Design and Development of IOT-Based Improved Electric Smart Meter to Monitor Domestic Energy Consumption

Amrutha M, Anusha M S, Preksha S, Shashank Purohit, Dr. Kishore G R

[1]Student, [2]Student, [3]Student, [4]Student, [5] Associate Professor
[1]Department of Information Science and Engineering,
[1]Jyothy Institute of Technology, Bengaluru, India

Abstract - With the start of ARPANET (Advanced Research Project Agency Network) and computing development, a wireless network device was created to share, gather, create, and receive data. This is referred to as the internet of things (IoT). This design and development of an IoT-based improved electric smart meter for monitoring domestic energy consumption is aimed at providing a more efficient, cost-effective, and eco-friendly energy solution for households. The smart meter consists of Arduino, Node MCU ESP8266, microcontroller, power monitoring unit and GSM module. One of the key features of the electric smart meter will be the implementation of an SMS feature, which will allow users to receive updates about their energy consumption alerts via text message. This information can then be monitored and managed through a mobile application by users. This project aims to provide households with real-time energy consumption data and energy management tools, which will help to reduce bill shock, energy wastage and save costs. The implementation of this system will also provide a more accurate method of energy billing and enhance the overall energy management process in domestic areas. The use of IoT technology will ensure that the system is user-friendly and scalable, making it suitable for use in both small and large households.

Index Terms - Arduino, Microcontroller, Power Monitoring, SMS gateway, GSM module, Web Application, Node MCU ESP8266

I. INTRODUCTON

The need for a more efficient and eco-friendly energy management solution in households is growing, as energy costs continue to rise and the impact of climate change becomes more apparent. The traditional methods of energy management, such as manual meter readings and estimated billing, are becoming less effective and increasingly outdated.

To address these challenges, the design and development of an IoT-based improved electric smart meter for monitoring domestic energy consumption has been proposed. This system will consist of a smart meter that displays real-time energy readings and is equipped with an SMS gateway that sends energy consumption alerts to the users. The information collected by the smart meter can then be monitored and managed through a mobile application, providing households with real-time energy consumption data and energy management tools.

This system is designed to provide households with a more efficient, cost-effective, and eco-friendly energy solution. By having real-time information on energy consumption, households will be able to identify areas where energy is being wasted and implement changes to reduce energy consumption and costs. Additionally, the use of IoT technology will ensure that the system is user-friendly and scalable, making it suitable for use in both small and large households.

The smart meter will be equipped with advanced technology, including a microcontroller, a GSM module, and a power monitoring unit. This technology will enable the smart meter to collect data on energy usage and transmit it to a central server, where it can be accessed by the users. Additionally, the SMS feature of the smart meter will allow users to receive real-time updates about their energy consumption via text message.

The implementation of this system will also provide a more accurate method of energy billing and enhance the overall energy management process in domestic areas. This will not only benefit households but also contribute to reducing the overall energy consumption.

Overall, by adopting this project a valuable solution for the Domestical sector will be provided. Improving energy efficiency, reducing costs, and helping users to make informed decisions about their energy usage and make a positive impact on the environment.

The rest of the paper is structured as follows: Section II outlines the review criteria. Section III covers the literature survey and a discussion of related works. In sections IV and V, the system architecture and implementation will be presented. Section VII, is the outcome of this project, Section VIII, includes a comparative study, presented in the form of a table for gap identification. The paper concludes in the final section with Acknowledgement and references used.

II. REVIEW CRITERIA

For an independent SMS application/service provider, any technology should be open, interoperable, and operator independent. Carrier-grade SMS-data technology that is used today is not interoperable.

SMS allows sending and receiving of text messages to, and from, mobile stations. It is called short message as an SMS is limited to 160 characters of English text of 7 bits character (ASCII character), or 140 octets of 8 bits character (some European languages or binary data). SMS can also be used for 70 characters of Unicode message (Hindi, Chinese Arabic, or other Asian languages). SMS is never fragmented. SMS uses MAP messages.

In India 1-600-xxxxxx are used for non-geographic toll-free numbers. In telecommunications network, the mapping between a non-geographic number and a physical link is done through the mechanism of Global Title Translation (GTT). Through GTT, a dialed number (which is a non-geographic virtual number) is translated to get a circuit number where the call will be routed. Similarly, the routing of SMS from an MS to any data services is achieved through masked SDSI. The USRS is an intelligent node within the SS#7 network and is outside the scope of administrative control of the home SC or the serving network.

When the intended communication is intermittent and low data rate is not required, GSM-SMS technology offers a straightforward and affordable alternative for remote data access in embedded systems. In addition, GSM encryption naturally offers data security in SMS transmission, and features like delivery report, automatic resend in case of transmission failure, etc. increase its effectiveness. In many remote monitoring and controlling tasks, a further limit on the number of characters that can be conveyed via SMS is perfectly acceptable. Due to all these advantages, GSM-SMS technology has been effectively used for remote data access in a variety of embedded applications. It can be boiled down to the fact that the system is powered by a staged power source with a regulated supply. To ensure correct operation of the system, the power input as AC voltage is first stepped down, then converted to DC voltage, filtered, and regulated before reaching the main circuit. This level includes processes such as transformation, rectification, filtering, and voltage regulation.

The detection of pulses and switching of the stage are used to detect current pulses and convey this data to the microcontroller. During the processing step, all computation and processing are completed. The project concludes with the GSM module providing the consumer's billing information acquired through the previously outlined steps.

III. LITERATURE SURVEY AND RELATED WORKS

Several recently published articles have proposed the design and implementation of IoT gateways for smart homes. Some researchers have proposed a remote water temperature control system with a wired home automation system using the Internet Protocol (TCP/IP) protocol and inexpensive hardware.

However, installing special software before using the system is cumbersome and it is difficult to use multiple sensors simultaneously within the system. Providing communication links between devices and installing backend systems seems to be a challenge for basic wired systems. Customer interest in purchasing home automation systems may decline due to rising construction and maintenance costs. Tor educe construction costs; researchers have created home gateways for Ethernet and ZigBee networks for eco-friendly green systems for applications such as air pollution monitoring and home care. However, traditional access point functionality was not supported by the ZigBee/Ethernet gateways that were created. The gateway can only use internet or intranet communication to send and receive orders between two devices. This integration allows for remote control of appliances and home systems through a mobile device, adding convenience and efficiency to daily life. Various communication systems are being researched, such as the Internet, GSM. However, early system architectures required very expensive equipment and little user interest. A low-cost energy meter with an embedded Node MCU ESP8266 module is used to analysis of energy consumption, enabling users to make informed decisions about their energy usage and reduce their carbon footprint. This automatically reads energy meter data in real time and updates it for energy users. The proposed system can reduce hardware costs as well as implementation and maintenance costs. It also supports the concept of Internet of Things (IOT).

IV. SYSTEM ARCHITECTURE

As advancements in telecommunications and computer technology continue, power utilities are installing increasingly automated power operation systems across their networks. The Internet of Things (IoT) is expected to drive internet standardization enterprises and create a future with real-world internet connectivity.

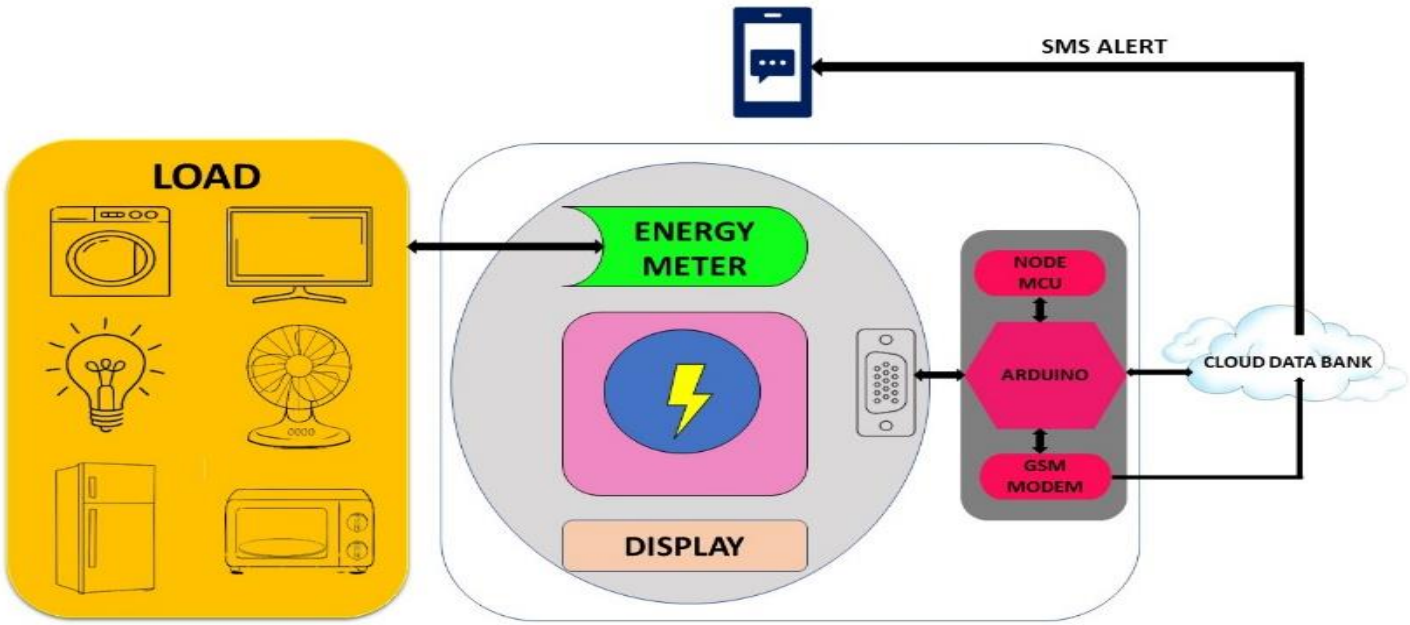

Fig.1.Working Prototype of Electric Smart Meter

From a business perspective, the convergence of these technologies will result in increased demand and opportunities for new approaches to IoT operation development, such as advanced applications, including early detection of structural issues, proactive maintenance of health-related devices, and seamless integration with other smart home technologies.

The suggested Node MCU ESP8266 predicated single phase energy meter for IoT is depicted in Fig 1. Working Prototype of Electric Smart Meter that communicates through the TCP/ IP protocol. In order to achieve effective energy operation, the suggested system incorporates an intertwined digital energy meter, an IoT gateway, and a web- based system.

V. SYSTEM IMPLEMENTATION

The Node MCU ESP8266 is a Wi-Fi module that can be used in the implementation of a smart meter system. It allowsfor the creation of a wireless network connection between the smart meter and a web application,enabling real-time data access and communication. The ESP8266 is a cost-effective and compact solution for adding Wi-Fi capabilities to a smart meter, as it has integrated TCP/IP protocol support and can be easily programmed using the Arduino IDE. By using the ESP8266, the smart meter system can be connected to the internet and remotely monitored, providing utilities and consumers with valuable information about energy consumption and usage patterns. The use of theESP8266 in the implementation of a smart meter systemenhances its functionality and efficiency. Fig. 2 Circuit Diagram of Electric Smart Meter

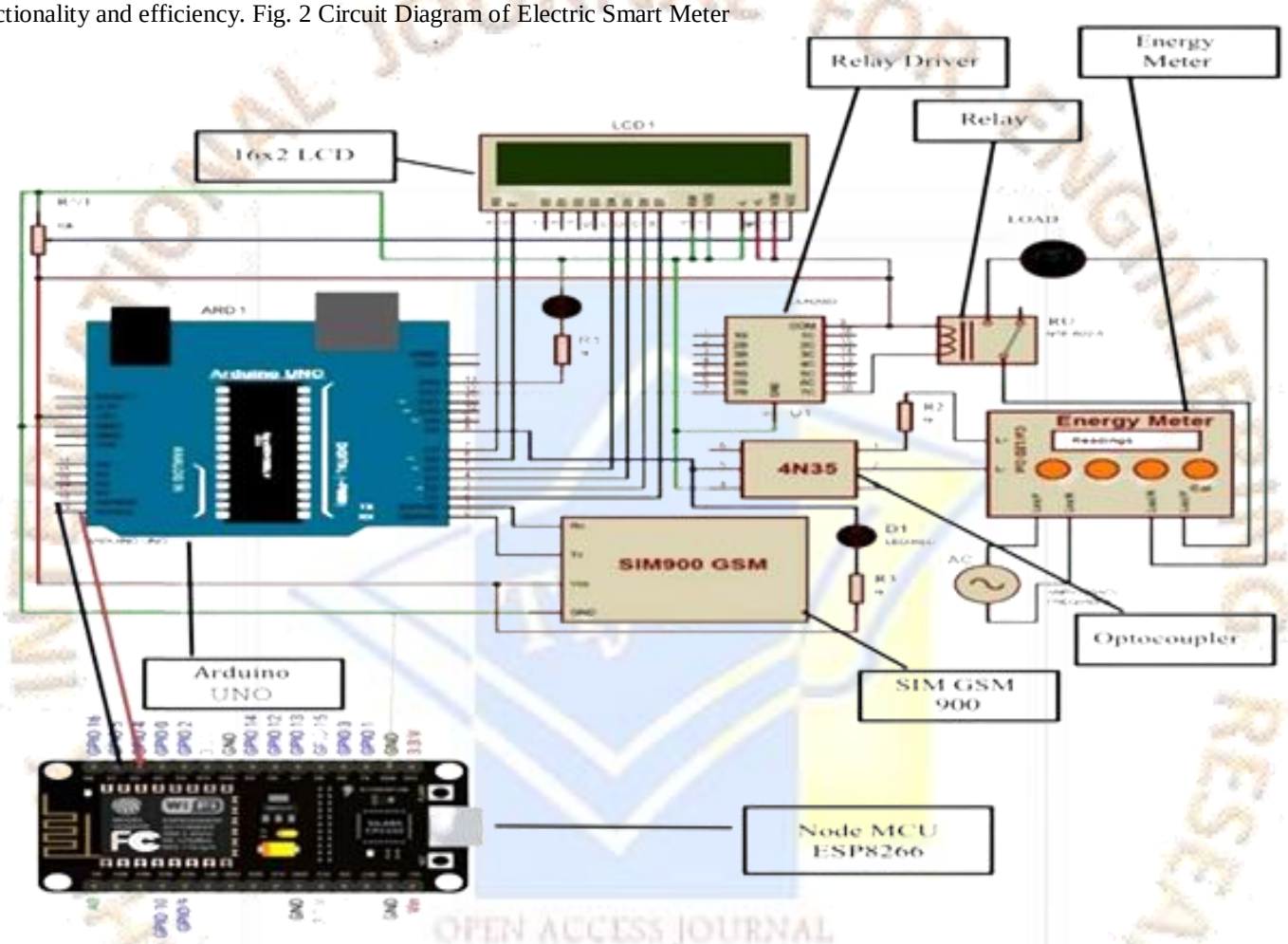

Fig.2. Circuit Diagram of Electric Smart Meter

The advanced energy meter in the proposed framework computes key boundaries like voltage, current, power in kVAr and kW, and energy in kVarh and kWh utilizing an Arduino Leonardo Star Miniature. The ongoing sensor, ACS712, is fit for taking care of up to 30 Amperes and functions admirably with microcontrollers like the Arduino. It is great for applications, for example, load recognition, exchanging mode power supply, and over current insurance. The ZMPT 101B voltage transformer precisely gauges voltage and power with a stockpile voltage of 5VDC and a simple sign result.

The DS3231 ongoing clock module is a minimal expense and exact I2C RTC with an inherent precious stone and temperature-repaid oscillator. It holds exact timekeeping in any event, when the primary power is lost and has a battery input, with the capacity to run on either a 12-hour or 24-hour premise with PM/AM sign. There are configurable square-wave outputs and time-of-day alerts available. I2C bidirectional bus is used to serially transport address and data. With black lettering on a green backdrop and 16 characters per line, the 16x2 LCD display module can show information. For commands and data, there are two registers on the LCD. It can be readily programmed and has no display restrictions.

The digital energy meter's operating flowchart is shown in Figure 4 after the LCD and UART have been initialized. The first step in the procedure is to define the load profile for 15 minutes at a time, with energy calculations occurring every 1 millisecond. To ensure for the time of power down, the load profile data will be recorded into EEPROM, and then the data will be saved into the

memory right away. When a user requests to read a meter parameter from memory, Table 1-3 will display the system's protocol. Let's take a look on the values from the tables below:

TABLE I: THE PROTOCOL FORMAT

Start	Meter ID	Command	Stop
1 byte	10 bytes	3 bytes	1 byte

TABLE II: THE COMMAND TABLE FOR THE METER PROTOCOL

Value to read	Command of protocol
kW	001
kVAr	002
kWh	003
kVarh	004
Instantaneously kW, kVAr, kWh, kVarh	005

TABLE III: THE RETURN COMMAND FOR READING KW

Start	Meter ID	Command	Stop
1	001	Floating point value with 3 Decimal place	-

The ESP8266 Wi-Fi is a free-standing system on a chip with an inbuilt TCP/IP protocol stack that may allow any microcontroller access to a Wi-Fi network. It is manufactured by a Chinese company with headquarters in Shanghai called Express if Systems. The Node MCU ESP8266 may doall Wi-Fi networking tasks by offloading them from another application processor in addition to hosting anapplication.

The software of the ESP8266 module is pre- programmed with AT instructions, making it simple to connect it to an Arduino device for Wi-Fi. Because the ESP8266 includes on-board computation and storage, it is simple to interact with sensors and other IoT devices viaits GPIOs with minimal development and runtime overhead. The chip's high level of integration minimizes the need for external components and takes up limited PCB space. Additionally, the ESP8266 features a self-calibrated RF for reliable operation in any situation, eliminating the need for external RF components. It also supports Automatic Power Save Delivery for VoIP applications and Bluetooth coexistence interfaces. By utilizing this technology, consumers may lower power waste and consumption costs by being aware of how muchelectricity is being used in their homes. The experimental findings demonstrate that the suggested system operates effectively and efficiently, and that it can be put into use inreal-world scenarios for very low-cost automatic energy meter reading in order to investigate factors that influence individual decisions to accept and use smart meter systemsin the area of electricity consumption.

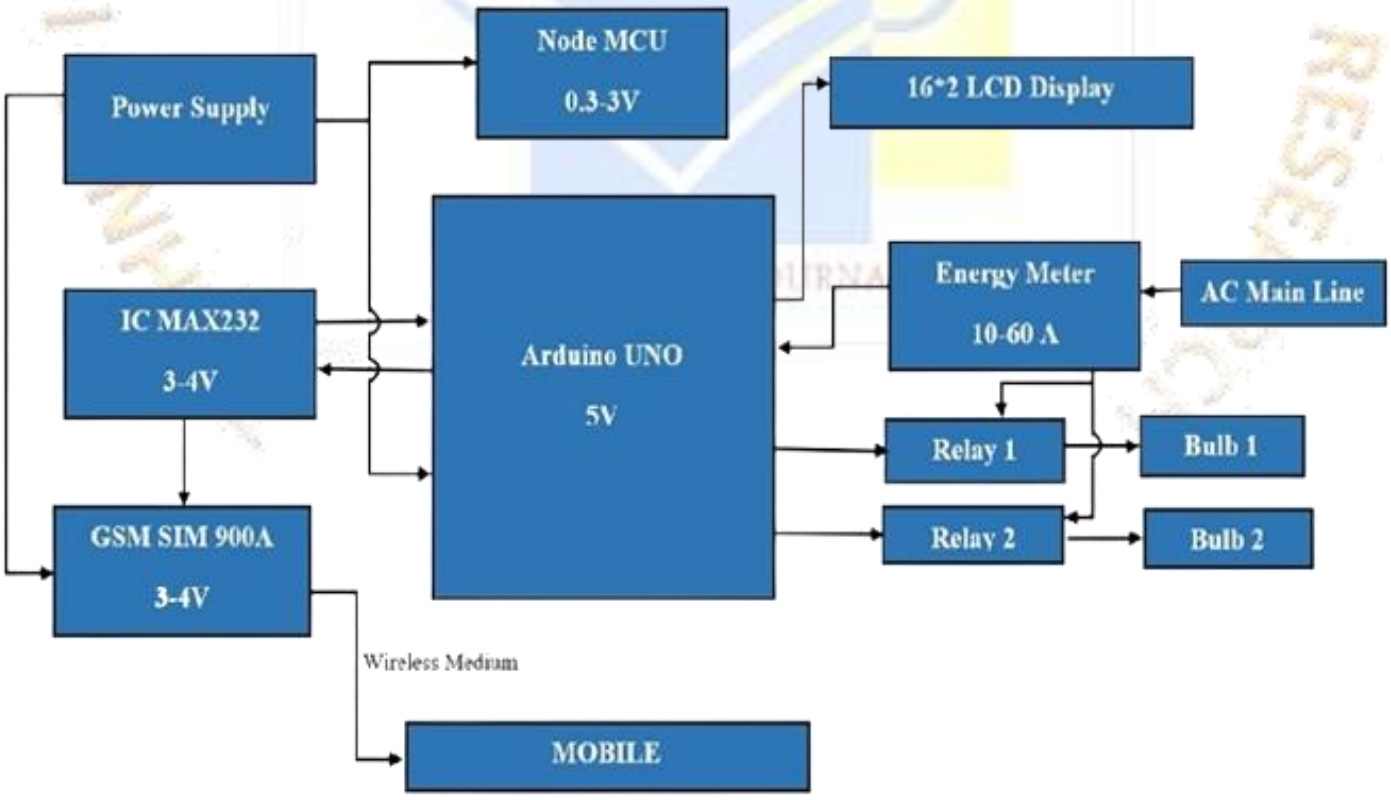

Fig.3. Block Schematic of Elecrtic Smart Meter

By utilizing the Google search API, a robot (software agent) may programmatically find the websites thatcorrespond to the phrases "free SMS." Some people send phone anonymous SMS messages using these APIs. Some writing has referred to this as SMS spoofing. Inthese situations, people send unwanted bulk SMS texts in an effort to make money. A 32-bit random number generator is used to produce the target IP address in cases of computer worms and other sorts of DDoS assaults onthe Internet. The destination addresses, however, must follow the SMS E.164 addressing protocol. The opponent needs to work a little more in this circumstance to create the proper address. The W2S site-specific addresses will be used for these. However, it is not difficult to determine any mobile operator's address range. These are publicly accessible online.

The opposition will set up HTTP links to several W2S (Web to SMS) websites. The SME or the SMS gateway will receive any messages the robot sends over the Web. These SMS would be submitted by the SME to different local SC. A carefully chosen Web to SMS site will enable SC selection and target MSISDN in such a way as to allowSC of different operators to be selected. The attack will be more deadly if these operatives are spread out globally. Millions of SMS might be sent simultaneously to several SCs throughout the world if all URLs were hacked. DDoS attacks will then be launched on the SMS channel and the SS#7 network as a result. It would seem obvious that theseSMS assaults will only target the operators whose SMSCis active. However, this is not the case in actuality. Any network typically has 5% or more subscribers who are continually roaming. On average, 40% or more of these users use international roaming. As a result, there is a possibility that an SMS sent by an attacker to a cellphone in the UK will reach the recipient in Australia. In this scenario, the SMS will be sent through the SS#7 network between the UK and Australia, and the delivery report willbe sent over the SS#7 link between Australia and the UK. As an outcome, as was already mentioned, as long as SCs are dispersed globally, SMS flooding will cause the SS#7 network to become congested globally.

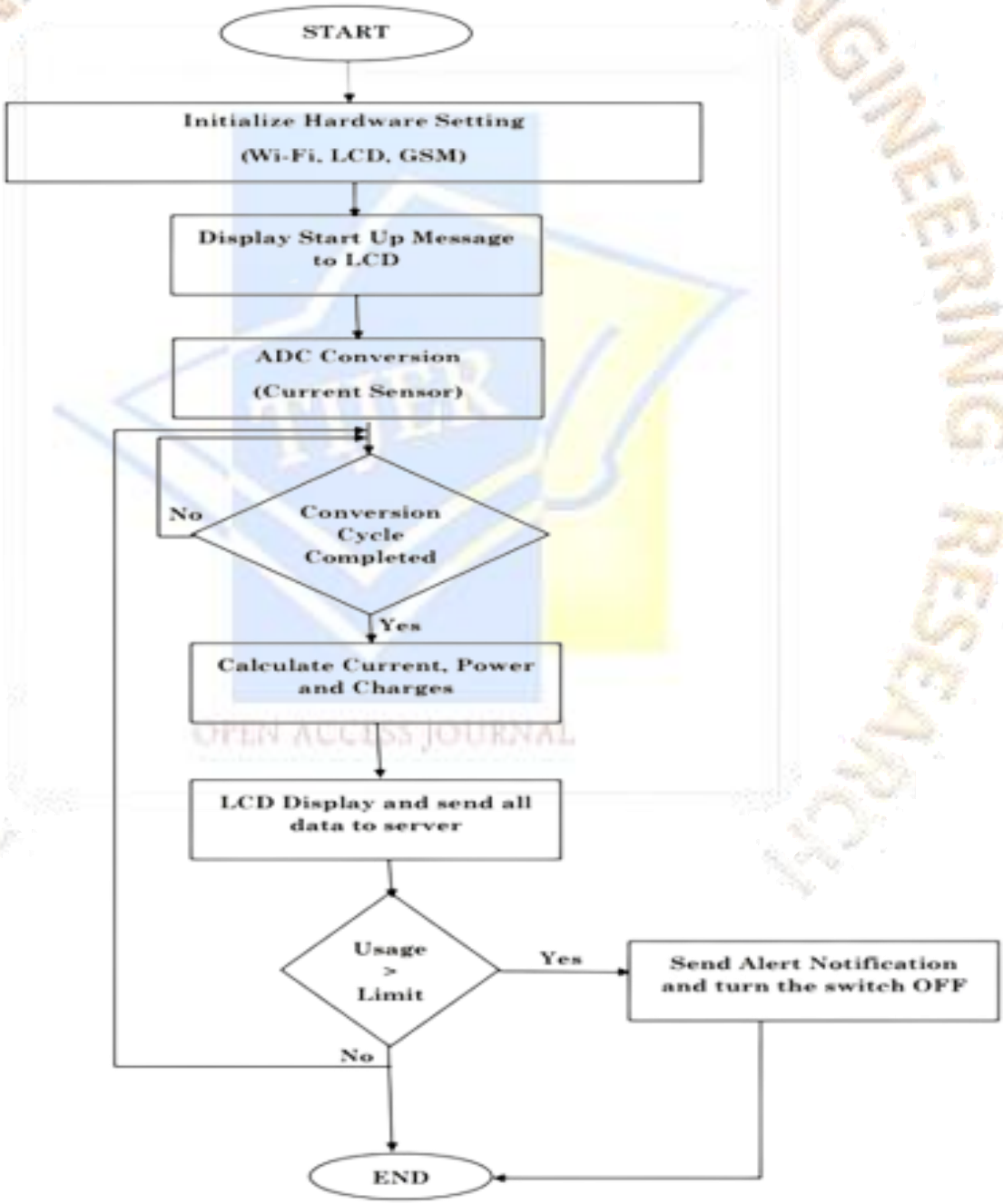

Fig.4. Flow Chat

The content security model for an ASP is depicted. In this architecture the ASP environment is divided into three regions. These are,

1. Operator infrastructure,
2. Enterprise infrastructure
3. ASP infrastructure

The interfaces between operator's infrastructure and the ASP infrastructure are secured by VPN (Virtual Private Network) Depending on the security requirement, SMS-data is encrypted using RSA and DES within the framework of GSM-03.48 standards as described above. This is an application-level encryption understood only by the Java applet in the tamper resistant SIM card and the application running at the MVNO/ASP premise.

In case of offline data, it is stored in the persistent storage of MVNO/ASP. Within the ASP infrastructure, data are protected through Virtual Private Database. The suggested design involves putting in place a very affordable wireless sensor network, protocol, and web application for smart energy that can automatically read the unit and send the data for power users to view their current energy meter reading and even via SMS to the customer about the number of units used and the total electricity bill, making it simple and convenient for the customer to pay bill online.

By utilizing this technology, consumers may lower power waste and consumption costs by being aware of how much electricity is being used in their homes. Digital energy meters, an ESP8266 Wi-Fi module, online administration tools, and an SMS gateway make up the system. It is feasible to investigate the elements that influence individual decisions to adopt and use smart meter systems in the field of power consumption in practical applications for extremely low- cost automatic energy meter reading.

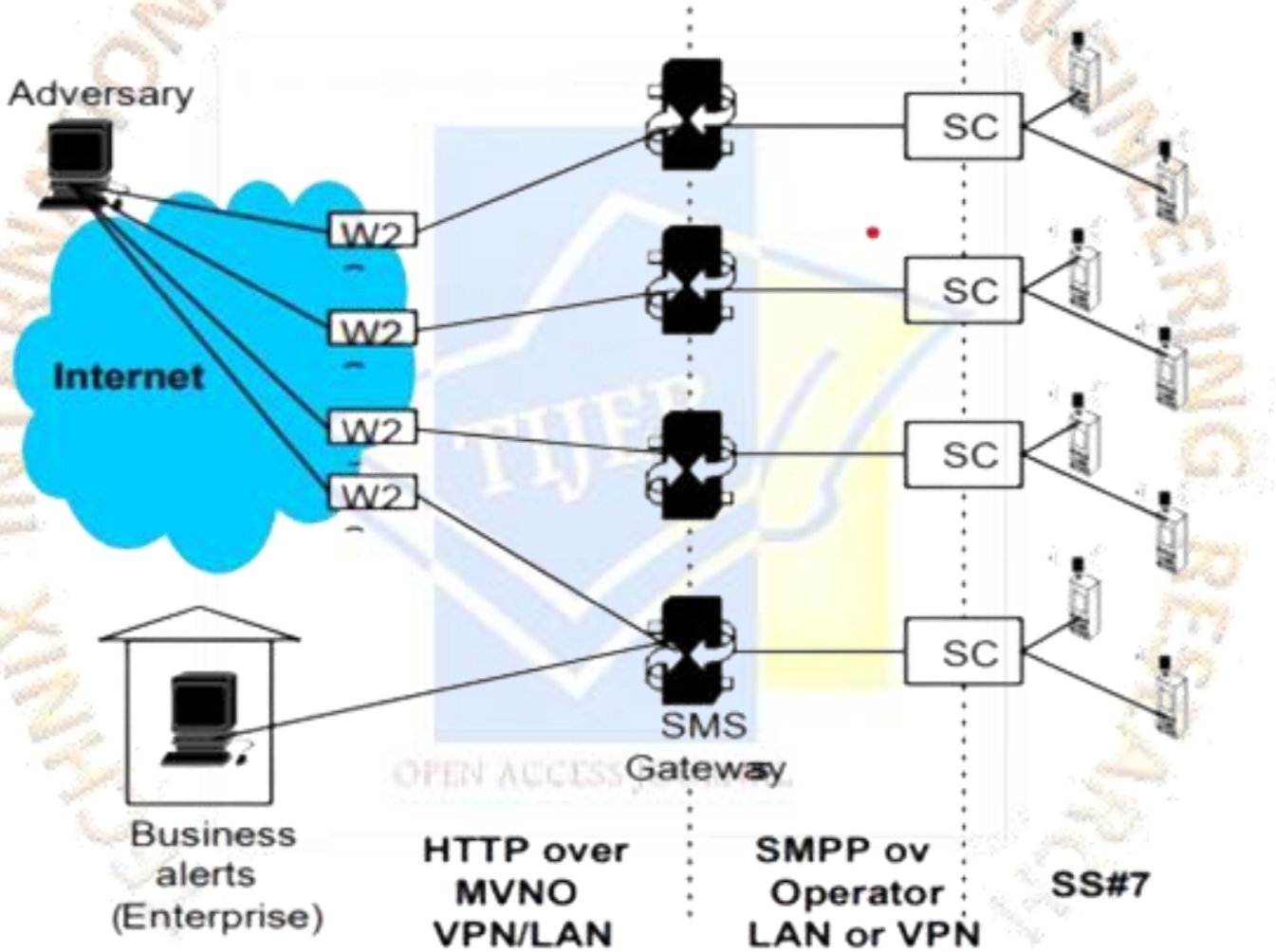

Fig.5.TheWebto SMS(W2S) Architecture

The SMS-based metering architecture consists of four major components: power supply, pulse detection and switching, processing, and output. The power supply unit ensures proper operation of the system by converting incoming alternating current voltage to regulated direct current voltage. The pulse detection and switching component detects current pulses and sends the data to themicrocontroller for processing. All computations and processing occur during the processing stage. Finally, the output stage communicates the charging data to the user through a SIM900 GSM module. The SMS feature allows for real-time data access, communication between utilitiesand consumers, and the sending of alerts and notifications.The use of SMS in this architecture provides a reliable and cost-effective solution for energy consumption monitoring and billing processes, as SMS is widely available and accessible even in areas with limited internet connectivity. The SMS-based architecture enhances the overall functionality and efficiency of a Wi- Fi based smart meter system.

The processing unit is responsible for handling the communication between the smart meter and the web application. This section of the system handles all computation and processing. Energy usage and billing data, as well as the power cutoff function, are calculated using the sensing pulses. This involves receiving and analyzing the data from the sensing pulses, calculating the energy usage and billing information, and sending notifications through the SMS feature in case of power cuts or other emergency situations. The microcontroller (such as Arduino) is the main component of the processing unit, performing these computations and carrying out the necessary operations. The processing unit is critical to the functionality and success of the implementation of an SMS feature to a Wi-Fi based smart meter**.**

VI. OUTCOME

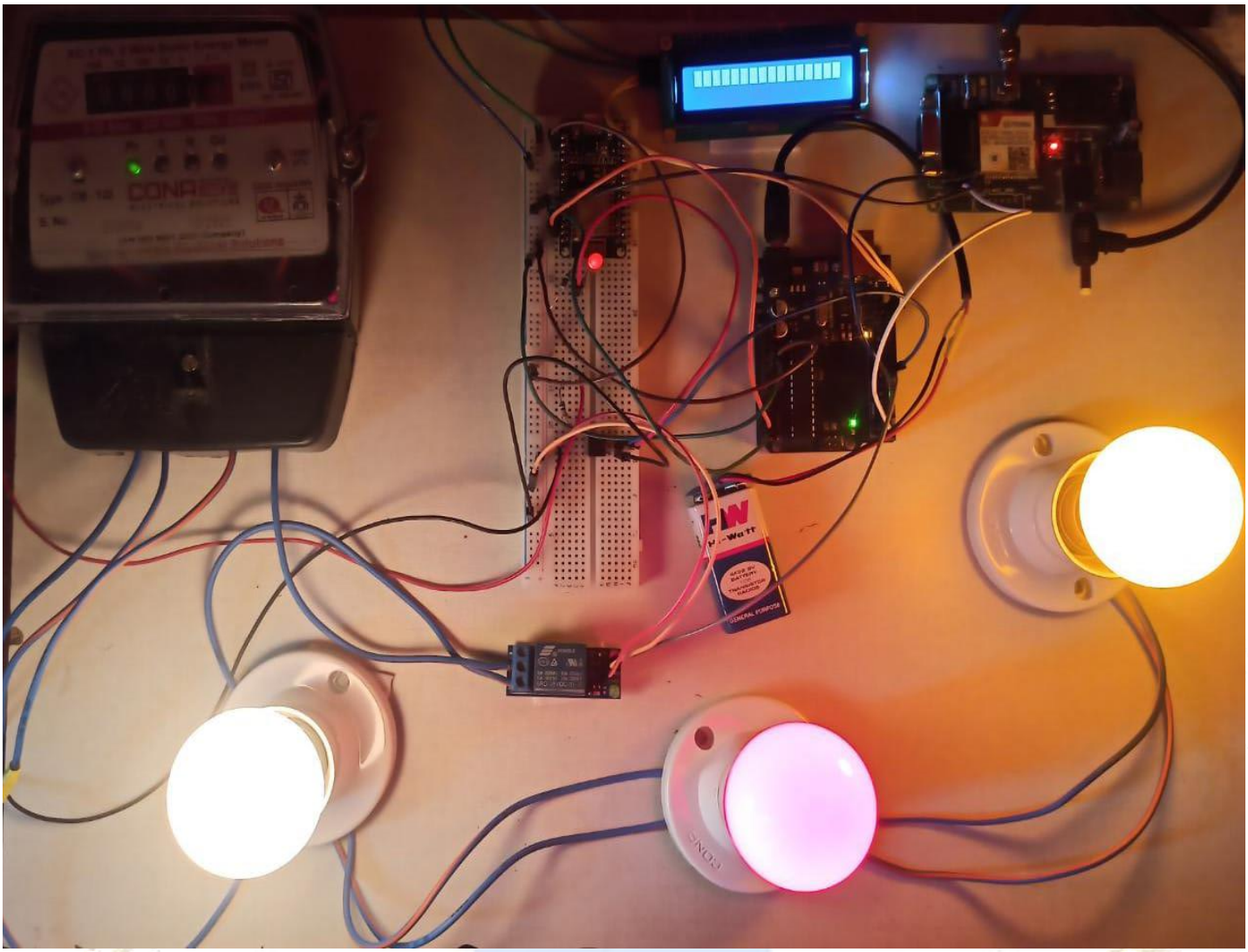

Fig.6. Outcome of Electric Smart Meter

In this paper we proposed an Electric Smart Meter which help households become more energy efficient, SMS gateway provides real-time information about energy usage via message. This information can help consumers make informed decisions about how to conserve energy and reduce their overall energy costs. It makes easier for user to understand their energy costs and make informed decisions about their energy usage and can set limit for the energy consumption accordingly. Node MCU is used to monitor the switch through mobile application which help utilities better manage their energy grid by providing real-time information on energy usage and demand, which can help utilities make informed decisions about energy generation and distribution. The implementation of this electric smart meters can result in cost savings for both utilities and customers, as smart meters can help reduce energy waste and improve energy efficiency, leading to lower energy costs over time.

The proposed system can be implemented with fewer complications by incorporating the ESP8266 Wi-Fi module into the meter and using the TCP/IP protocol for communication between the meter and the web application. They also mention that future works will aim to improve the performance of the system by incorporating features such as tamper detection and outage notifications. The integration of the ESP8266 Wi-Fi module and the use of the TCP/IP protocol makes the system easy to implement and provides a convenient way for the meter to communicate with the web application. The addition of tamper detection and outage notifications works will further enhance the security and reliability of the system.

VII. GAP IDENTIFICATION

Sl No.	Author(s)	Year	Approach	Description	Gap Identification
1.	Zohaib Sultan, You Jinag, Adil Malik, Syed Faiz Ahmed	2019	Smart Wirelessly Controlled GSM-Based Digital Energy Meter	This article describes the creation of the GSM automatic power meter reading (GAPMR) system. Every consumer unit has a GSM digital power meter installed, and the GAPMR system also includes an electrical eBilling system on the side of the energy supplier.	Inaccurate billing displayed. GSM networks may not be available in all areas, which could limit the usefulness of a GSM-based energy billing system. Implementing a GSM-based system can be expensive,
2.	Md. Mohitul Haque, Zakir Hasan Choudhury, Fakir Mashuque Alamgir	2019	Smart Energy Metering System for Power Consumers Using IoT	Because of rising electricity use and depleted natural resources, various nations are implementing new energy regulations and R&Dprogrammes. An IoT (Internet of Things) based smart energy metering system for power consumers is a technology solution that allows for remote monitoring and managementof electricity usage.	Setting up and maintaining an automatic meter reading system can be complex, especially for homeowners who are not technically savvy. A gap in terms of the end-users experience, is the difficulty in the understanding and interpreting the data collected and provided by the system.
3.	Qi Mini". PanJuwe, Sang Shida	2020	The Development of a User Meter Reading System Using GSM and ZigBee	The design involves the integration of two separate communication technologies in order to collect and transmit data on energy consumption.	The ZigBee technology may be impacted by interference from other wireless devices. Because they are accustomed to using conventional meter reading techniques, some people could be reluctant to adopt a GSM-based power meter reading system.
4.	Maha Aboelmaged, Yasmeen Abdelghani, Mohamed A.Abd El Ghany	2017	Smart Cities using Wireless IoT-based Metering for Energy Efficiency	The system typically includes a network of smart energymeters, which are installed at various locations throughoutthe city, and a cloud-based platform that is used to collect and analyze data on energy consumption. The smart meters are connected to IoT devices, such as sensors and gateways, which are responsible for transmitting data to the cloud platform.	The installation and maintenance of the system can be relatively expensive, especially when itneeds to cover a large area. The cost of the smart meters, IoT devices, and cloud-based platform can be significant, and there may also be additional costs associated with connecting the devices to the internet andmaintaining the system.
5.	Vivek Kumar Sehgal, Nitesh Panda, Nipun Rai Handa, Shubhrangshu Naval and Vipul Goel	2018	Electronic Energy Meter with Billing in Real Time	An electronic energy meter with instant billing is a system that monitors and records electricity usage in a home or business and gives the customer with real-time billing information. This paper discusses automated energy meter billing. It resembles a postpaid cell connection exactly.	One potential gap in electronic energy meters with instant billing is that they may not be able to accurately measure energy usage in all cases, such as when there are disruptions to the power grid or when appliances are being used in an unusual way.

VIII. CONCLUSION

This research showed a low-cost Wi-Fi-based Electric Smart meter for the Internet of Things (IoT). The suggested system can efficiently measure and manage various energy efficiency metrics, such as load profile, demand value, and total energy consumption, while also assuring dependable operation. The ESP 8266 Wi-Fi module was integrated into the meter to implement the system, and communication between the meter and web application was enabled via the TCP/IP protocol. The suggested system provides a viable solution for monitoring and managing energy consumption in the Internet of Things environment. The expected outcome is improved performance in terms of accurate readings and power outage alerts. Also, we have used SMS gateway where we mostly center around IoT's energy observing and SMS gateway.

This solution provides real-time data access, enhances communication between utilities and consumers, and offers cost savings through reducing manual meter reading and billing errors. Moreover, the SMS feature can be used for emergency notifications, load management, and power outage alerts, further increasing the benefits of smart meter technology. Overall, the implementation of an SMS feature to Wi- Fi based smart meters is a valuable step towards a more efficient, transparent, and sustainable energy management system.

IX. ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Associate Prof Dr. Kishore G R for their invaluable support, guidance, and encouragement throughout the design and development of our IoT project. Their expertise in IoT Applications was instrumental in shaping this project into its present form and successful completion. We greatly appreciate their willingness to share their knowledge and experience with us, and we are truly grateful for their contribution.

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