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IoT-based Smart Energy Meter Reading and Billing System

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ABSTRACT- There has been rapid progress towards the development of smart cities in the recent past. A smart city is an urban area that uses advanced technology for efficient monitoring and managing of resources- with an aim of improving the quality of life of its residents, and also optimizing the cost and energy requirements. Focusing on energy related monitoring, the basic component which serves as the foundation for all data collection, analysis and automation is a smart energy meter. This paper takes a conventional energy meter and with few modifications like Arduino and GSM module added to it convert it into a smart energy meter. This smart energy meter is further enhanced with the use of Internet-of-Things (IoT). In order to transmit data over a GSM mobile network, such as consumed energy in kWh, generated bills, etc., the smart energy meter system will integrate an embedded controller (Arduino) with a GSM modem. The data collected from the user end can be provided to the Energy providers or Power companies, enabling them to monitor and control the services for their customers without the need for human labour can be achieved using IoT. Also integrating the smart meter with IOT, the user can access the data from anywhere in the world using an Id and Password provided to them. Our project will be helpful for major energy corporations to cut down extra labour cost and minimize the error and losses while also being User friendly.

KEYWORDS- Arduino (Microcontroller), Global System for Mobile (GSM), Internet-of-Things (IoT), Smart Energy Meter (SEM), Short Message Service (SMS), Wireless Fidelity (Wi-Fi).

I. INTRODUCTION

As in developing countries, urbanization results in a faster rate of increasing technology, gadgets, and appliances, while at the same time there is rapid growth in population, which results in an increase in energy demand. Emerging markets need to experience rapid economic growth and development, which contributes significantly to the rise in energy demand due to the rapid increase in industrial and commercial activities. As a result, if we stick to the traditional energy management system, it will cause a big problem for the power production, transmission, and distribution systems. Addressing these challenges requires a multifaceted approach, including energy efficiency measures, the adoption of renewable energy sources, and the development of technologies that can fulfill energy needs while minimizing environmental impacts. This paper will help the energy distribution companies manage the data on energy consumption and billing systems faster and smoother, which will further help the distributing companies work faster and improve accuracy.In the present scenario, our electrical system is using digital energy meters, which are operated manually for reading, billing, and monitoring. And this process requires a lot of time and a lot of effort for monitoring and billing. The aim of this paper is to develop a smart energy meter that works on the principles of IOT (Internet of Things) for monitoring, recording, and billing. Here, the IOT acts as the heart of this project, which plays a crucial role in transforming a traditional energy meter into a smart and efficient energy metering system. It made it possible to read and monitor the data remotely. This shift not only enhances the working ability and efficiency of utilities but also gives power to the distribution company to monitor and control the energy management system in a smart and easy way. This also empowers consumers with tools to access, monitor, and control their data using Internet. These capabilities of this smart meter can be achieved with the help of IOT. This will allow the companies to keep the energy consumption data constantly in check. The system helps the user monitor real-time energy consumption on their smartphone via IOT. This project will use the best of two methods, i.e., GSM and IoT, to contribute to society.

This system provides main features like,

1. Real-time monitoring
2. Automatic billing
3. Remote access and controlling the data, etc.

This system will bring a revolution in the field of energy data management, reading, and billing systems, which will overcome manual efforts and save labor costs and time as there is less need for human effort by automating the process. It minimizes the chances of manual errors, delays in processing, and electricity theft, so you can get accurate readings and justified electricity bills.According to the Smart Meter National Program (SMNP), which is steered by the Government of India-owned Energy Efficiency Services Limited (EESL), there are only 1.7 million household all over India which has smart energy metering services as of May,21.

Through this survey the Government of India set a target to install 250 million smart meters in the next three to four years in all the states which gives this paper much more importance and relevance.

II. LITERATURE SURVEY

More than 200 years have been passed since the development of Electric Meters which are used from household to large industries. The basic function of the Electric/Energy Meters are to calculate the total energy consumed by the appliances connected to it and display it in the form of units consumed. It was until late 20th century when Energy meter became popular and terms like power generation, distribution and power grids came into existence. Scientists are currently working to convert conventional energy metering systems into smart automated metering systems in the age of smart technologies. To this end, numerous studies and designs have been proposed in an effort to create low-cost, energy-efficient smart meters.Himanshu Patel and colleagues released a study in which they offered an easy-to-use billing system that minimizes human mistake by utilizing contemporary technology that is compatible with both older and newer metering units. The system uses GSM for two-way communication, and even in the event of a supply outage, the timer provides the current time. Users may simply track and monitor their energy usage with the device [1]. Another paper described about a model for measuring voltage, current, and figuring out how much power a home use. When the load exceeds, the user is notified using this data to track energy use [2]. A technique was demonstrated by the authors for Korean homes of different sizes and locations for energy management. They verified the outcome of self-power savings with utilizing simply in-Home Display (IHD) without altering the tariff or managing appliances externally through the survey of 77 participant households. This suggests that giving consumers feedback on their energy use in real time encourages self- regulation [3]. The goal of another published paper was to design an affordable, IoT-based energy-efficient meter that would allow users to monitor their power consumption and bills through an Android app. The system also included a database and website for energy suppliers to monitor power usage. Compared to previous systems, the design of this smart meter reduced power consumption [4]. Some authors in their work, convert smart meter into IoT based smart meters through various modifications, such as integrating a GSM module to transmit notifications regarding energy use and invoicing. A website makes it simple to view the cost and meter reading. The user may also set a threshold number and turn the meter on and off automatically [5].

A microcontroller-based system for detecting and controlling energy meters against power theft was presented in a paper in 2017. The components of this system include an Arduino microcontroller, a digital energy meter, a GSM modem, and an SSR. This design has made a significant contribution to improving power efficiency by enabling Suppliers to cut off a specific power network in the event of theft instead of shutting down the whole system [6]. The primary focus of the author's work in another publication is on how to achieve high efficiency electric consumption load data transfer through the internet while avoiding human interaction with the household's current electricity billing system. They have employed LDR to count the pulse of the energy meter and Beagle Bone Black to monitor energy consumption in real time. A webpage that displays consumption data via the intranet has been built. What sets this design apart from the others is the use of Neural Network Time Series in MATLAB. In addition to being inexpensive, this system has characteristics like online payment, quick real-time settlement and error detection, the removal of human intervention, and the ability to easily watch the entire process from a distance [7]. Somewhere else, writers attempted to design a device that would be able to measure and report energy use over a network. The design was separated into three sections in this paper: the internet of things, controllers, and electricity measuring circuit. The hall effect principle is used in the measurement circuit to sense current. After receiving the measured data from the sensor, Arduino Uno sends the computed data to the Raspberry Pi. They used a platform called Smart Living Make and ThingSpeak in the IoT section. Users can view their data and see their consumption at any moment due to the cloud's storage of real-time data. Additionally, users can operate the meter with a smartphone application [8].The reference paper published in 2018 represents the design of a wireless smart energy meter. The aim of this paper was to obtain a household's monthly use reading by utilizing the wireless meter reading concept. The energy meter's power was detected by an infrared sensor, which then transmitted the data to a microcontroller. The data was then uploaded to the web database using the Wi-Fi module. Cost per unit of power used is computed and shown online using the data gathered and saved in a database. The objective of lowering the labor required for power management has been made possible by this design. It also keeps data safe. Since the values are received straight from the meter and stored in their database, it gives the suppliers better power control [9]. Two other authors suggested a prepaid energy meter system that allows consumers to regulate how much electricity they use, reducing power wastage and electricity theft. In prepaid mode, the system functions by inserting a smart card to display the power consumed and bill. If the bill exceeds 500, buzzers will activate, and if it is less than 200, power will be disconnected. In postpaid mode, power data is transmitted to the base station. An SMS is sent to the local operator to notify them of a potential power theft case, should there be any discrepancy between the total power delivered and the feedback [10].Several more research papers and published articles about Energy metering services have been studied and reviewed to learn about the basics of a smart energy meter and the enhancements going on related to them. These papers are cited in the References section.

III. COMPARATIVE STUDIES

After Reviewing and going through the published research

papers, there exist two method of energy metering services i.e. Conventional method and Smart Method. Conventional method is related with the use of old electromechanical meters and Smart Method mostly use IC based meters. And in Smart Energy Metering method the work has been going on in the field of GSM based model and IoT based model.

Table 1: Smart Energy Meter Vs Conventional Energy Meter

Features	IoT based SEM	GSM based SEM
CommunicationTechnology	Utilizes various communication protocols such as CoAp, HTTP or other IoT protocols	Relies on GSMtechnology for communication
Data Transmission	Sends and receivesdata over the internet, enabling real time monitoring and control	Transmits data through SMS or GPRS (General Packet Radio Service) for remote monitoring
Connectivity	Can connect to theinternet through Wi-Fi, Ethernet orLocal Area Network (LAN) options	Uses GSM networks for remote connectivity, allowing communication inareas with mobile network coverage
Scalability	Generally scalable,allowing integration with other IoT devices and Platform	Limited scalability due to reliance on GSM infrastructure
Data Security	May leverage advanced encryption protocols for securedata transmission	Security is dependent on GSMnetwork encryptionstandards and may be susceptible to certain vulnerabilities
Flexibility	Offers flexibility interms of integratingwith different sensors and devices	Limited flexibilityin terms of device integration.
Remote Management	Enables remote management and update through IoTplatforms	Limited Remote management capabilities due todependency on GSM
Affordability	More Affordabledue less and cheap equipment	Less Affordable due to high cost ofGSM modules

Table 2: IoT based SEM Vs GSM based SEM

Features	Smart EnergyMeter	ConventionalEnergy Meter
Communication	It uses wireless or wired communication fortransfer of data remotely.	Typically, does nothave communication capability
Data Collection	Automatically storeand transfer the realtime data	Requires manuallyreading by utility personal or consumers
Billing	Enables more accurate and actualtime-based bill for the data consumed	Billing is obtainedbased on estimatedreading until an actual reading is taken
Reading Frequency	Provides real timefrequent interval reading	Readings are takenperiodically, often monthly
Consumer Awareness	Provide consumerwith real time information on energy uses	Consumers may nothave immediate access to detailed usage data
Remote Access	Allows utility to remotely monitor control and manage energy uses	Requires physicallyaccess for reading and maintenance
Cost	Initially more expensive but maylead to long term cost saving	Generally, less expensive upfrontbut have high operational costs

IV. GENERAL SYSTEM DESCRIPTION

A single-phase, low-cost domestic SEM system that records energy use has been detailed, and it is based on recent efforts and developments. The wireless medium and smart energy meter (sensing device) make up the system. The sensing device is connected to the wireless medium for communication purposes with the whole system. The energy meter's data is gathered and sent to a microcontroller (such an Arduino, Raspberry Pi, etc.) over a wireless means for communication.

A. Methodology

A traditional energy-meter is connected to a microcontroller, Arduino in most case. The Arduino is responsible for all the computations required on the demand-side which is then required to be communicated to the server-side. The communication device used for data transfer is a GSM Module mostly. The server-side then efficiently stores data and updates on the web itself, and then generates an automated bill at the end of each cycle. There is also a server-to-client communication involved which helps to gain remote control of the various parameters which can be altered for efficient power management. Thus, this two-way

communication channel ensures both automation and optimization, which is the foundation block on top of which the entire power management takes place. The IoT design includes an external circuit attached to the traditional energy meter which firstly connects to an LCD display to show the current value or reading of the energy consumption. The Arduino is the heart of the system. It constantly monitors the pulses provided by the opto-coupler and calculates the units as well as the corresponding price for it then sends the value to the display and GSM module connected to the Arduino. The GSM module is used as a focal point for the IoT hardware design and the cloud infrastructure. It communicates the data received from the Arduino to the user by sending a notification (SMS) or the values can be monitored on various web-apps that connect to the GSM using a secret API key.

B. Block diagram

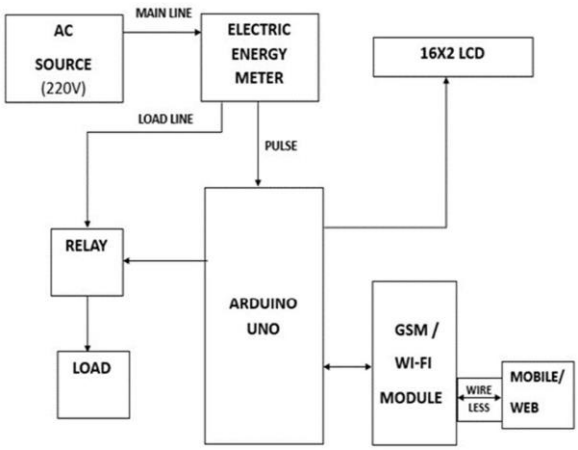

Figure 1: Block diagram for SEM

A smart energy meter system's operation relies on various elements and technologies. In the proposed design Arduino is the heart of the system. It works as the brain of the system. Here Arduino is connected to an LCD display, GSM/WI-FI module, relay and to the energy meter. The Energy meter is connected to the AC source through the main line and to the load through Load line. A relay is also present between the meter and load which is controlled by the Arduino itself. The relay is use to deter the load from supply whenever needed.

The Energy meter is connected to the Arduino which receives input signals from it in the form of pulses. The Arduino is embedded with codes to work in the intended manner. It deciphers the pulses into data and displays it on the LCD connected to it. The data proposed here is the units consumed by the user and its cost.The GSM/Wi-Fi module here has two-way communication between the Arduino and itself. Arduino initiates the module while module communicates between the circuit and the cloud infrastructure. The function of the module present here is to mainly take the calculated unit values and send it to any wireless medium. This wireless medium connects the module to a device such as mobile or web servers.Here the GSM module and WIFI module are two different modules which are connected to the Arduino. The GSM module connects the mobile with SMS services while the WIFI module connects the web server through IOT.

C. Development using IoT

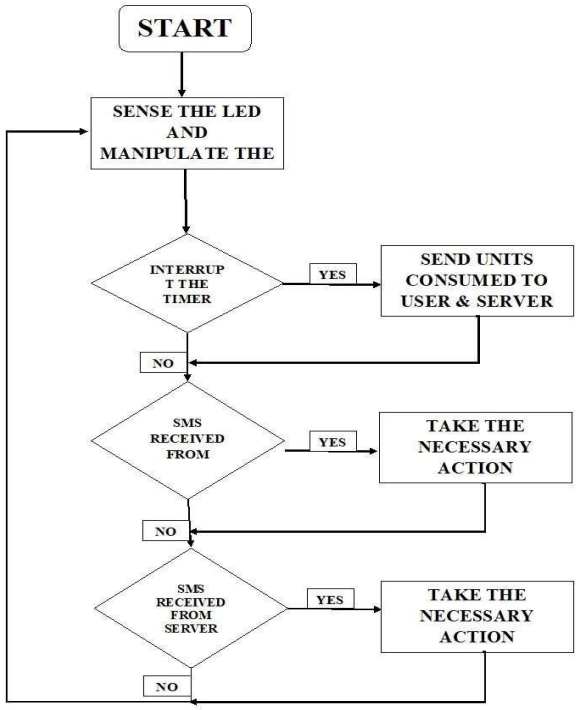

Figure 2: Flowchart for IoT

IOT stands for the Internet of Things. The node MCU module plays a critical role in Internet of Things-enabled smart meters. It is a network for interconnected devices that can exchange data and make it possible to communicate with the different devices through the internet. Devices can be of any type, like home appliances, vehicles, industrial machines, electronic devices, and all the network-operated machines and sensors. The main aim of the IOT is to connect the devices with each other through the network and use these devices to collect and share information, which helps to improve efficiency, performance, automation, and the system's decision-making capability.IOT makes it possible for systems to transfer information and control the system through a network to different parts of connected devices remotely. The different components are connected to the Arduino, and it takes the measurements of current, voltage, and power consumed from the meter and transfers the data to the communication module and LCD. The LCD displays the data (power consumed), and the communication module sends the data to the server. The central system is used for accessing the data from the server, and it decides the main control of the smart meter. It also provides a key for the consumer to access the data remotely through the internet. Encryption,

authentication, and other security mechanisms are included in smart meters to safeguard the confidentiality and integrity of transmitted data. This is necessary to stop tampering and illegal access.

V. CONCLUSION

In this Review paper, it has been discussed about the Energy Metering Services. It also discusses about the present model use in every household i.e. conventional energy metering and how it is getting transformed into Smart Energy Metering system with help of microcontrollers. Further about IoT enhancing the whole process of SEM system and making it more efficient is also described. General description for SEM is also discussed. This review paper can act as a base for the further research in the domain of Energy Metering.

VI. LIMITATION AND FUTURE WORK

In the discussed model for Smart Energy Metering there is one major limitation which is Network connectivity. Places without proper network services and lack of internet connectivity can cause the loss of IoT services but metering services will still be provided. But in future, with development in technology and better network services in remote location can remove this limitation.
Further in future this IoT based SEM can be use to connect it to the grid and help in grid management.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

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