Smart Energy Meter Reading and Billing

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Abstract

The existing system depends heavily on the availability and accuracy of the data acquired using manpower-based process. This process has many faults in it, which make it vulnerable to frauds and non-payment of bills. The proposed system works by using a modified energy meter to read the energy consumption data. This data is relayed to the microcontroller unit (MCU) along with various other sensory data. The MCU, in turn, relays all the acquired data to a secure database, by utilizing latest wired or wireless transmission technologies. We can easily observe, where maximum electricity is being consumed and thus use our distribution system more efficiently. A database will store the acquired data according to various parameters. The server will automatically generate an online bill corresponding to the service number, which can be paid via online/offline payment. The login – based user interface provided via a website, will help users keep track of their consumption, bills and payment history. This paper also presents a brief review of the various works done in this field.

Keywords: Smart Energy meters, AMR, AMI, Power Line Communication, energy measurement, MCU, Wi-Fi, GSM, Web Interface, Database, Analytics.

1. Introduction

Energy meters in the world have evolved from old analog models to latest digital models. However, in India, the majority of the population still use old electromechanical energy meters. Work is being done on changing this scenario by replacing these old meters with better and accurate digital meters. Even with all these efforts, our approach towards reading and billing of electricity hasn't changed. To account for the ever-increasing load requirements and unauthorized electricity usage we have to utilize the latest and developing technologies and create a system that will solve the problem. The age-old way of reading energy meter readings and billing them is highly inefficient. This method makes use of huge manpower to reach out all the households across the country and then manually reads and bills the electricity consumption. The major disadvantage of the existing system is that human error is highly possible. We also have a probability of meter tampering, unauthorized usage for purposes like festivals and marriages. We lose around 23% of the total electricity we produce. This loss will lead to huge revenue losses as well.

Various countries in the world have adopted various methods to overcome these issues we face today. The use of Smart Energy meters or Automated Reading Units (ARU), is one such method. These ARUs, are fully capable of computing the amount of power consumed with respect to time of the day. One other method is the Advanced Metering Infrastructure (AMI). This is a system used by private utility companies where all their meters are linked to a central database and monitored from there. This system also provides users with data regarding their usage costs, which helps in reducing wastage of electricity. To overcome the various issues we face in India, we are proposing an automatic system, that

will handle the meter readings automatically. This system was designed with reference to the advanced methods currently being employed in various parts of the world.

Smart meters are being used in many developed countries to ensure real-time data acquisition and accurate generation of usage bills. Previously one-way communication was used to gather data from the consumers. This method was known as Automated Meter Reading (AMR). This method is now being slowly replaced by its better successor, AMI, which was built to ensure two-way communication between the consumer and supplier. Prepaid energy meters would reduce all these problems, but the implementation and acceptance of such a system in a country with a huge population such as India would be time-consuming and would require huge efforts in the means to provide awareness about the new system to the masses.

This paper proposes a new system which was designed with reference to various methods being adopted around the world and the urban scenario of the Indian Subcontinent. This system will replace the manpower-based system and, in their place, more accurate meter readings will be noted. These readings will be stored in a secure database along with various other information. With reference to the various information stored in the database, a bill will be automatically generated periodically. We can also implement an active notification system, which will alert the consumers on their excessive electricity usage habits. In the long run, the implementation of such a system would benefit the whole country by providing an architecture for monitoring the electricity consumption over large areas, by reducing the wastage of electricity in areas with less electricity generation capacities and also help keep the cost of electricity generation under control, by maintaining the supply-demand ratio.

2. Related works and Methodologies used

2.1. Power Line Communication (PLC):

The first and foremost method which was employed around the world was Power Line Communication (PLC). Power Line Communication used the existing supply lines to receive usage data from the consumers. It operated by adding a modulated carrier signal to the wiring system. Various systems used various frequency bands. Since AC supply lines were only intended for frequencies up to 50 ~ 60 Hz, these systems had a limited ability to carry higher frequencies. The major limiting factor for this method was the propagation problem. The power lines stretched over hundreds or thousands of kilometers and that increased the propagation problem. Hence this system was not capable of providing services over a large area.

Broadband over Power Lines (BPL) was a system, based on PLC, designed to transmit two-way data over existing AC MV (medium voltage) electrical supply lines. This reduced the costs by eliminating the need for a dedicated data communication network since it used the broadband network for its communication as well.

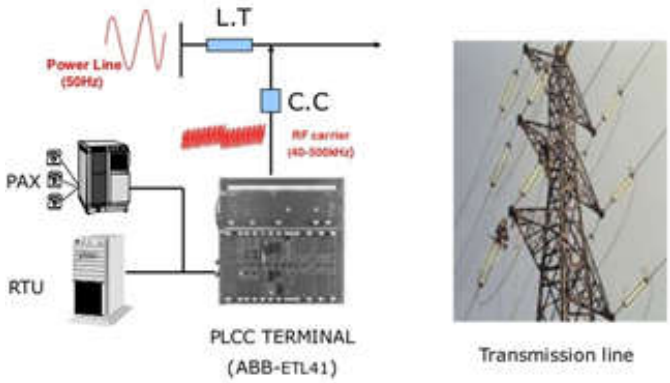

Figure 1. Block diagram of PLC

However, with the recent innovations in the fields of microwave transmissions and fiber optic communications, the utility companies are using these methods to establish a communication network for receiving the usage statistics from users over very large areas.

2.2. Automatic Meter Reading (AMR):

Automatic Meter Reading(AMR), is a technology used by the utility companies for automatically collecting usage and status data from consumers. This collected data would then be transferred to a central database for billing, troubleshooting and analyzing purposes. This technology mainly reduces the efforts and expenses for the utility providers for making multiple periodic trips to all the consumer locations to gather data. This also allows us to get precise real-time data from the consumer's end, which will allow us to bill properly and also help us predict consumption patterns. with this information, both the consumers and providers can easily control their use and production of electrical energy.

Originally, AMR devices used to just collect the meter readings electronically and match them with the consumer accounts. With the advancements in technology now, additional data can be captured, stored and transmitted to the main computer and all the AMR device could be controlled remotely. Many AMR devices can easily capture time interval data and log meter events. The logged data can be then used to collect or control "time of use" or “rate of use" data that can be used for energy usage profiling, billing, remote shutoff etc.

Figure 2. First commercially available AMR based system

In AMR systems, there were various versions which were based on various technologies for transmissions. Systems based on radio frequency networks, handheld consoles, mobile or drive-by

systems etc. These systems were remotely controlled without an actual physical presence at the locations. All the data was collected in central database and bills were generated periodically and mailed to the consumers via post.

After the advent of satellite communication, transmitters were installed near the field next to the existing meters and the readings were taken over a fixed or mobile satellite network. Later on, Wi-Fi was also used for AMR devices, but it wasn't of much use as the cost of setting up and maintaining a constant Wi-Fi network over a large area was very high. AMR devices were mainly developed and marketed by Metretek, Inc.

2.3. Advanced Metering Infrastructure (AMI):

Advanced Metering Infrastructure (AMI), is not a single technology. It is a highly configured infrastructure that combines various technologies to achieve its goals. Various infrastructure includes Smart meters at consumer's end, different types of communication networks at various levels of the infrastructure hierarchy, a system called meter data management system (MDMS) and software platform to integrate all the collected data at the utility provider's end.

The implementation of smart meter technologies can range from monitoring and control the consumption of resources at the connection to a complete building, to monitoring and control the consumption at every outlet in the whole building. In AMI, each of the individual components is modular and driven by an intelligent agent. As the customer will make use of all the modules available, it will make it easy for the provider to create a robust system for the whole building and will give ease of access to them. We can program the AMI modules to provide us with various performance indicators of the system: Specific, Measurable, Accurate, Relevant, Timely, Evaluative, and Recordable.

The Utility companies would only have to install one device instead of many individual meters and get all the data periodically. The consumer is provided with an advanced solid-state electronic meter which will transmit all the acquired data periodically via the communication methods prescribed. This data is received at the AMI host system and then sent to MDMS to manage the data storage and analysis. AMI provides two-way communication so that commands sent from the host system can be executed at the consumer end.

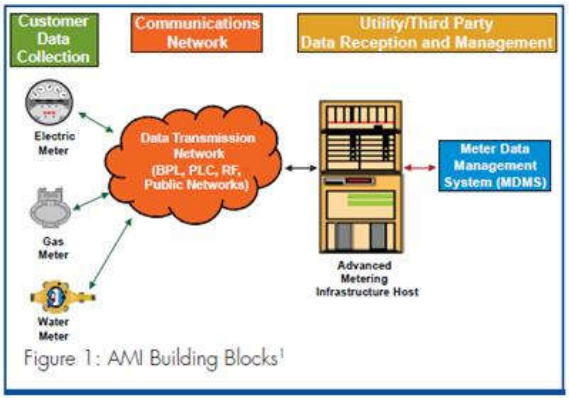

Figure 3. Advanced Metering Infrastructure Block Diagram

These systems are currently being developed and deployed as the awareness and technological advancements in the Internet of Things (IoT) have increased.

3. Proposed System of Meter Reading

In our proposed system, we are modifying the existing analog and digital energy meters and are adding a special unit to them. This unit consists of components like a microcontroller unit (MCU), a real-time clock (RTC) and a Wi-Fi module. These are the changes at consumer's end. As for the utility provider's end, we have a central database hosted on a secure server along with a web portal, which will act as the interface for consumer interaction. If an internet connection is unavailable then we have a second type of unit, in which Wi-Fi module is replaced by a GSM shield (SIM900).

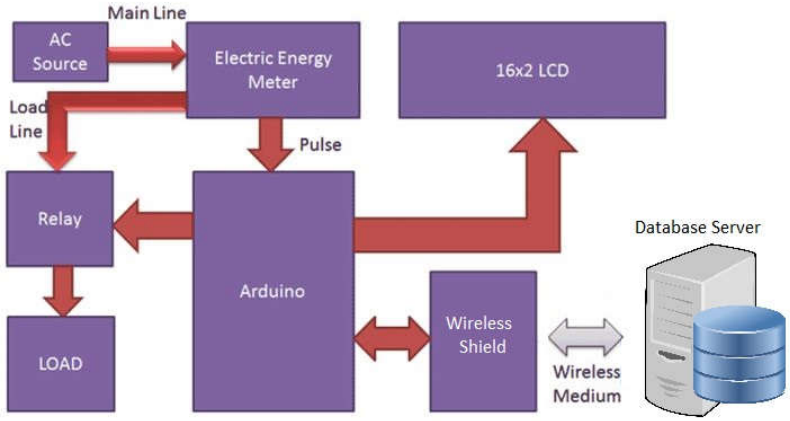

Figure 4. Proposed System Block Diagram

3.1 Microcontroller Unit

For the microcontroller unit, we opted to make use of the Atmega 2560 microcontroller due to its advanced capabilities. Another reason for choosing this MCU was the availability of it in the form of an Arduino development board (Arduino Mega 2560). The Arduino board provides an easy method of programming the microcontroller as per our requirements.

Atmega 2560 is a high-performance, low-power Microchip 8-bit AVR RISC-based microcontroller combining 256KB ISP flash memory, 8KB SRAM, 4KB EEPROM, 86 general purpose I/O lines, 32 general purpose working registers, real-time counter, six flexible timers/counters with compare modes, PWM, 4 USARTs, byte-oriented 2-wire serial interface, 16-channel 10-bit A/D converter, and a JTAG interface for on-chip debugging. The device achieves a throughput of 16 MIPS at 16 MHz and operates between 4.5-5.5 volts.

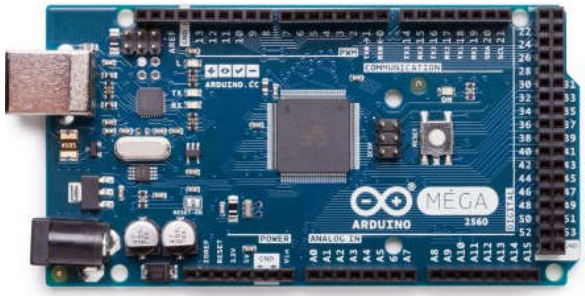

Figure 5. Arduino Mega with Atmega 2560

3.2 Real-Time Clock

We opted for an RTC module, as it would make it easy for us to gather time-related data in accordance with the consumption statistics. We used a DS3231 RTC module as it fit our needs very comfortably.

The DS3231 is a low-cost, extremely accurate I²C real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input and maintains accurate timekeeping when main power to the device is interrupted. The DS3231 is available in commercial and industrial temperature ranges and is offered in a 16-pin, 300-mil SO package.

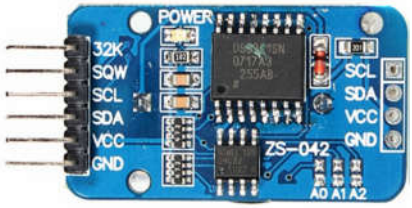

Figure 6. DS3231 RTC Module

As the RTC has its own battery, it won't die out until a long time. It will keep track of seconds, minutes, hours in both formats (12/24), day, month and year including corrections for leap years.

3.3 Wi-Fi Module

For the Wi-Fi module, we made use of the Espressif chip ESP8266-01 version. This chip is very easy to program and comes with onboard Ai Cloud from AI Thinker. This will allow the MCU to connect to the internet and fill the database.

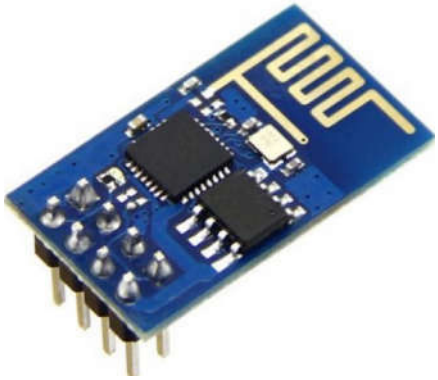

Figure 7. ESP8266-01 Wi-Fi Module

ESP8266 is a complete and self-contained Wi-Fi network solution that can carry software applications, or through another application, processor uninstalls all Wi-Fi networking capabilities. ESP8266 when the device is mounted and as the only application of the application processor, the flash memory can be started directly from an external Move. Built-in cache memory will help improve system performance and reduce memory requirements. Another situation is when wireless Internet access assumes the task of Wi-Fi adapter, you can add it to any microcontroller-based design.

4. Conclusion

Automatic meter reading system has experienced significant changes in the past years. Different state electricity boards in INDIA like the Kerala State Electricity Board (KSEB) adopted this system for its fast, efficient and error-free working. This paper describes the overviews of different technologies used for overcoming the problems and at last come up to this level. New technologies and methodologies which are already used to improve applications of AMR have been discussed in this paper. Till now PLC, Smart meters, WSN, GSM/GPRS are used in Automatic meter reading system. After reviewing various methodologies, we have come to the conclusion that GSM or Wi-Fi based smart meter reading and billing systems are very useful in a country like India. It will help us maintain our energy distribution networks in proper condition until cheap and better alternate smart meters are designed.

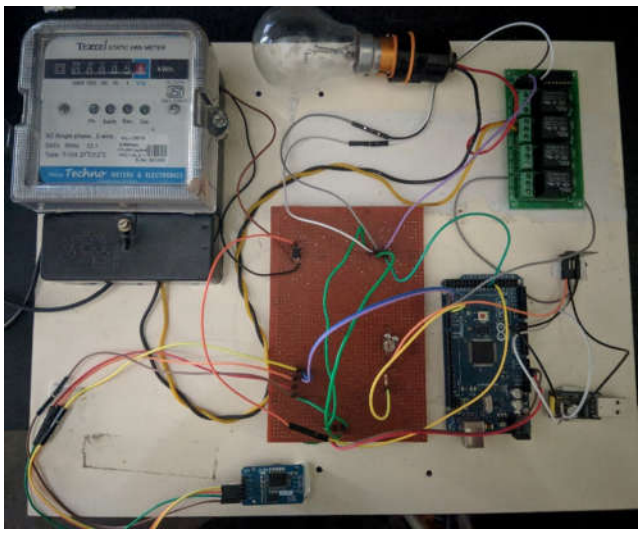

Figure 8. Our Project Prototype

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