DESIGN AND CONSRTUCTION OF ENERGY METER OVER IOT WITH ANDROID APPLICATION

BY

Your name

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SUBMITTED TO:

THE DEPARTMENT OF ELECTRICAL ELECTRONICS ENGINEERING, INSTITUT E OF TECHNOLOGY,

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF HIGHER DIPLOMA (HND) C ERTIFICATE IN ELECTRICAL ELOCTRONICS ENGINEERING

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CERTIFICATION

This is to certify the project work was carried out and submitted by **your name** of Matric Number: **HND/23/EEE/FT/0256** to the Department of Electrical/Electronics Engineering i s accepted having confirmed with the requirements for the Award of Higher National Dipl oma (HND) in the Department of Electrical/Electronics Engineering, Institute of Technolo gy, Kwara State Polytechnic, Ilorin.

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DEDICATION

"To the Almighty Allah, for guiding and blessing me on this journey.

To my late mother, whose love, sacrifices, and prayers continue to inspire and motivate me.

To my dear sister Mrs. OLAYEMI, who has shouldered responsibilities with c ourage and dedication, thank you for being a pillar of strength and support

ACKNOWLEDGEMENTS

All praises belong to Almighty God for all His wondrous work in my life

I sincerely express my profound gratitude to my supervisor **ENGR. KABIRU LATEEF**, for his fatherly support, advice, time and correction toward the completion of this project. Indeed I and my project partners can testify that you are a true father to us, may God bless you sir!

I will not fail to express my gratitude to the Head of Department, **ENGR. DR. LAWAL AHMED O**. and the entire staff of Electrical/Electronic Department, Kwara State Polytechnic, Ilorin for their contribution successful completion of this work.

I'm extremely grateful to my lovely and beloved parents for their support throughout my academic pursuit, may Almighty God bestow you long life and good health to eat the fruit of your labour, (Amen)

ABSTRACT

This project presents the design and implementation of a smart energy meter monitoring system using Internet of Things (IoT) technology integrated with a n Android application. The system aims to provide real-time energy consumpti on data to users, promoting energy efficiency and enabling better control over electricity usage. The core of the system consists of a microcontroller-based energy meter interfaced with sensors to measure voltage, current, and power consumption. This data is transmitted wirelessly via Wi-Fi to a cloud server, w here it is stored and processed. An Android application is developed to provid e a user-friendly interface, allowing consumers to monitor their energy usage r emotely, receive alerts for abnormal consumption, and track usage history thr ough graphical representations. The integration of IoT and mobile technology in this system offers a scalable and cost-effective solution for smart energy m anagement in residential and commercial settings.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The global demand for electricity continues to rise with population growth, rapid industrialization, and the increasing reliance on electrical and electronic appliances. Efficient energy consumption and management are more important than ever to meet these demands while reducing environmental impacts and operational costs.

Traditional electricity metering systems primarily rely on analog or digital meters that are manually read by utility personnel. This process is often slow, labor-intensive, prone to errors, and incapable of providing real-time insights into energy consumption. Furthermore, delayed billing and inefficiencies in energy distribution have further contributed to power loss, increased utility costs, and revenue leakages for utility companies.

In recent years, the Internet of Things (IoT) has emerged as a powerful paradigm, revolutionizing the way data is collected, processed, and acted upon. By embedding sensors and communication modules in physical systems, IoT enables remote monitoring, data-driven automation, and proactive management across various industries—including the power sector.

Combining IoT with smart energy metering allows for:

- Real-time energy monitoring.
- Automated billing.
- Instant notifications on anomalies or excessive consumption.
- Remote access via mobile applications.

This project seeks to design and construct a functional prototype of an IoT-based energy meter that allows users to monitor their power consumption in real-time using an Android application. This integration not only improves transparency and reliability but also empowers users to adopt energy-saving habits, thereby contributing to a sustainable energy ecosystem.

1.1.1 DEFINITION OF TERMS

IoT (Internet of Things): A system of interrelated computing devices capable of transferring data over a network without requiring human interaction.

i. Energy Meter: A device that measures the amount of electrical energy consumed.
ii. Smart Meter: An advanced version of an energy meter with communication and control features.
iii. kWh (Kilowatt-hour): Standard unit for electrical energy usage.
iv. Microcontroller: A compact integrated circuit that controls electronic devices.
v. Android App: A software application designed to run on devices using the Android operating system.

1.2 PROBLEM STATEMENT

The traditional methods of energy monitoring and billing come with multiple shortcomings:

- Manual readings are time-consuming and susceptible to human errors.
- Lack of real-time monitoring makes it difficult for consumers to track consumption and control usage.
- Inefficiencies in billing systems lead to estimated charges, delays, or overbilling.
- Inability to promptly detect power theft or system faults contributes to revenue losses and service disruptions.
- No proactive user engagement—consumers often receive feedback only after billing, by which time energy-saving opportunities may have been lost.

This project aims to address these issues by providing a smart, accurate, and user-friendly energy monitoring solution that ensures timely feedback, remote accessibility, and greater efficiency for both end-users and utility providers.

1.3 AIM AND OBJECTIVES

Aim:

To design and construct an IoT-enabled energy meter integrated with an Android application that enables real-time monitoring, usage alerts, and data analytics.

Objectives:

- Design and build a reliable energy metering circuit using appropriate sensors.
- Integrate a microcontroller (e.g., ESP32) with IoT communication modules.
- Interface the system with cloud services for data storage and retrieval.
- Develop an intuitive Android application for users to track energy usage in real time.
- Implement alert systems to notify users about abnormal usage or thresholds.
- Ensure accuracy, stability, and security of the system during operation.

1.4 Significance of the Study

This study contributes to both academic research and practical implementation by empowering users to monitor and control their electricity usage habits, leading to reduced costs, while also enhancing operational efficiency for utility providers through improved load management, faster fault detection, and reduced reliance on manpower. It showcases innovation in the power sector by demonstrating how embedded systems and mobile platforms can revolutionize traditional electricity management. Additionally, the system promotes environmental sustainability by encouraging energy efficiency and reducing carbon footprints. Its scalable design allows for adaptation across various settings, including homes, schools, industries, and national power grids, with appropriate modifications.

1.5 SCOPE OF THE STUDY

This project focuses on:

Real-time measurement of electrical energy using current and voltage sensors.Transmission of data to a cloud platform using Wi-Fi or GSM.Development of an Android mobile application to display live consumption data and usage history.Alert generation based on user-defined thresholds.The project does not cover prepaid billing integration, advanced tariff structures, or industrial-grade load analysis.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In recent years, the increasing global demand for energy, the need for accurate metering, and the push toward smart cities have made energy monitoring a focal point in power systems and consumer management. Traditional energy metering systems are plagued by inefficiencies such as manual readings, lack of real-time data, and inaccurate billing, which not only hinder energy conservation efforts but also affect user experience and revenue collection for power companies. The integration of the Internet of Things (IoT) into energy metering systems has paved the way for intelligent and remote monitoring solutions that can be accessed via mobile platforms like Android applications. This chapter presents an in-depth review of the relevant literature covering energy metering systems, smart meters, IoT frameworks, embedded systems, data communication protocols, Android interfaces, cloud platforms, cybersecurity concerns, machine learning integration, user adoption, energy policy, standards, renewable integration, and identified gaps in current im plementations.

2.2 ENERGY METERING SYSTEMS

An energy meter, also known as an electricity meter, is a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. Traditional energy meters are electromechanical and operate using a rotating aluminum disc influenced by magnetic fields created by voltage and current coils. These types of meters, although robust, are limited by their analog nature and dependence on manual readings.

With the advancement of electronic components and digital signal processing, modern digital energy meters have emerged. These meters use microcontrollers or digital signal processors to sample the voltage and current waveforms, calculate the real-time power, and integrate it over time to determine energy consumption. Digital meters offer better accuracy, memory storage capabilities, and the potential for further automation.

Prepaid energy meters represent another evolution in energy metering, where consumers pay in advance for electricity. These meters help in revenue assurance and give users better control over their consumption. However, they still largely depend on human intervention for recharging and are limited in offering real-time insights.

More advanced meters now include features such as automatic meter reading (AMR) and advanced metering infrastructure (AMI). AMR systems enable the automatic collection of consumption, diagnostic, and status data from energy metering devices without the need for manual readings. AMI expands on AMR by enabling two-way communication, which provides utilities with better control over the grid and consumers with detailed information on their energy use.

2.3 SMART METERS AND THE INTERNET OF THINGS (IOT)

Smart meters are at the heart of smart grid innovation. By leveraging IoT, th ese devices transcend traditional functionality and provide intelligent features such as real-time data analytics, fault detection, remote disconnection, dynamic pricing, and integration with renewable energy sources. These systems are essential for the effective deployment of distributed energy resources (DERs), especially in residential solar PV systems.

IoT smart meters use various sensors to measure voltage, current, frequency, and power factor. Data collected by the sensors is processed locally using microcontrollers and then transmitted to cloud platforms for remote access and analysis. This transformation has led to the development of energy intelligence systems capable of detecting anomalies, forecasting loads, and even suggesting load shifting to reduce energy costs.

2.4 EMBEDDED SYSTEMS IN ENERGY METERING

The choice of embedded platform determines the capability and efficiency of a smart metering system. The most common choices include:

- Arduino UNO/MEGA
- ESP32/ESP8266
- STM32 Series
- Raspberry Pi

Embedded firmware design focuses on real-time sampling of electrical signals, performing RMS calculations, power factor determination, and detecting zero-crossings for frequency calculations. The efficiency of these operations directly impacts system responsiveness. Real-time operating systems (RTOS) are increasingly being used in advanced designs to manage multiple tasks with precise timing.

2.5 COMMUNICATION PROTOCOLS AND NETWORK ARCHITECTURES

The selection of communication protocol impacts system performance, especially in terms of latency, range, cost, and power consumption. Common protocols include:

- Wi-Fi
- GSM/GPRS
- Zigbee
- LoRaWAN
- NB-IoT

Hybrid communication architectures are gaining traction to balance the limitations of individual technologies. Star, mesh, and tree topologies are analyzed based on reliability, range, and energy efficiency.

2.6 ANDROID APPLICATION FOR MONITORING AND CONTROL

Mobile applications are critical for bridging the user interface gap. Beyond data monitoring, advanced features now include:

- Real-time device control
- Load prediction via ML models
- Scheduling high-consumption appliances
- Alert and notification systems for irregular usage
- Offline storage with sync-on-connect capabilities

UX/UI studies emphasize the role of simplified visuals, user onboarding tutorials, and interactive energy dashboards in boosting adoption.

2.7 CLOUD PLATFORMS AND EDGE COMPUTING

Cloud platforms like AWS IoT, Microsoft Azure, and Google Cloud IoT provide scalable backends for data storage, real-time analytics, and remote control. These systems utilize:

- MQTT, CoAP, and WebSockets
- Serverless architectures
- Edge computing gateways for pre-processing

Recent frameworks combine cloud and fog computing to optimize latency-sen sitive tasks, reduce bandwidth use, and ensure local autonomy during network outages.

2.8 SMART GRID INTEGRATION

Smart meters play a critical role in demand-side management and renewable energy integration. Their benefits include:

- Integration with solar, wind, and bio-energy sources
- Real-time balancing of demand and supply
- Identification of load profiles
- Support for net metering and energy credit systems

Additionally, virtual power plants (VPPs) use data from smart meters to coordinate DERs and optimize grid load balancing.

2.9 CYBERSECURITY AND PRIVACY CONSIDERATIONS

As smart meters generate and transmit real-time user data, cybersecurity becomes vital. Threat vectors include:

- Data interception
- Spoofing and replay attacks
- Unauthorized firmware updates

Recommended security measures:

- End-to-end encryption
- Blockchain-based data logging
- Tamper detection systems
- Intrusion detection powered by AI

2.10 AI AND MACHINE LEARNING APPLICATIONS

AI is transforming energy systems through:

- Anomaly detection in consumption
- Load forecasting
- User classification for personalized suggestions

- Predictive fault detection in the meter hardware

Deep learning models such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) are being explored for their accuracy in energy load predictions.

2.11 RENEWABLE ENERGY AND ENVIRONMENTAL IMPACT

Smart metering supports environmental sustainability by:

- Reducing energy waste
- Monitoring carbon footprints
- Supporting dynamic pricing to discourage peak usage

Smart meters also support carbon credit systems and renewable energy certificates (RECs) by accurately tracking consumption and generation.

2.12 REGULATORY POLICIES AND STANDARDS

Global and regional energy bodies have developed standards such as:

- IEEE 802.15.4 for low-rate WPANs
- IEC 62056 for DLMS/COSEM protocols
- IS 13779 and IS 15959 for Indian smart meter interoperability

Policies from regulatory commissions define acceptable accuracy classes, communication protocols, and data privacy laws governing smart metering.

2.13 SOCIOECONOMIC AND ADOPTION BARRIERS

Challenges include:

- High deployment costs
- Lack of infrastructure in rural areas
- Consumer mistrust
- Political and economic instability

Addressing these requires public-private partnerships, subsidy programs, and consumer education campaigns.

2.14 THEORETICAL FRAMEWORK

This study is underpinned by the Cyber-Physical Systems (CPS) model, Diffusion of Innovation Theory, Systems Theory, and the Technology Acceptance Model (TAM). Together, these frameworks explain the structure, behavior, user acceptance, and integration patterns of IoT-based smart metering systems.

2.15 SUMMARY

This chapter has thoroughly explored the literature surrounding IoT-based energy metering systems. It has expanded the scope to cover cybersecurity, AI, cloud-edge synergy, renewable energy integration, policy, socioeconomic impacts, and theoretical foundations. These reviews provide the context for the design and construction of a smart energy metering solution that is not only technically sound but also user-centric, secure, and adaptable to modern energy management demands.

CHAPTER THREE

SYSTEM DESIGN AND ANALYSIS

This chapter presents a detailed design of the system, including functional blocks, system architecture, component selection, and *extensive* design calculatio ns for each section of the circuit diagram. The objective is to make each design de cision clear, measurable, and defendable based on real-world engineering standar ds.

3.1 SYSTEM ARCHITECTURE OVERVIEW

The energy meter monitoring system consists of the following main blocks:

i. **Power Supply Section** (Step-down Transformer, Rectifier, Filter, Voltage Reg ulator)
ii. **Sensor Unit** (Voltage and Current sensing)
iii. **Processing and Communication Unit** (ESP32 Microcontroller)
iv. **Cloud and Mobile Monitoring Interface** (Firebase and Android App)

Below is the block diagram:

3.2 POWER SUPPLY DESIGN (WITH DETAILED CALCULATIONS)

3.2.1 Transformer Selection and Design

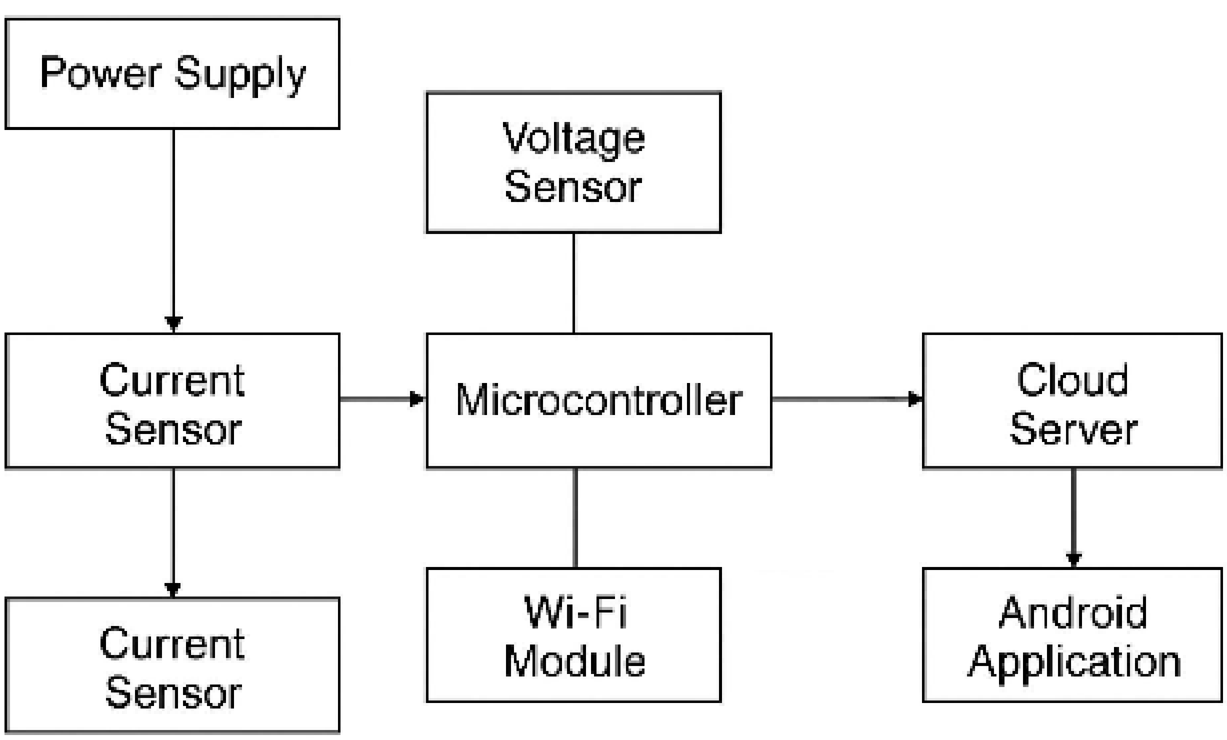

Figure 3.1: Block diagram of the system

Objective: Convert 230V AC (Nigerian mains) to a lower AC voltage (9V) for safe D

C conversion.

Why 9V?

- The ESP32 and sensors require 5V DC.
- After rectification and regulation, voltage drops occur.
- A 9V AC transformer ensures sufficient input voltage for the regulator to wo rk.

Step-by-Step Calculation:

i. Desired DC Output: 5V (for ESP32 and sensors).

ii. Voltage Drops:

- Bridge Rectifier: 1.4V (2 diodes × 0.7V each).
- Voltage Regulator (LM7805): Needs at least 2V above output (5V).
- Total Required DC Input:

  V_{rect}=5V+2V=7V

3. Calculate AC Voltage (RMS):

- Rectified DC voltage ≈ AC voltage (RMS) × √2 (peak) − diode drops.
- Including efficiency (≈90% for real transformers):

  $V_{sec(rms)} = \frac{Vrect + Diode\ drops}{\sqrt{2} \times Efficiency} = \frac{7V+1.4V}{1.414 \times 0.9} = 6.6V$
- Standard 9V transformer selected (to account for load fluctuations).

Turns Ratio Explained:

- Turns Ratio Formula:

$$\frac{Np}{Ns} = \frac{Vp}{Vs}$$

Where:

- N_p = Primary turns (230V side).
- N_s = Secondary turns (9V side).
- V_p=230V, Vs=9V.