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GSM Based Automatic Energy Meter Reading and Instant Billing System

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***Abstract*: Now-a-days, electricity energy demands requested from down-stream sectors in a smart grid constantly increase. And that is ultimately increasing the load demand on the distribution centres. With this increasing demand on smart grid the Advanced Metering Infrastructure (AMI) has turn into the initial ever-present and permanent platform for performing computational operations. Power theft is one of the most significant concerns connected to the implementation strategy of smart grid. The utility companies lose more than $15 billion every year due to power theft around the world based on the estimation data gathered. The Household data automatically reading is important in the process of power system information. It is also an urgent problem that power industries want to solve because the exactness and real time of meter data copy have an effect on the power system information level, management decisions, and economic benefits. To take necessary precautionary actions against these issues the Automatic Meter Reading (AMR) technology is proposed. The energy meter is designed for reading electrical energy consumed in units and in rupees to display on an LCD screen to the user. This data is also provided to the electrical department using GSM technology for billing purposes. In this proposed system, the consumer will get his energy consumption data on real time basis on a LCD display. The same data is sent through GSM modem to the electricity department via SMS. An Arduino UNO is interfaced to the energy meter to get the Watt Hour pulses. The Arduino UNO then processes these pulses according the program written in it, to calculate the units consumed and cost involved. The same data will be sent to the electricity department through the GSM modem via SMS after command given by the Arduino UNO.**

***Keywords*: Energy Meter, DB9 connector, Arduino UNO, GSM Modem, e-metering, SIM, Automatic Meter Reading (AMR), LCD.**

1. Introduction

The electrical metering instrument technology has come a long way from what it was more than 100 years ago. From the original bulky meters with heavy magnets and coils, there have been many innovations that have resulted in size & weight reduction in addition to improvement in features and specifications [1]. The existing system has, manual meter reading systems using electro-mechanical meters are installed within the premises of residential or commercial consumers and data on information consumption are collected on a monthly basis. Manpower must be hire to go from domestic after domestic to read energy consumption, record data and communicate with a receiving module. Use of manual meters may possibly convert to meter reading mistakes and errors of leakage [2]. The technology of e-metering (Electronic Metering) has gone through rapid technological advancements and there is increased demand for a reliable and efficient Automatic Meter Reading (AMR) System. This paper presents the wireless GSM energy meter and its associated web interface for automatic billing and managing the collected data. The proposed system replaces the traditional mater reading methods and enables remote access of existing energy meter by the energy provider [3]. Today the metering instrument technology grown up significantly, such that the consumed energy can be calculated mathematically, displayed, data can be stored, data can be transmitted, etc. Presently the microcontrollers or the Arduino UNO are playing major role in metering instrument technology. The present project work is designed to collect the consumed energy data of a particular energy consumer through wireless communication system (without going to consumer house), the system can be called as automatic meter reading (AMR) system.

A. Necessity

1) Existing system

The existing system has, manual meter reading systems using electro-mechanical or digital energy meters are installed within the premises of residential or commercial consumers and data on information consumption are collected on a monthly basis. Manpower must be hire to go from domestic after domestic to read energy consumption, record data and communicate with a receiving module. The block diagram of the existing meter reading system is as shown in fig.1 below.

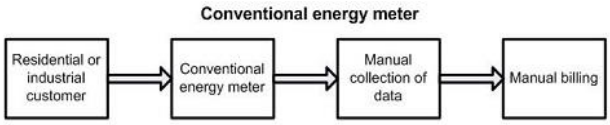

Fig. 1. Existing system

2) Disadvantages of existing system

As an overview this existing system seems to be a simple one. But this traditional system has many limitations as summarized below:

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1. Traditional electro-mechanical meters, still widely used today, are prone to drift over temperature and time.
2. Use of manual meters may possibly convert to meter reading mistakes and errors of leakage [2].
3. Manpower must be hire to go from domestic after domestic to read energy consumption, record data and communicate with a receiving module [2].
4. And there are main factors is vehicle theft, yearly 60% of energy theft in India according to the recent survey and variety of malicious theft generated and theft the energy power [2].
5. Electricity department sends employees to take meter reading every month, which is an expensive and time consuming job.

2. Literature Survey

Fig. 2. Traditional Electromechanical meter vs. Electronic meter

For this work existing meter reading techniques in India are analyzed and conducted an extensive study on different energy measuring instruments available now. In existing system either an electronic energy meter or an electro-mechanical meter is fixed in the premise for measuring the usage (as shown in Fig 2 above). The meters currently in use are only capable of recording kWh units. The kWh units used then still have to be recorded by meter readers monthly, on foot. The recorded data need to be processed by a meter reading company. For processing the meter reading, company needs to firstly link each recorded power usage datum to an account holder and then determine the amount owed by means of the specific tariff in use. Many systems built on various platforms have been proposed by different research groups all over the world for Automatic Meter Reading [3]. Advanced metering can be implemented with different levels of intelligence associated to the meter. Typically, three types can be distinguished, in order of increasing interaction level and feature contents; these are [4]:

1) *AMR* is a remote reading system based on an advanced technology that permits utilities to read electronic meters over long distances. Through AMR, the energy consumption can be read on an annual, weekly, daily or on an hourly basis. Consumption and status data, such as time stamps, are through various connection media being transmitted to a central system for billing and analysis. The automatic data collection enables billing based on real time consumption as opposed to an estimated consumption.

2) *AMI* refers to systems that measure, read and analyses energy consumption. AMI systems can be defined as an extension of the simpler AMR-system. The AMI always communication two-way and comprises the whole range of metering devices, software, communication media, and data management system.

3) *AMM* (Automatic Meter Management) or smart metering is another expansion of a remote reading system that includes the possibility of performing technical measurements and functions and carrying out customer-oriented services.

Rong Jiang, Rongxinglu, et al., The power grid has become a necessity in the modern society. Without a stable and reliable power grid, tens of millions of people's daily life will be degraded dramatically. For instance, the India blackout in July 2012 affected more than 60 million people (about 9% of the world population) and plunged 20 of Indian 28 states into darkness. Indeed, the traditional power grid, which is surprisingly still grounded on the design more than 100 years ago, can no longer be suitable for today's society. With the development of information system and communication technology, many countries have been modernizing the aging power system into smart grid, which is featured with two-way transmission, high reliability, real time demand response, self-healing, and security. Within smart grid, Advanced Metering Infrastructure (AMI) gives an imperative role which is very closely related with day today life of people life. AMI performs advanced functionality in the metering system of electricity by utilizing smart meters instead of using old mechanical meters. This mechanism provides two-way communications between energy consumers and utility companies.

In 2009, the FBI reported a wide and organized energy-theft attempt that may have cost up to 400 million dollars annually to a utility following an AMI deployment. In Canada, BC Hydro reports $100 million in losses every year. There are many losses around $4.5 billion and $5 billion in the various utility companies located around in Brazil and India happens due to the theft done in electricity. There is even a video which shows how to crack the meter and cut the electricity bill in half in Youtube. As a result, energy-theft matters turn into one of the majority significant concern which exclude the growth of AMI. The exclusive dispute for theft of energy in AMI calls for the improvement of successful detection method [2].

Sudhish N George, Ashna. K. Existing meter interpretation system in India are investigated and conducted a widespread

reading on various recently available energy measuring instruments. For the mechanism of Automatic Meter Reading various research groups has proposed systems built on a variety of platforms have been planned all over the world [3].

So a new approach of using an energy measurement technique that encompasses the GSM network as a mean of transmitting energy data is more relevant. The GSM/GPRS network offers most coverage in most developed and developing countries. This method is also effective in rural areas, which are not densely populated, and in which, most people do not have access to a fixed telephone network. So in a country like India we need to focus more on this method as it can be implemented very easily and effectively [3].

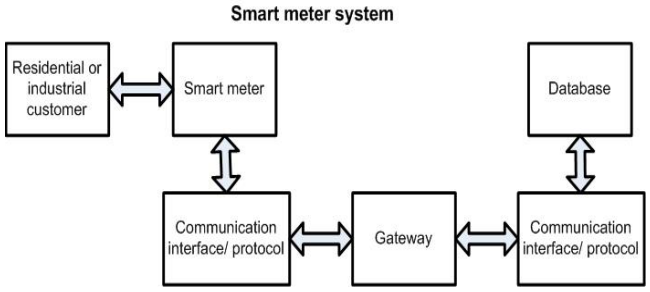

Fig. 3. Advanced meter reading system

3. Smart Meter System

When developing a technology that might replace one which has been in use for more than thirty years, not only the key issue needs to be addressed, but added functionality and solutions to other obstacles presented by the previous technology need to be addressed. Even existing meter readers and other employers have to accept the quality and effectiveness of the proposed system.

Different methodologies implemented for the Automatic Meter Reading (AMR) are summarized as [5]:

ZigBee is a collection of communication protocols used to build small personal networks using low power digital radios. and is based on IEEE 802.15.4 standard. The range of an average ZigBee based device is restricted to 10 - 100 meters and can be further extended using a mesh network of ZigBee devices. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. ZigBee was designed to provide high data throughput in applications where the duty cycle is low and low power consumption is an important consideration. The rate of ZigBee is definite with 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

SCADA (Supervisory Control and Data Acquisition) is a system operating with coded signals over communication channels so as to provide control of remote equipment. It is a category of software application program for process control, the gathering of data in real time from remote locations in order to control equipment's.

Power Line Communication Systems use the existing power cables as a communication medium. This ultimately allows us to both control the devices remotely and also retrieve data from it in a half-duplex manner. The main advantage of PLC is that the existing wiring can be re-used. Thus Power Line Communication can be used to transfer meter readings data to the central servers along with the use of GSM/GPRS. The data from every meter is collected using PLC.

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates. WiMAX supports mobile, nomadic and fixed wireless applications. WiMAX brings with it the ability to transmit over far greater distances and to handle much more data.

The proposed system for energy billing is automatic, do not require human effort to read the meter, consumer can directly know the amount he has to pay at the time of bill preparation itself and can even pay the amount online.

Among the various implementations of Automated Meter Reading system, the main modules that make difference are the Automated Meter Reading Module and the Communication Module. The following systems consider the *GSM Network for Communication* purposes. GSM network provides a global coverage across countries thus enabling communication to every nook and corner without the need to implement a new communication infrastructure solely for this purpose. Apart from seamless coverage. The *GSM technology* also provides services like SMS (Short Message Service) and GPRS (General Packet Radio Service) for requesting and retrieving reading from individual houses back to the energy provider wirelessly. Moreover, the GSM network is a more efficient, reliable and secure communication standard that is being widely used for more than several years now without any technical issues.

The generalised block diagram for the Smart Meter System using GSM technology is as shown in fig. 4 below:

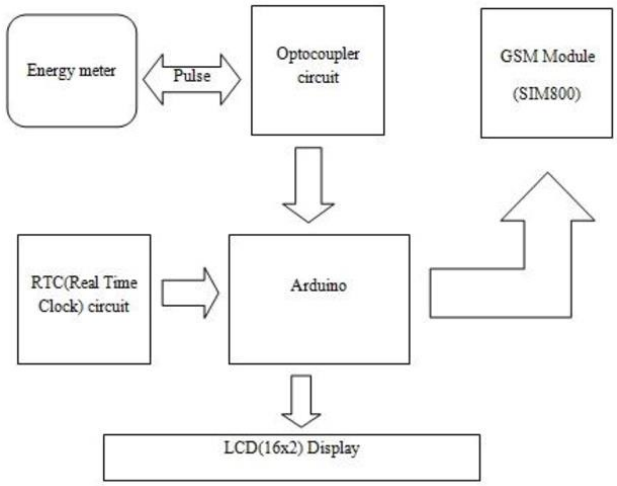

Fig. 4. GPS technology in smart meter block diagram

4. Proposed Technique

The proposed system for energy billing is automatic, do not require human effort to read the meter, consumer can directly know the amount he has to pay at the time of bill preparation itself and can even pay the amount online. The proposed system replaces traditional meter reading methods and enables remote

access of existing energy meter by the energy provider. Also they can monitor the meter readings regularly without the person visiting each house. A GSM based wireless communication module is integrated with electronic energy meter of each entity to have remote access over the usage of electricity. A PC with a GSM receiver at the other end, which contains the database acts as the billing point. Live meter reading from the GSM enabled energy meter is sent back to this billing point periodically and these details are updated in a central database. The complete monthly usage and due bill is messaged back to the customer after processing these data. This project has a GSM ENERGY METER, which will be used as the electronic device, and also a GSM modem, which is the latest technology used for communication between the mobile and the embedded devices. We will use liquid crystal display for displaying the message; we will also use GSM modem (Motorola W220) as an interface between mobile and Arduino UNO. It will send message to any phone irrespective of the GSM network through the modem connected to the programmable device.

This GSM energy meter is constructed using digital electronic meter, a display, Arduino UNO and GSM modem. Embedded GSM modem which utilizes the existing GSM network to send its power usage value as SMS to the energy provider wirelessly. While sending the message each time, the same data is also stored in the associated non-volatile memory (EEPROM). RTC module is also integrated in the meter to have time stamped recording of usage details. The detailed design blocks are shown in fig. 5.

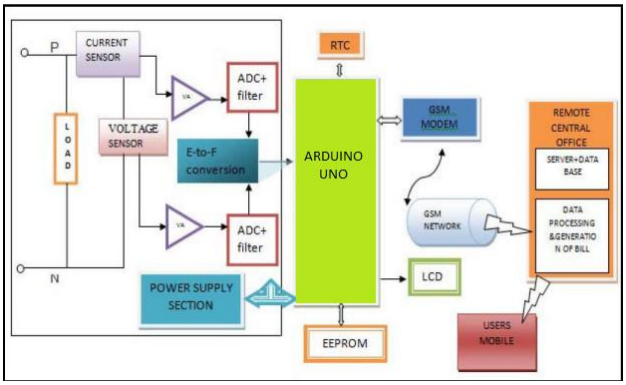

Fig. 5. Detailed block diagram of proposed scheme

A. Working Principle

The system is made efficient by SIMs so that the SMS can be received by number of devices boards in a locality using techniques of time division multiple access. The main components of the toolkit include microcontroller, GSM modem. These components are integrated with the device board and thus incorporate the wireless features. The GSM modem receives the SMS. The AT commands are serially transferred to the modem. In return the modem transmits the stored message through the wireless link. A new concept of energy meter will be discussed, where maximum demand of energy of a consumer will be indicated in the meter used by the consumer. After exceeding the maximum demand, the meter and hence the connection will automatically be disconnected by an embedded system inserted in the meter itself. The block diagram of system is shown in fig. 6 below.

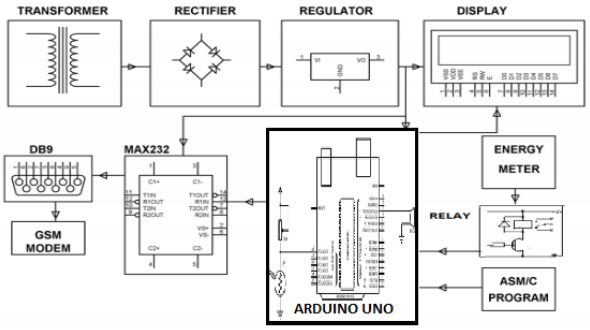

Fig. 6. Block diagram

This GSM based wireless energy meter consists of major components or blocks such as Arduino UNO, relays, loads, electricity consumption meter, LCD display, power supply circuit, GSM modem, DB9 connector, MAX232, and relay driver. GSM MODULE SIM 300 is used to produce communication between load circuit and utility side. We actually have used max232 along with DB9 connector to interface it. The SMS system is used for requesting and retrieving energy meter readings from every house at any time and even for cutting off the electricity connection if the bill remains unpaid.AT commands set which stands for attention terminal are used by energy meter to communicate with the GSM Modem.

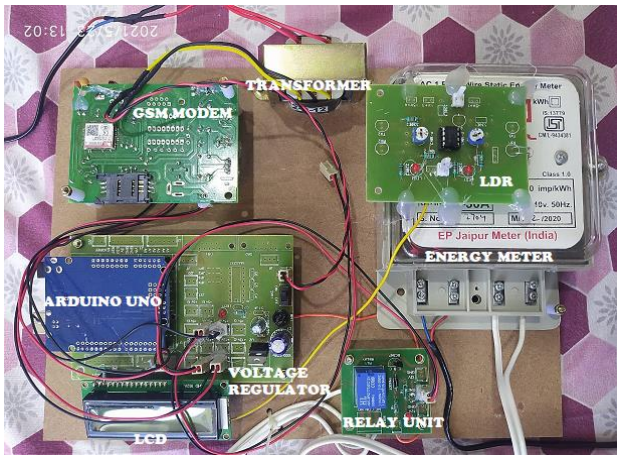

Fig. 7. Project Setup for proposed scheme

5. System Development

The proposed system is designed and developed by using different components. The components details are explained as:

A. Hardware Detailed Design

1) Power supply

Any invention of latest technology cannot be activated without the source of power. So in this fast moving world we deliberately need a proper power source which will be apt for a particular requirement. All the electronic components starting from diode to be only work with a DC supply ranging from 5V to 12V.We are utilizing for the same, the cheapest and

commonly available energy source of 230V-50Hz and stepping down, rectifying, filtering and regulating the voltage.

2) Energy meter

An energy or electric meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically-powered device. Electric meters are typically calibrated in billing units, the most common one being the kilowatt hour.

3) Opto coupler

Optocouplers, is a combination of light emitting device and a light sensitive device. These two are connected into a single package but not connected together. The light sensitive devices we could able to use are photo diodes, LDR, photo transistor and TRIAC etc. Present world will be using these in many electronic equipment. The signal is applied to the LED, which then shines on the transistor in the IC. Here in my paper am using the opto coupler used to measure the number units that are produced by energy meter.

4) Max 232

The MAX232 is an integrated circuit that converts signals from an RS-232serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals. When a MAX232 IC receives a TTL level to convert, it changes a TTL Logic 0 to between +3 and +15V, and changes TTL Logic 1 to between -3 to -15V, and vice versa for converting from RS232 to TTL.

5) Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins, 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts.

6) Relay

Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults.

7) GSM Modem

GSM stands for Global System for Mobile Communications. GSM networks operate in a number of different carrier frequency ranges (separated into 2G and 3G). GSM networks operate on the 850MHz, 900MHz, 1800MHz, and 1900MHz frequency bands. Most 3G networks in Europe operate in the 2100 MHz frequency band. GSM module is device that communicates over GSM network. This GSM Modem is used to send units bill to subscriber's phone number or to a utility company. AT commands are used to communicate with modem. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages.

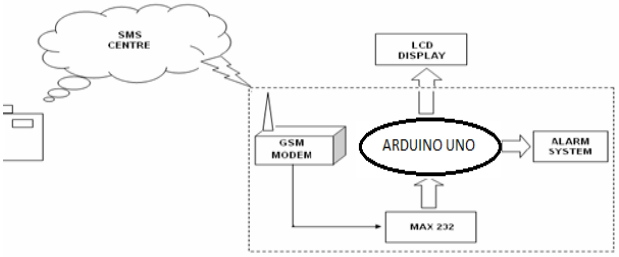

Fig. 8. GSM security

8) LCD display

The LCD panel's Enable and Register Select is connected to the Control Port. The Control Port is an open collector/open drain output. Therefore, by incorporating the two 10K external pull up resistors, the circuit is more portable for a wider range of computers, some of which may have no internal pull up resistors. In this paper we use a 16x2 LCD, means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

B. Implementation Details

In this proposed design the components used which are explained in previous section. This system is just a prototype of smart metering or Automatic Meter Reading (AMR) system. In this prototype the digital electronic energy meter is used and the monitoring of this meter is done by using the Arduino Uno and GSM Modem which are interfaced to the same meter. As this digital electronic energy meter has its own meter constant as specified by manufacturer, like mostly if the LED in the meter blinks or the pulses of the LED completes 32000 pulse then the meter will count 1 unit i.e. 1kWh. so we can say that,

1 Unit=32000 blinks or pulse.

Similarly, in this prototype these pulses are monitored with the help of LDR (Light Dependent Resistor) used in Optocoupler. This modification is for the exactness and fully automation purpose only. The LDR is interfaced with the Arduino Uno which is the heart of this prototype. According to the LDR output the same data is fetched and the result is displayed on the LCD. All this process is carried out according

to the programming, which is compiled in the Arduino Uno. In this prototype we have programmed the Arduino such that if the LED in the energy meter blinks once the LCD will display the consumption of 1 unit of energy.

1 Unit Consumption=1 blink.

GSM Modem is also interfaced with the Arduino for the communication purpose. The mobile numbers on which the bill will generate are already mentioned in the programme itself.

The Relay unit is also present in the proposed scheme for the isolation purpose only. According to the programme if the consumer fails to pay the bill before deadline then this relay unit will disconnect the load from the supply.

In programming different coded signals are present to operate or monitor the meter like, for deactivating the relay if you send the message "*0#" to the mobile number which is interfaced with the GSM Modem, the relay gets open.

The implemented scheme is quite simpler, secure and easy to handle.

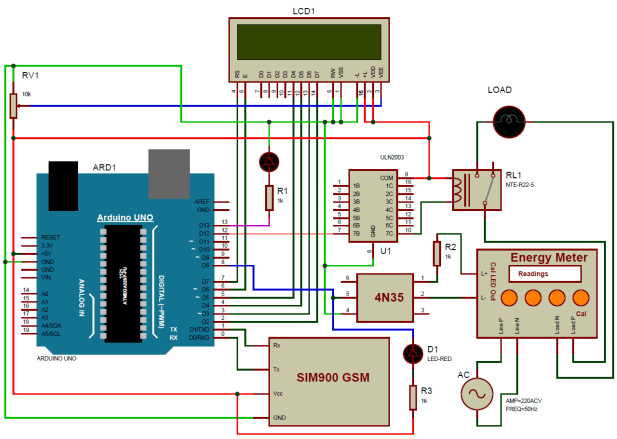

Fig. 9. Detailed implemented circuit diagram

Fig. 10. Prototype arrangement and SMS received at consumer's mobile

1) Advantages

- The development of a fully Automated Energy Meter which is having capabilities like remote monitoring and controlling of energy meter will lead to transparency in the energy meter reading and billing system.
- Automatic Meter Reading system (AMR) will continuously monitors the energy meter and sends data on to a server system of service provider through wireless communication where data will be stored as well. Later the bill details will be sent to the customer through SMS.
- It saves huge human labor.
- Global System for Mobile communication (GSM) technology is used to communicate between the service provider and the customer.
- This system avoids the human intervention in power management. If the customer does not pay the bill in time, the user is informed through SMS system using GSM.
- The low cost, simple setup, wide operating distance, less human intervention are some of the other salient features of this GSM based system [5].

6. Conclusion

The prototype of the GSM based display electronic notice board was efficiently designed. This prototype has facilities to be integrated with a display board thus making it truly mobile. The toolkit accepts the SMS, stores it, validates it and then displays it in the LCD module. The SMS is deleted from the phone each time it is read, thus making room for the next SMS. The major constraints incorporated are the use of '*' as the termination character of the SMS and the display of one SMS as at a time. These limitations can be removed by the use of higher end microcontrollers and extended RAM. The prototype can be implemented using commercial display boards. In this case, it can solve the problem of instant information transfer in this campus Using this project, we can reduce the manual effort to take the reading from the energy meter which is cost effective solution. Reduces man power. It is user friendly and we can enhance this project, in which an electricity department can send message to the consumer about the billing information. Various electronic meters have been developed and are still being developed. However, the use of GSM in this particular system provides numerous advantages over methods that have been previously used. Data transmission is charged at standard SMS rates; thus the charges are not based on the duration of data transmission [3].

The system can be modified by using latest SPI metering ICs which will provide more parameters. By using the Microchip three phase IC MCP3909 the same idea can be extended to three phase systems also. Power factor improvement options can be added in future. By adding an initialization message option at the time of installation the meter time can be updated from the server. If energy provide is willing to add online payment options in the hosted web page, instant payment by the consumer from anywhere in the world is also possible [3].

Based on all the systems surveyed, their advantages and drawbacks, this paper presents the features that make up an ideal AMR system and provides a overall insight of the various methodologies applied for AMR so far thus providing a base for further research in this area. Based on the performance criteria considered, several systems where compared and now we come to a conclusion that, when it comes to Reliability and

Feasibility GSM topped the charts [5].

Table 1
Summary of PLC vs GSM [4]

Measure	Power line carrier	GPRS/GSM
Reach ability	95%	97%
Capital costs	Medium	Low
Operational or running costs	Low	Medium
Operation	Own	Mobile phone operator
Addressability of meter	Via concentrator	Directly
Suitability (bandwidth)	Functions with low BW	Functions with high BW
Suitability for real time application	Yes	No
Flexibility	Medium	High
Reliability	High	Very high

The capabilities of the AMR system are described. The functions and features of the AMR system can really be enhanced to include Home Automation (HA), Alarm/status monitor, loop maintenance for telephone companies and remote electric load distribution/control. The potential opportunity of the AMR system seems to be bright [6].

Acknowledgement

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Goal makes us to do work. Vision is more important than goal which makes us to do work in the best way to make work equally the best. Thanks to Principal, Dr. Mohan B. Vanarotti for his support and vision.

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