LoRa Based Smart Energy Meter

[1*]F. Richard, [1*]R. Ragul, [1*]M. Abdul Majeed, [2#]V. Hamsadhwani

[1*]UG Students, [2#]Associate Professor
Department of Electrical and Electronics Engineering
Periyar Maniammai Institute of Science & Technology, Thanjavur, Tamilnadu, India

***Abstract*: The Electricity Board employs persons to physically go from house to house as well as business premises to read the energy meter and calculate the amount that has to be paid for the energy consumption. This is a routine process carried out month after month throughout the year. The amount to be paid is recorded and posted online for payment by the consumer. Every consumer has to pay the indicated amount before the due date to avoid penalty. The main drawback of this system is that a person has to go area by area and has to read the meter installed in all premises that possess energy meter and handover the bills. Many times, there are errors like extra bill amount, wrong entry, or unnecessary notification from the Electric Board even though the bills have already been paid. To overcome these drawbacks, a novel idea which will eliminate the presence of a third party between the consumer and service provider has been suggested. So the smart energy meters have been introduced. In this paper, the idea of smart energy meter using IoT and Arduino with the LoRa technology has been suggested. This method involves usage of an Arduino kit because it is energy efficient i.e., it consumes less power and is comparatively faster. It also has two Universal Asynchronous Receiver/Transmitters (UARTs).**

Index Terms: LoRa, energy meter, Arduino, smart meter, Semtech

I. INTRODUCTION

An energy meter is an electronic device that records information such as consumption of electric energy, voltage levels, current and power factor. Smart meters communicate this information to the consumer for greater clarity of consumption behavior and the electricity distributor for system monitoring and customer billing. Smart meters typically record energy consumption in real-time and report regularly at short intervals throughout the day. They also enable two-way communication between the meter and the central system. Such an Advanced Metering Infrastructure (AMI) differs from Automatic Meter Reading (AMR) as it enables two-way communication between the meter and the distributor. Communications from the meter to the network may be wireless, or via fixed wired connections such as Power Line Carrier (PLC). Wireless communication options in common use include cellular communications, Wi-Fi (readily available), Wireless Ad Hoc Networks over Wi-Fi, Wireless Mesh Networks, Low Power Long Range wireless (LoRa), ZigBee (low power, low data rate wireless), and Wi-SUN (Smart Utility Networks). LoRa devices offered by Semtech have compelling features for IoT applications including long range, low power consumption and secured data transmission. This technology can be utilized by public, private or hybrid networks and provides greater range than Cellular networks. LoRa Technology can easily plug into existing infrastructure and enables low-cost battery-operated IoT applications. Semtech's LoRa chipsets are integrated into numerous devices that are manufactured by multitude IoT solution providers. They are connected to Lora WAN- based networks around the globe. LoRa connects various devices or all things to the Cloud.

II. RELATED WORKS

The present billing system by the distribution companies are unable to keep track of the changing maximum energy demand of the consumers [1]. Some of the practical problems that Consumers face are receiving due bills for the bills that have already been paid as well as poor reliability of electricity supply along with poor quality, even if the bills are paid regularly. The remedy for all these problems is to keep track of the consumers load on timely basis, which will lead to an assurance of accurate billing, track maximum demand and to detect the threshold value. All these features are taken into account for designing an efficient energy billing system while addressing the problems faced by both the consumers as well as distribution companies. Energy theft is a very common problem in countries like India where consumers of energy are increasing consistently as the population increases [2]. Due to energy theft, there is a negative impact in the amount of revenue earned each year that has contributed to huge losses. The newly designed AMR used for energy measurements focus on the working of new automated power metering system, but this directly increases the Electricity theft causing administrative losses because of non- regular interval checkout at the consumer's residence. It is quite impossible to check and solve these issues by going to every consumer's door step. Therefore, new procedure is followed based on Atmega328P which is used to detect and control the energy meter from power theft and solves the problem by remotely disconnecting and reconnecting the service (line) of a particular consumer. A Short Messaging Service (SMS) will be sent automatically to the utility central server through the GSM module whenever unauthorized and illegal activities are detected. A separate message will be sent back to the microcontroller in order to disconnect the unauthorized supply. A unique method is implemented with GSM features into smart meters with Solid State Relays to deal with these non-technical losses, billing difficulties and voltage fluctuation complication. A Smart Electricity meter using GSM can reduce human errors and helps to retrieve the real time meter value via GSM and send the reading to the consumer's mobile phone [3]. This also allows Electricity Board to modify the variable package price in a specific period. The administrator can analyze the customer's power consumption data and generate online reports from the data collected. The prototype that has been developed allows the customers to use the billing system, and get the power consumption data from smart meter, as well as keep the data in a centralized database along with report generation. Existing energy meter system have many problems associated to them and one of the key problems is that there is no full duplex communication [4]. To solve this problem, a smart energy meter is based on Internet of Things (IoT) such that it controls and calculates the energy consumption using

ESP 8266 12E, a Wi-Fi module and uploads it to the cloud from where the consumer or distributer can view the reading. Therefore, energy consumption analysis by the consumer becomes much easier and controllable. This system also helps in detecting power theft. Thus, this smart meter helps in home automation using IoT and enabling wireless communication which is a great step towards Digital India.

III. System Analysis

A. Existing System

In existing systems either an electronic energy meter or an electro-mechanical meter is fixed in the premises for measuring the consumption. The meters currently in use are only capable of recording kWh units. The kWh units still have to be recorded by meter readers monthly, by persons who have to walk from building to building. The recorded data needs to be processed by a meter reading company. For processing the meter reading, the company needs to first link each recorded power usage datum to an account holder and then determine the amount owed by means of the specific tariff in use. So, the wireless smart energy meters are replaced for accurate tariff calculation and reducing the errors caused by the human readers. These smart energy meters used the GSM, Wi-Fi like wireless technologies. The main drawback of these systems is the necessity of network access in the consumer side for the smart energy meter to connect wirelessly.

B. Proposed System

The current system of Electricity consumption billing has some errors in recording and also is very time consuming. Errors are likely to be introduced at every stage due to electro-mechanical meters, human errors while noting down the meter reading and errors while processing the paid bills and the due bills. Smart energy meter is a novel technique which can reduce these problems associated with billing and also reduces the deployment of manpower for recording meter readings. It has many advantages from both the distributor side as well as the consumer's point. This smart energy meter has been developed based on LoRa technology. While using the LoRa technology, the disadvantages that are associated when using the GSM, Wi-Fi like wireless networks can be overcome. It does not require any additional towers or network access in the consumer side for these smart energy meters to connect in wireless mode. So, these smart energy meters have the data that is transmitted wireless from the consumer to the distributor using LoRa technology. In the distributor side, the obtained data will be uploaded in the webpage to be viewed by the consumer at anytime and anywhere.

IV. System Design And Implementation

A. Block Diagram

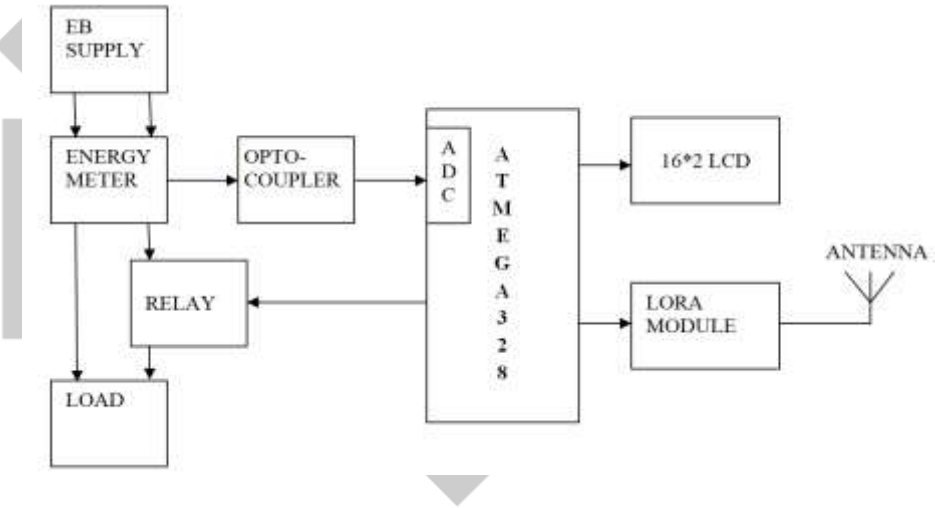

Fig. 1 Block Diagram of Smart Energy Meter - Consumer Side

The block diagram of the proposed model of LoRa based smart energy meter is shown in the Figure 1 and Figure 2. The Figure 1 shows the connections on the consumer side and Figure 2 shows the connections on the distributor side.

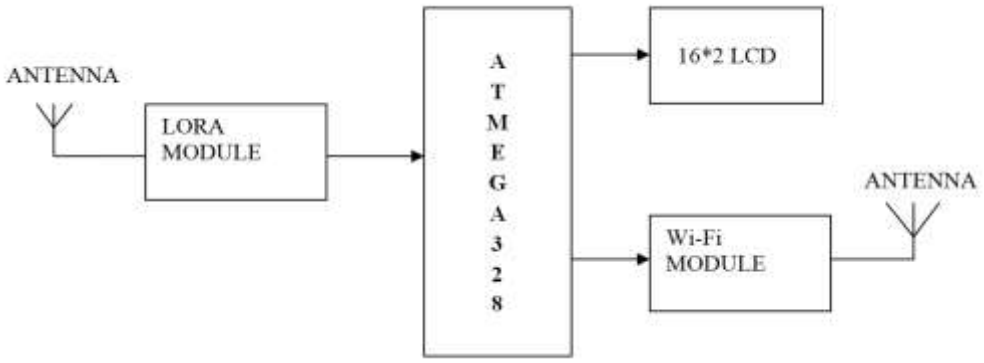

Fig. 2 Block Diagram of Smart Energy Meter - Distributor Side

The Consumer side consists of a microcontroller which controls the input and output as well as an opto-coupler that is used to collect the data from CAL.(Calibration) LED to calculate the consumed energy and display it in the LCD unit. The data can be transmitted through LoRa module from the consumer side as shown in Figure 1. The transmitted data is received in the distributor side LoRa module and the received data will be fed to the microcontroller and displayed in the LCD unit and will be uploaded in the web page through a Wi-Fi module.

4.2 HARDWARE IMPLEMENTATION

The Figure 3 shows the consumer side hardware connections which consist of components such as the Energy meter, Microcontroller ATMEGA328P, 16*2 LCD display unit, opto-coupler, relay and relay drivers, push buttons, LoRa module, transformers and rectifier for power supply.

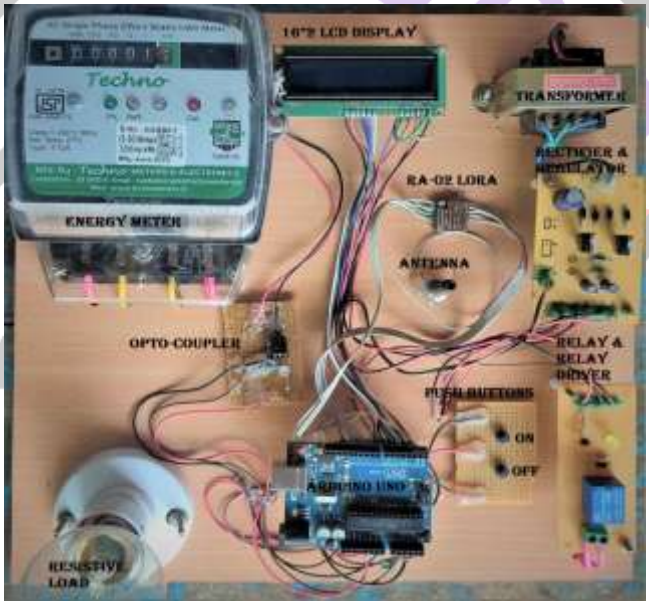

Fig. 3 Hardware Setup on the Consumer Side

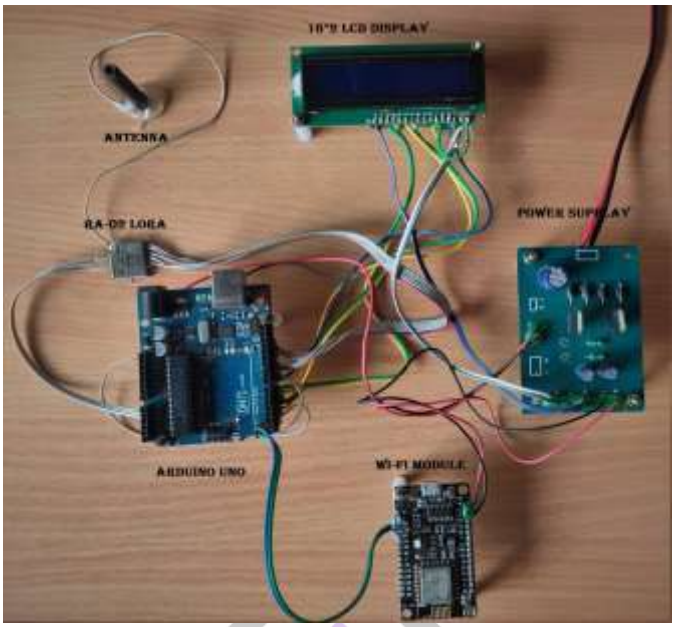

Fig. 4 Hardware Setup on the Distributer Side

The Figure 4 shows the distributor side hardware connections which consists of components like microcontroller Atmega328p, 16*2 LCD display, ESP 8266 Wi-Fi Module, LoRa module and power supply

4.3 COMPONENTS

A. ARDUINO UNO

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller. The board is equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards and other circuits. It has 14 digital input output pins of which 6 can be used as PWM O/P and 6 analog I/P. The Arduino Uno can be powered via USB connection or with an external power supply. The Arduino Uno original contains everything needed to support the microcontroller. This can be simply connected to a computer with a USB cable. The reason for using this microcontroller instead of other microcontrollers is because it is convenient for interfacing the hardware and software and has less power consumption.

Fig. 5 Arduino Uno Board

B. Ra02 LoRa MODULE

Ra-02 can be used for ultra-long distance spread spectrum communication. This is compatible with FSK remote modulation and demodulation quickly and can be used to solve the traditional wireless design that cannot take into account the distance, anti-interference and power consumption. Ra-02 can be widely used in a variety of networking occasions namely, for automatic meter reading, home building automation, security systems, remote irrigation systems etc. Hence it is an ideal solution for things networking applications. Ra-02 is available in SMD package and can be used for rapid production by standard SMT equipment. It provides customers with high reliability connection.

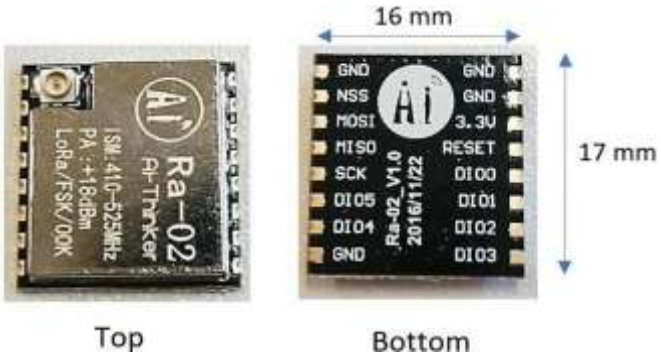

Fig. 6 Ra02 LoRa Module

C. ENERGY METER

An electric meter or energy meter is an essential device that goes with the consumption of commercially distributed energy. It enables systematic pricing of energy consumed by individual consumer as it measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. They are typically calibrated in billing units, the most common one being the Kilowatt-hour(kWh), which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules.

Generally, electricity meters operate by continuously measuring the instantaneous voltage (Volts) and current (Amperes) and finding the product of these to give instantaneous electrical power (Watts) which is then integrated against time to give energy used (Joules, Kilowatt-hours etc.). Meters for smaller services (such as small residential consumers) can be connected directly in-line between source and customer. For larger loads, more than 200A of load, current transformers are used, so that the meter can be located anywhere other than in line with the service conductors.

Fig. 7 Energy Meter

D. ESP8266 Wi-Fi MODULE

The ESP8266 Wi-Fi Module is a self-contained SoC with integrated TCP/IP protocol stack that can give any microcontroller access to the Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, which means that it can be hooked to the Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers. Figure 8 shows the ESP8266 Node MCU.

The ESP8266 module is an extremely cost-effective board with a huge and an ever-growing community. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area.

Fig. 8 ESP8266 Node MCU

E. OPTO-COUPLER P817

The Figure 9 shows the simple internal working of opto-coupler which is used as signal conditioning block. In a working energy meter, the CAL. LED in energy meter continuously blinks. This indicates the measure of power consumption. Whenever the power is consumed, the LED blinks and produces 0.7V. As the output is taken out in parallel, it is not suitable for Arduino board to capture. To remove this error, the signal conditioning block is used. When the LED blinks the photo diode will conduct and the transistor becomes active. This produces 5V at the output which is externally given to the transistor. So, whenever the LED blinks 5V supply is provided to the Arduino board which counts the number of blinks. The signal conditioning block is used to increase the voltage.

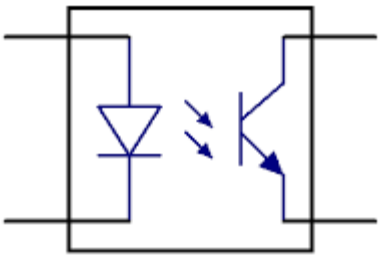

Fig. 9 Signal Conditioner

F. RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be switched ON or OFF so, relays have two switch positions and so they are double throw (changeover) switches. The Figure 10 shows a simple relay.

Relays allow one circuit to switch ON a second circuit which can be completely kept separate from the first. For example, a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical.

Fig. 10 RELAY

G. LCD DISPLAY

Liquid Crystal Display (LCD) is an electronic display module used in many applications. These displays are mainly preferred for multi-segment Light-Emitting Diodes and seven segments. Most commonly used LCDs are 16*2 and 20*2. In 16*2 alphanumeric LCD, there are 2 rows and 16 columns while in 20*2 alphanumeric LCD there are 2 rows and 20 columns. The Figure 11.

Fig. 11 LCD DISPLAY

4.4 SOFTWARE

A. ARDUINO IDE 1.8.13

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program *avrdude* to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. By default, *avrdude* is used as the uploading tool to flash the user code onto official Arduino boards.

B. WEB SERVER

A web server is a server software, or a system of one or more computers dedicated to running this software, that can satisfy client HTTP requests on the public World Wide Web or also on private LANs and WANs.

A web server can manage client HTTP requests for Web Resources related to one or more of its configured / served websites. A web server usually receives incoming network HTTP requests and sends outgoing HTTP responses (one for each processed request), along with web contents, through transparent and / or encrypted TCP/IP connections which are started by client user agents before sending their HTTP request(s).

The primary function of a web server is to store, process and deliver web pages to clients. Examples of Web contents may be HTML files, XHTML files, image files, style sheets, scripts, other types of generic files that may be downloaded by clients, etc.

4.5 EXPERIMENTAL SETUP

Whenever the load in a building starts consuming power, the energy meter reads the reading continuously and this consumed power can be seen on the energy meter. As the power is consumed the CAL. LED on the meter continuously blinks. The speed of the blinking varies based on the power consumption. Based on the blinking, the units are counted. Normally, the CAL. LED blinks 3200 times per unit (1kWh). The LoRa Based Energy Meter consists of Arduino Uno which acts as a main controller and continuously monitors the energy meter. Based on the blinking of LED on energy meter the Arduino Module will measure the unit consumption. The price for the units consumed is calculated by the microcontroller and then the number of units and the price to be paid is continuously displayed on the LCD. These details of the price and units consumed are transmitted over the LoRa in the consumer side. In the distributor side, the data transmitted in the consumer side over LoRa is received in the distributor side LoRa module. The module communicates only with another LoRa module where the data will be displayed on the LCD as well as the data is transmitted to the webpage called pushing box API through the NodeMCU. The reading will be continuously notified to the registered consumer mobile phone number that may be a Smartphone or a laptop through push bullet application.

4.6 CALCULATION

This system makes simple calculations. Usually, 1500 blinks of the CAL. LED are considered as one unit(1kWh). But for experimental demonstration purpose, a 60Watts incandescent lamp was allowed to glow for 60 seconds and the CAL.LED is tuned to blink once. This one blink is assumed to be equivalent to 10 units of power consumption. Hence the price for power consumption at the end of one minute is calculated as Rs.15 at the rate of Rs.1.5 per unit. This is displayed in the LCD unit that shows the power consumption as well as the amount to be paid to the distributor side at that instant of time. The same information is sent from the transmitter LoRa module to the distributor LoRa module. This information is displayed in the LCD unit on the distributor side. Simultaneously, the information can be viewed in the designated webpage as well as the mobile device that has been registered with the consumer's phone number using an appropriate application that can be downloaded from the Play store.

5 RESULT

The Figures 12 to 15 shows the experimental setup on the Consumer side and the Distributor side along with the LCD module used for displays.

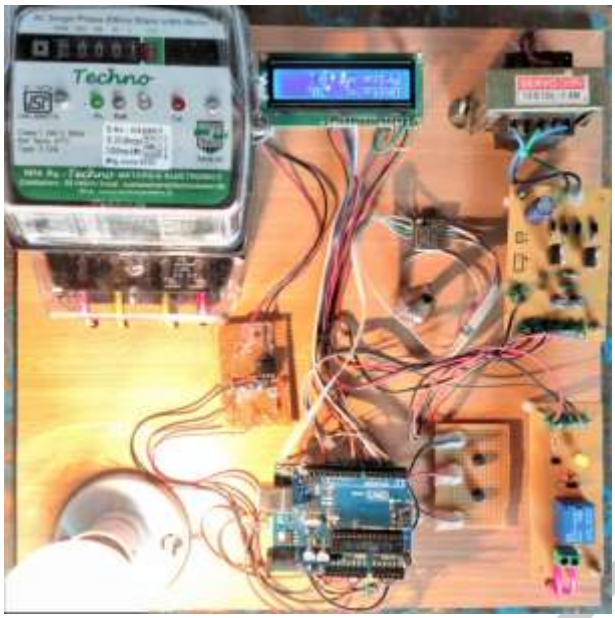

Fig. 12 Experimental setup of consumer side

Fig. 13 LCD Display in the consumer side

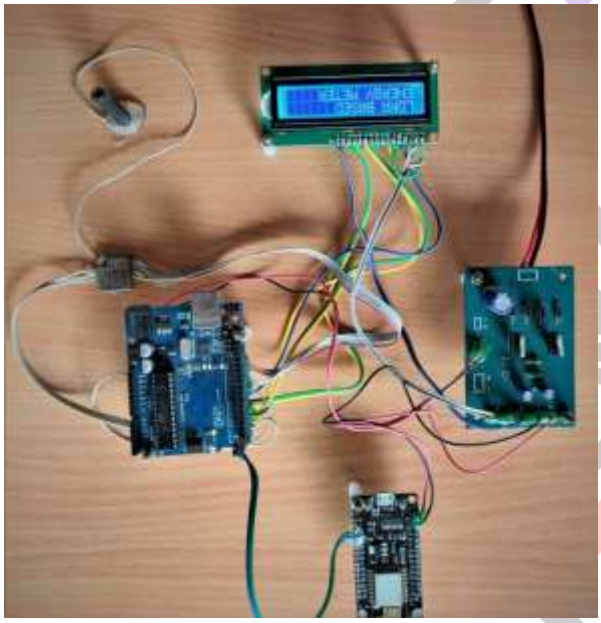

Fig. 14 Experimental setup of distributor side

Fig. 15 LCD Display in the distributor side

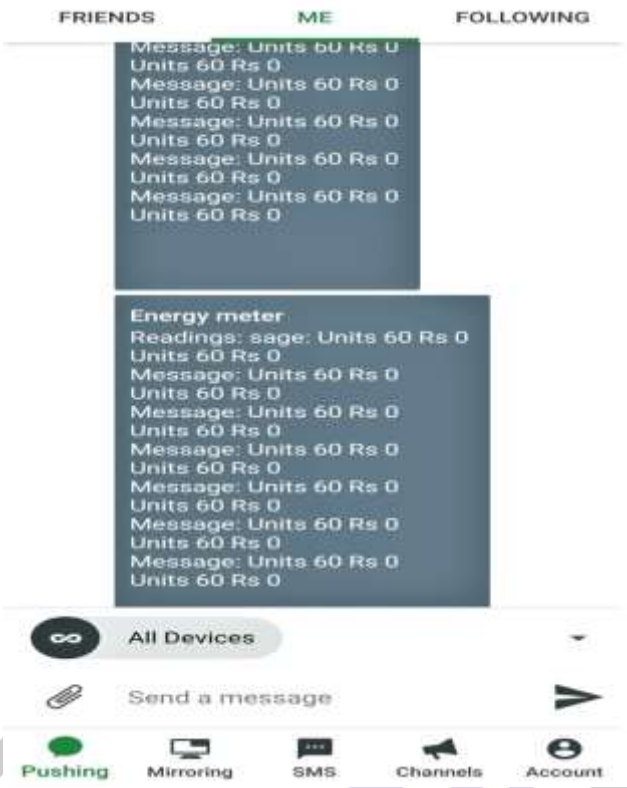

Fig. 16 Screenshot from Consumer Mobile Phone

The Figure 13 and Figure 14 show the Experimental setup on the consumer and distributor side. The Figure 16 shows the screenshot of the energy consumption reading by the consumer at that instant of time. This is transmitted through the web server by the distributor to the consumer and the consumer can check their Power usage and its relevant price from anywhere and at any time instant. The energy consumption of the household can be monitored and suitable steps can be taken to reduce unnecessary usage. Hence it reduces the wastage of energy and brings awareness among all. The data from the CAL. LED is taken as input to microcontroller through opto-coupler and calculates the price for the consumed energy based on the units consumed as per the government tariff and displays the cost in the LCD. The regular usages of Power consumption are informed to the user to overcome a huge bill.

6 CONCLUSION

The proposed prototype model of LoRa based smart energy meter has been successfully implemented tested. This paper is mainly focused to be used rural areas where there are many "no network coverage" areas, so implementation of GSM or Wi-Fi based energy meters are difficult to be installed in those areas because of various network coverage issues. Using LoRa technology these difficulties can be overcome. Rural area consumers can also make use of this smart application. This system is convenient for the users and distributor for monitoring the regular usage of the power consumption and the relevant price for the consumed power is displayed for the consumer in the LCD and the data is also uploaded in the website for make the consumer to easily monitor the data from anywhere at any time interval from their smart devices. It provides wireless meter reading system that can monitor and analyze the data at any time providing accurate results with less error. Good governance will be possible with this setup. It is possible to monitor the energy requirements of each consumer. With the easy governance it becomes easier to make plans and decisions for the next year power supply requirements. Based on the information about power generation can be predicted to avoid uninterrupted power.

REFERENCES

[1] "IoT Based Smart Energy Meter", Birendrakumar Sahani, Tejashree Ravi, Akibjaved Tamboli, (2017), International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 04.

[2] "Smart Energy Metering and Power Theft Control using Arduino & GSM", Visalatchi S, Kamal Sandeep K, (April 2017), Institute of Electrical and Electronics Engineers (IEEE).

[3] "Smart Energy Meter", Brinda.S, Vishal Kumar Sah, Jaladi Harish, (2018), International Journal of Engineering Science and Computing (IJESC)Volume 8, Issue 3.

[4] "IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid", Bibek Kanti Barman, Shiv Nath Yadav, Shivam Kumar, (2018), Institute of Electrical and Electronics Engineers (IEEE).

[5] "IOT Based Smart Energy Meter Billing Monitoring and Controlling the Loads", Subba Rao, Sri Vidya Garige (2019), International Journal of Innovative Technology and Exploring Engineering (IJITEE) Volume 8, Issue 4.
[6] "Embedded Edge Computing for Real-time Smart Meter Data Analytics", T.Sirojan, B. T.Phung, and E.Ambikairajah, (2019), Institute of Electrical and Electronics Engineers (IEEE).
[7] "Smart Energy Meter and Monitoring System using IoT", Naziya Sulthana, Prakyathi, Rashmi, Bhavana, (2020), International Journal of Engineering Research & Technology (IJERT), Volume 8, Issue 14.
[8] "Designing Prepaid Smart Energy Meter and Deployment in a Network", Sagar Rathee, Aayush Goyal, Anup Shukla, (2020), Institute of Electrical and Electronics Engineers (IEEE).