNEXURE

Algorithm for setting up the ESP8266 board in Arduino IDE

1. Install Updated Arduino IDE.

Figure 89: Double Click on Setup or Right Click -> Run as administrator ->ok.

Figure 90: Click on "I Agree" to continue installation.

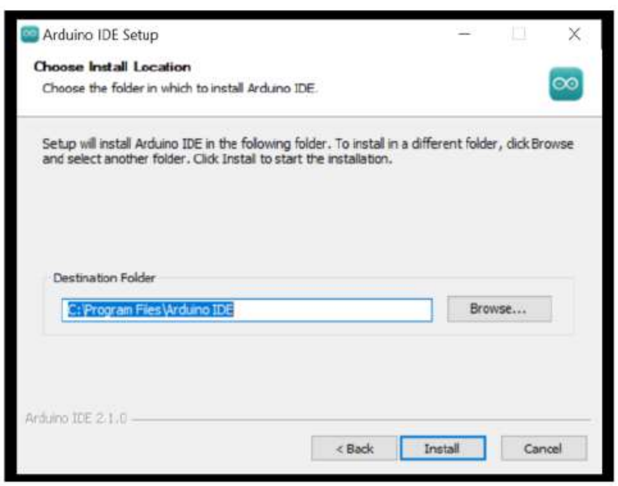


Figure 91: Select Destination Folder where you want to install setup.

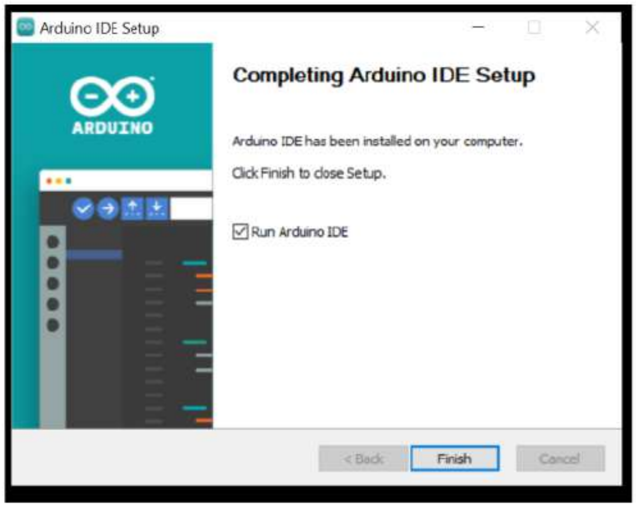


Figure 92: Click on Finish

2. Open Arduino IDE.

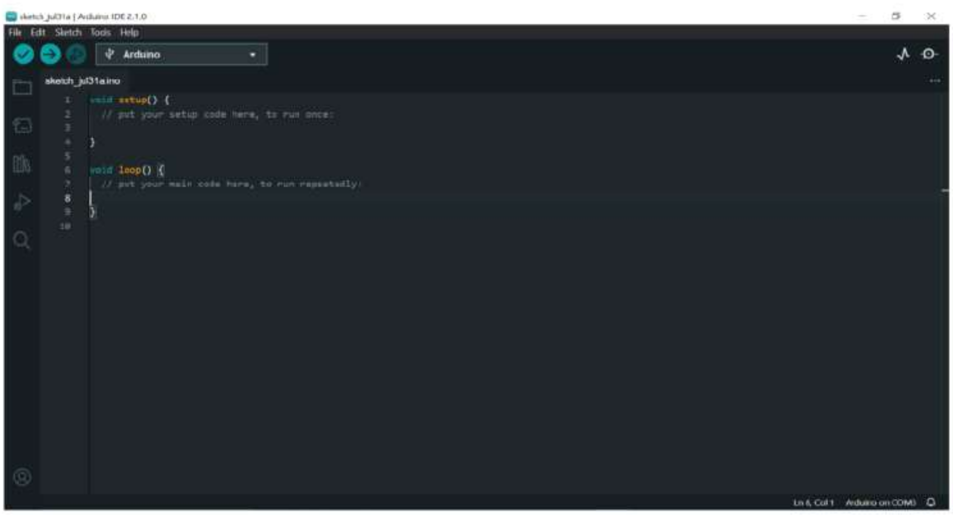


Figure 93: Arduino IDE

3. Connect the Wemos D1 mini to PC using a micro-A-type USB cable and select the connected COM port from the "Tools" menu.

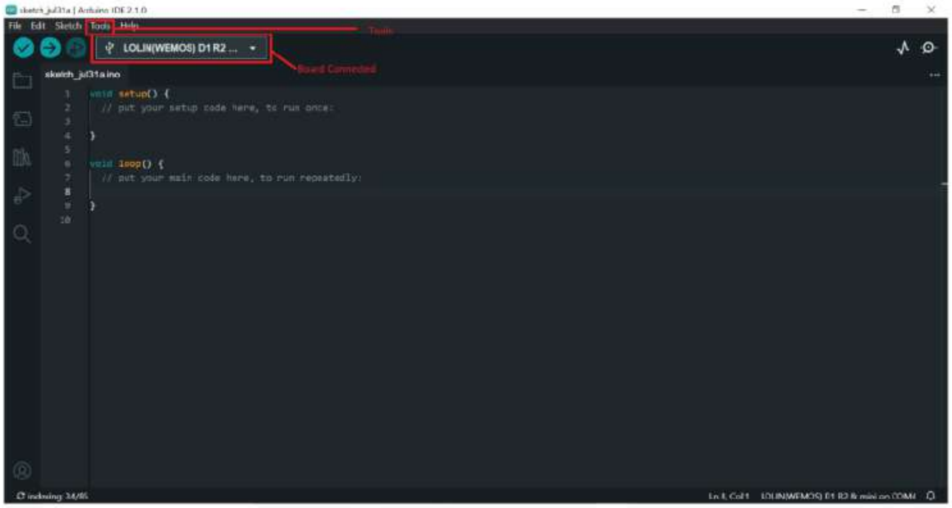


Figure 94: Board Connection and Tools Menu

4. Choose "Preferences" from the "File" menu.

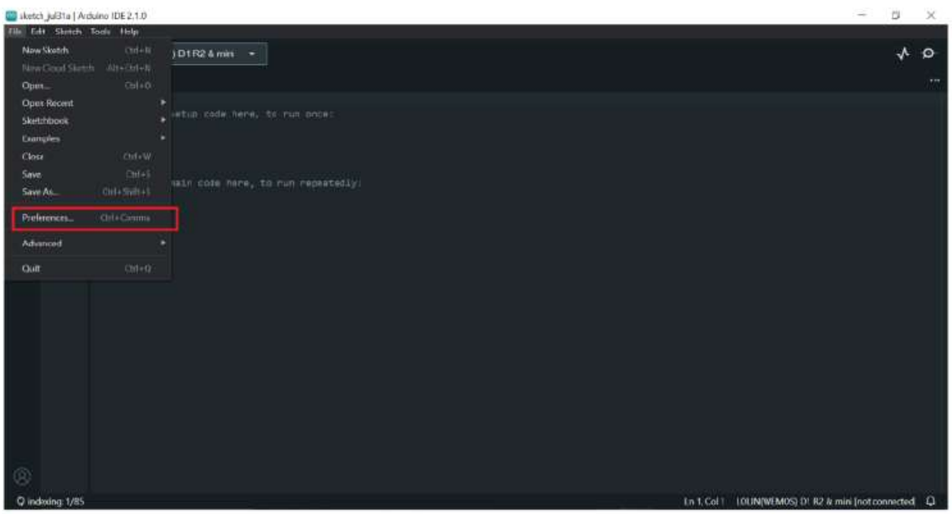


Figure 95: Preferences from File Menu

5. The "Additional Boards Manager URLs" field is in the "Preferences" pane. Put the URL http://arduino.esp8266.com/stable/package_esp8266com_index.json in this box.

6. To save your changes and dismiss the "Preferences" window, click "OK."

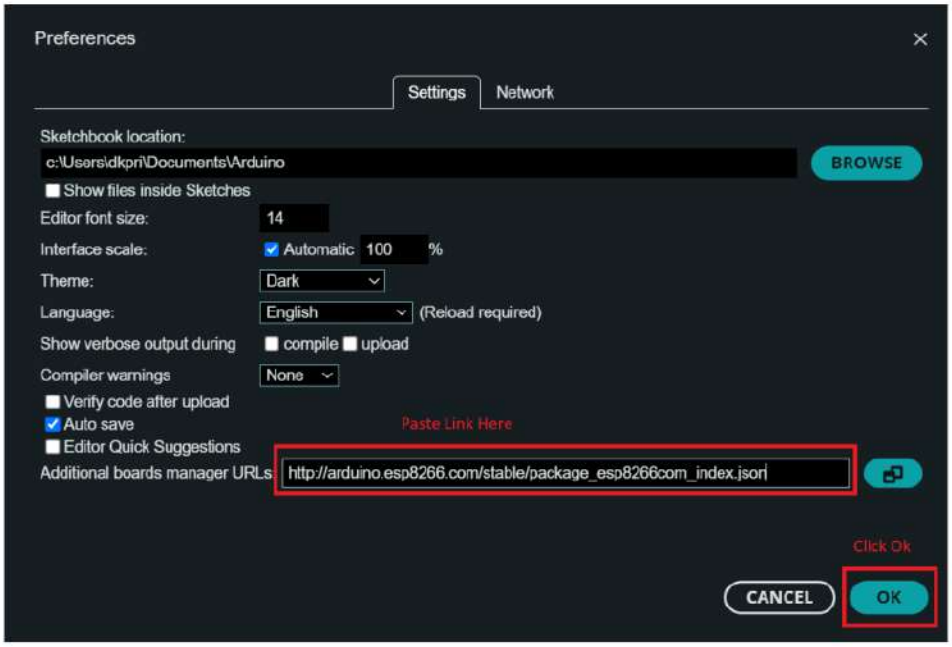


Figure 96: Paste link and Click OK

7. Pick "Boards Manager" from the "Tools" menu's "Board" section.
8. Enter "ESP8266" in the "Boards Manager" window's search field.

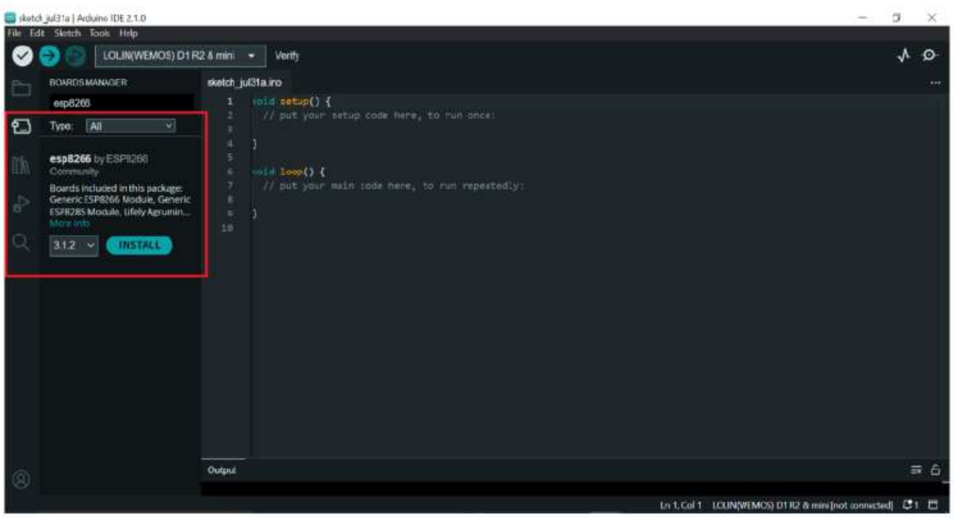


Figure 97: ESP8266 in Board Manager Menu

9. Hold off until the installation is finished. Close the "Boards Manager" window once you're finished.

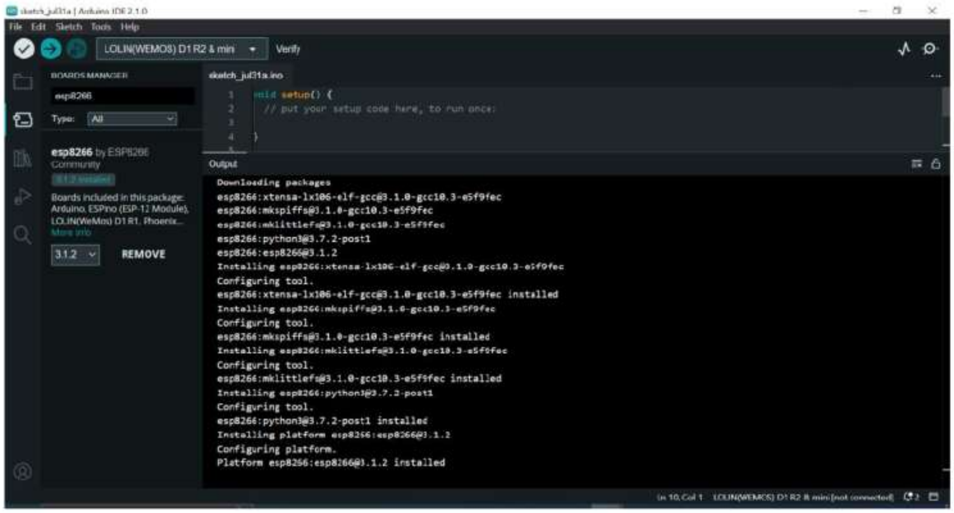


Figure 98: Successfully Installed

10. Return to the "Tools" menu, choose "Board," then scroll down until you find the ESP8266 boards. Choose your exact ESP8266 board from the list; in this example, "WeMos D1 R1" from the list.
11. After choosing the board, you may write code or upload sketches to your ESP8266 board based on your needs.

Code

Sensor with Arduino

```
#include <PZEM004Tv30.h>

PZEM004Tv30 pzem(16, 17);

void setup() {
    Serial.begin(115200);

    // Uncomment to reset the internal energy counter
    // pzem.resetEnergy()
}

void loop() {

    Serial.print("Custom Address:");
    Serial.println(pzem.readAddress(), HEX);

    // Read the data from the sensor
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float freq = pzem.frequency();
    float pf = pzem.pf();

    // Check if the data is valid
    if(isnan(voltage)){
        Serial.println("Error reading voltage");
    }
    else if (isnan(current)) {
        Serial.println("Error reading current");
    }
    else if (isnan(power)) {
        Serial.println("Error reading power");
    }
    else if (isnan(energy)) {
        Serial.println("Error reading energy");
    }
```

```
    else if (isnan(freq)) {
        Serial.println("Error reading frequency");
    }
    else if (isnan(pf)) {
        Serial.println("Error reading power factor");
    }
    else {

// Print the values to the Serial console
Serial.print("Voltage: "); Serial.print(voltage);Serial.println("V");
Serial.print("Current: "); Serial.print(current);Serial.println("A");
Serial.print("Power: ");   Serial.print(power);  Serial.println("W");
Serial.print("Energy: ");  Serial.print(energy); Serial.println("kWh");
Serial.print("Freq: ");    Serial.print(freq);   Serial.println("Hz");
Serial.print("PF: ");      Serial.println(pf);

    }

    Serial.println();
    delay(2000);
}
```

```
#include <PZEM004Tv30.h>

PZEM004Tv30 pzem(16, 17);

void setup() {
    Serial.begin(115200);

    // Uncomment to reset the internal energy counter
    // pzem.resetEnergy()
}

void loop() {

    Serial.print("Custom Address:");
    Serial.println(pzem.readAddress(), HEX);

    // Read the data from the sensor
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float freq = pzem.frequency();
    float pf = pzem.pf();

    // Check if the data is valid
    if(isnan(voltage)){
        Serial.println("Error reading voltage");
    } else if (isnan(current)) {
        Serial.println("Error reading current");
    } else if (isnan(power)) {
        Serial.println("Error reading power");
    } else if (isnan(energy)) {
        Serial.println("Error reading energy");
    } else if (isnan(freq)) {
        Serial.println("Error reading frequency");
    } else if (isnan(pf)) {
        Serial.println("Error reading power factor");
    } else {
// Print the values to the Serial console
Serial.print("Voltage: "); Serial.print(voltage);Serial.println("V");
Serial.print("Current: "); Serial.print(current);Serial.println("A");
Serial.print("Power: ");   Serial.print(power);  Serial.println("W");
Serial.print("Energy: ");  Serial.print(energy); Serial.println("kWh");
Serial.print("Freq: ");    Serial.print(freq);   Serial.println("Hz");
Serial.print("PF: ");      Serial.println(pf);
    }
    Serial.println();
    delay(2000);
}
```

Figure 99:Code for PZEM with Arduino

Wi-Fi

```cpp
#include <ESP8266WiFi.h>

void setup() {
  Serial.begin(115200);
  // Connect to WiFi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
```

Figure 100: Wi-Fi Configuration

Webserver

```cpp
#include <ESP8266WebServer.h>

char auth[] = "################################"; // Replace with your Blynk authentication token
const char* ssid = "Wifi- Name";
const char* password = "passward";

ESP8266WebServer server(80);

void handleRoot() {
String html = "<html><body>";
  html += "<h1>SAKOON</h1>";
  html += "<p>Voltage: <span id=\"voltage\">" + String(voltage) + "</span>V</p>";
  html += "<p>Current: <span id=\"current\">" + String(current) + "</span>A</p>";
  html += "<p>Power: <span id=\"power\">" + String(power) + "</span>W</p>";
  html += "<p>Energy: <span id=\"energy\">" + String(energy) + "</span>Wh</p>";
  html += "<p>Frequency: <span id=\"frequency\">" + String(frequency) + "</span>Hz</p>";
  html += "<p>Power Factor: <span id=\"pf\">" + String(pf) + "</span></p>";
  html += "<p>Message: <span id=\"message\">" + message + "</span></p>";
  html += "</script>";
  html += "</body></html>";
}

void runLocalServer() {
  server.handleRoot();
}
```

Figure 101: Code for ESP8266 Web Server

Blynk Integration

```cpp
#include <BlynkSimpleEsp8266.h>

char auth[] = "################################";  // Replace with your Blynk authentication token
const char* ssid = "Wifi- Name";
const char* password = "passward";

void handleData() {
  String json = "{";
  json += "\"voltage\": " + String(voltage) + ",";
  json += "\"current\": " + String(current) + ",";
  json += "\"power\": " + String(power) + ",";
  json += "\"energy\": " + String(energy) + ",";
  json += "\"frequency\": " + String(frequency) + ",";
  json += "\"pf\": " + String(pf) + ",";
  json += "\"message\": \"" + String(message) + "\"";
  json += "}";
  // Send data to Blynk app
  Blynk.virtualWrite(V0, voltage);
  Blynk.virtualWrite(V1, current);
  Blynk.virtualWrite(V2, power);
  Blynk.virtualWrite(V3, energy);
  Blynk.virtualWrite(V4, frequency);
  Blynk.virtualWrite(V5, pf);
  Blynk.virtualWrite(V6, message);
}
```

Figure 102: Blynk Integration

Firebase Integration

```cpp
#include <FirebaseESP8266.h>

#define FIREBASE_HOST "https://name-#####-default-rtdb.firebaseio.com/"
#define FIREBASE_AUTH "**************************************************"
const char* ssid = "Wifi- Name";
const char* password = "passward";
FirebaseData firebaseData;

void sendDataToFirebase() {
  float voltage, current, power, energy, frequency, pf;
  voltage = pzem.voltage();
  current = pzem.current();
  power = pzem.power();
  energy = pzem.energy();
  frequency = pzem.frequency();
  pf = pzem.pf();
  // Send data to Firebase
  Firebase.pushFloat(firebaseData, "/voltage", voltage);
  Firebase.pushFloat(firebaseData, "/current", current);
  Firebase.pushFloat(firebaseData, "/power", power);
  Firebase.pushFloat(firebaseData, "/energy", energy);
  Firebase.pushFloat(firebaseData, "/frequency", frequency);
  Firebase.pushFloat(firebaseData, "/pf", pf);
  Firebase.pushString(firebaseData, "/message", message);
}
```

Figure 103: Firebase Integration

Cost Estimation

```
float ECOST = 30;
float CPDAY = 24;
float CPMONTH = 30;
float energyInKWh = power / 1000;
float cost = energyInKWh * ECOST;
float costpday = cost * CPDAY;
float costpmonth = costpday * CPMONTH;
Blynk.virtualWrite(V7, String(cost));
Blynk.virtualWrite(V8, String(costpday)); // Convert costpday to string
Blynk.virtualWrite(V9, String(costpmonth));
```

Figure 104: Cost Estimation (Real Time, Daily, Monthly)

High Load Detection

```
String message;

if (power >= 1000) {
  message = "Heavy Load Detected";
} else if (power >= 1) {
  message = "Light Load Detected";
} else {
  message = "No Load Detected";
}
```

Figure 105: Code for Heavy Load Detection

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