RESEARCH ARTICLE

IoT Based Smart Energy Meter for Smart Grid Applications

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ABSTRACT: The present competitive world is witnessing tremendous change in technology and its applications to the needs of mankind. The booming wireless technology IoT (Internet of Things) has captured the greater share of such. The present work explores the application of such technology in developing an energy meter and that unit transmits the used energy units to the control center using IoT. This wireless energy metering and E billing for the domestic user overcome the manual reading of energy from the consumer meter and undue delays in billing as well as associated erroneous readings etc. The proposed unit consists of a Arduino controller with associated hardware and display unit to indicate the consumed energy in the users meter as well as interactive messages to the user regarding Tariff, usage pattern, conservation opportunities and probable load shedding etc. The user can set the required probable maximum limit of usage of energy unit and an alert message is received as the usage is reached or just after crossing. An encouraging message is sent to the user on saving specific block of energy leading to the conservation. The meter relay turns off the power on special condition like door lock (Non usage of power) and avoid un intended billing and possible theft. An interactive message is sent to the consumer regarding the same as when such abnormalities are detected. The IoT WiFi module transmits the usage information for the E billing process and avoids actual paper work and delayed payment etc. The meter tampering is also monitored in the proposed work. The system from the billing center send the message to the user mobile with bill amount and encourage online payments through E-Seva centers, Net-banking and even through mobile phones. This kind of interfaces is really needed for the smart grids. It will help to monitor centrally and proper load management can be done controlling the user's consumption.

KEYWORDS: Smart Energy meter, Wireless metering, Energy Billing

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1. INTRODUCTION

The Electricity Board have got used to the manual process and they go along with it even though there are many concerns coupled with it. Because of the human errors after getting faulty bill, it becomes the problem of user to get it clarified and corrected from the energy supply board. In that case customer has to find the office, stand in a queue and get it corrected. The problem is just because of human intervention even though lot of improvement is practiced in such corporations to minimize errors and hassles. Further to avoid human intervention in the billing process, in this new production, an automatic meter reading system came into use. The present work takes the opportunity to develop a low cost IoT based Smart energy meter for electrical billing and Interactive messaging from electric control room for the consumers. In the existing energy metering method the electricity energy billing duration is either end of one month or end of two months. During the month electricity consumer will not come to know how much energy is consumed. The major drawback of this method is user cannot manage the power consumption. Another disadvantage of this system is tempering of energy meter cannot be traced easily and such practices are happening and increasing rapidly which is one of the major cause of power crises even though many strict vigilance teams haunting such cases.

On the other way the Smart Electricity Energy Metering method tries to eliminate the drawbacks and limitations of existing electricity energy metering. In this method there is a provision for the consumer that they can see their power consumption time to time so that they have an opportunity to manage the power consumption as they desire. This method is not only providing the facility to the consumer but also it is more helpful to supplier. If the consumer fails to pay their electricity billed amount within the stipulated time period mentioned,, the supplier can disconnect the power automatically from the distant end. These systems eliminate the physical disconnection procedure at consumer site so it will be helpful to avoid conflict between consumer and supplier at the time of disconnection and man handling situations etc. This system can also provide the facility of the reconnection of the power from the distant end. The current work also provides the information about the tampering and power theft. Such information will be very useful to control the practices of power theft and reduce the power crises. Monitoring and keeping track of consumer electricity usage is not an easy job as reader needs to go to meter reading room and take down readings. Well it is important to know if you are charged accordingly so the need is quite

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certain. Present work and its automation related to the metering system allow the users to monitor energy meter readings over the internet. Our proposed system uses energy meter with Arduino microcontroller to monitor energy usage using a meter. The system not only monitor units consumed it will transmit the units as well as cost charged using the internet. The system allows user to check the energy usage and bill using a simple web application resulting effective monitoring etc.

In current billing system the distribution companies are unable to keep track of the changing maximum demand of consumers. The remedy for all the problems that the consumer is facing can be solved by keeping track of the consumers load on timely basis, accurate billing, track maximum demand and set flexible threshold value. The proposed system enables the electricity authorities to read the meter readings wirelessly without a person visiting each house. This can be achieved by the use of Arduino unit that continuously monitor and records the energy meter reading in its permanent (non-volatile) memory location. This system also can be used to disconnect the power supply of the house when needed. Electricity and gas are more valuable commodities than water and also they have to be compelled to supply actual readings rather than calculable readings. AMR (Automatic meter reading) systems are those which use a technique of communication to take the reading of meters and different appropriate knowledge from serviceable meters without going to the residences to check the meters. This technology has catapulted meter knowledge to center stage of the utility business set up.

The present electric power system operation and control is finding rapid changes to reduce the aggregate technical and commercial losses and to maximize the benefits to the both the consumer and the supplier. In this direction the proposed mechanism helps to automate the energy consumption and billing mechanism to support smart grid approach. From the various articles and publications the evolution of electrical energy metering and billing was studied. The developments are presented in the following paragraph. Electro-mechanical meters with motorized nature of the segments utilized in many regions ruin due to long usage. Digital energy meters with precision, accuracy with LCD display replaced the conventional over the time. Evolution in this pathway includes AMR using digital energy meters, AMR using Bluetooth, GSM, GPRS, ZigBee, PLC, RFID and so on [1-4]. PLC system makes use of existing power lines to convey information from energy meter to the data server but has some issues related to solidity and consistency as the carrier wave is affected by the noise. Also these systems have critical setback like, transmission distance, transmission cost, maintenance and security.

The present system only provides feedback to the customer at the end of the month that how much energy is consumed in the form of bill. The consumer does not find the chance to view and track the energy usage. The consumers are growing exponentially fast and load on power providing divisions is rapidly rising. In the existing system meter tampering can be done easily and it's one of the major drawbacks for an energy crisis [5-8]. A low cost real-time ARM-based energy management system was proposed in the literature. It is conceived as part of a distributed system that measures the main power system quantities and gives the possibility to manage the whole power plant. An integrated Web Server allows collecting the statistics of power consumptions, power quality and is able to interface devices for load displacement. The device is characterized by easy access to the information and the combination of a smart meter and data communication capability allow local and remote access [9]. The ever growing demand of energy, the capacity limitations of energy management, one-way communication, the need of an interoperability of the different standards, the security of the communication and the greenhouse gas emissions, leads to emerge a new infrastructure grid: Smart Grid. Smart Meters are one of the proposed solutions for the Smart Grid.

The aim of this work is to realize a real time pricing thanks to the proposed communication infrastructure. This solution is with great interest in economical and low carbon society point of view [10-11]. The technological revolutions to replace the existing technology of electro-mechanical meters especially in China and India by electronic energy measurement and is continuously upgrading. A wireless digital energy meter would definitely offer greater convenience to the meter reading task. Bluetooth technology is chosen as a possible wireless solution to this issue. In this paper, the design and implementation issues of a Bluetooth-enabled energy meter is discussed and presented. The energy reader can collect the energy consumption wirelessly based on Bluetooth. Microcontroller based design and implementation of energy meter using IoT concept eliminates the human involvement in Electricity maintenance. The consumer needs to pay the dues for the usage of electricity on schedule, in case that he couldn't pay, the electricity authority can turn off the meter autonomously from the distant server. The consumer can view the energy consumption from a web page such systems will help in central monitoring and control of energy consumption and billing for the class of users and easy modifications in billing structure for the smart grid approach [12].

2. EXPERIMENTAL EXTRACTS OF THE WORK

Nowadays, smart metering and energy management installations are becoming very essential in building automations related to electrical energy systems. Field level integration in these kinds of installations could provide new features in buildings energy monitoring and improve control quality. The current technological opportunities in communication field like, IoT based applications becoming more popular and provide effective solutions for many real time problems. In the current model, real-time monitoring system for the energy meter is proposed. The presented system provides ubiquitous and continuous access to energy consumption to the consumer by exploiting the advancement of IoT technology. The proposed system is cost effective as it requires a simple upgrade on the existing meters than complete replacement. In recent years IoT is the booming

technology and recently IoT based smart meters are on demand and need of the hour. The block diagram of the proposed work is shown in the Fig 1. From the analog electronic /semi digital energy meters CAL indication signal is taken and interfaced to a microcontroller through an Opto coupler. The blinking LED flashes 3200 times for every 1 unit of measure of electrical energy. The opto coupler gives the pulse to the micro controller each time the meter LED flashes. The microcontroller utilizes these pulses to compute consumed energy and send it to the cloud using WiFi module ESP 8266. This Wi-Fi module provides internet facility for the Arduino Uno microcontroller. ESP 8266 transmits the data serially to the Thing Speak web page for user display which can be viewed from anywhere in the world in multi level graphical format. The Arduino micro controller use 5V, DC supply and is programmed using Arduino IDE which is integrated with the Wi-Fi module. The consumed energy reading is displayed on consumer portal developed using Thing Speak website along with cost to be paid for the consumption.

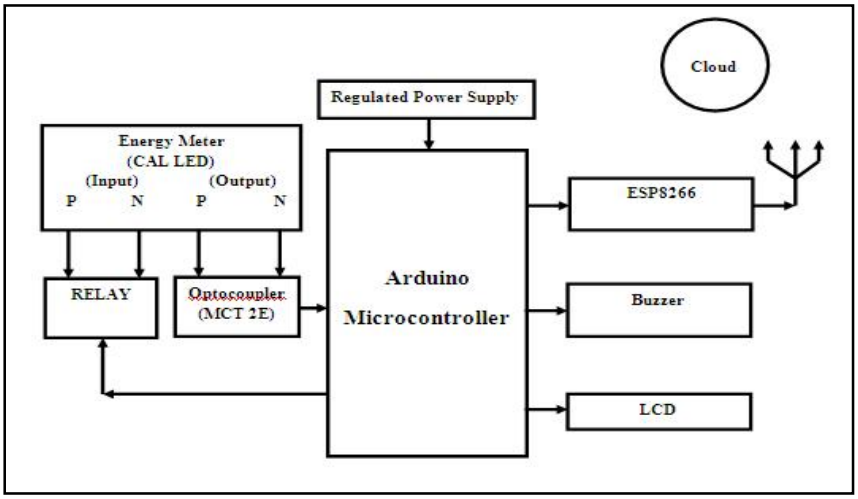


Figure 1 Block Diagram of IoT based Smart Energy Meter for Smart Grid

2.1 Methodology and Working of the system

The number of units of electrical energy consumed by the consumer is read from energy meter using Opto coupler IC (MCT2E) and the units consumed are displayed on meter LCD. The amount to be paid by the consumer to the electrical board using current tariff rate is computed and which is configured in the controller beforehand. The message is sent to the consumer via IoT about payment of electric bill for the month. If the deadline of the payment is about to lapse then a message is sent to alert and buzzer in the instrument is turned on for the specific duration. Relay is used on the input side of the energy meter to cut the supply to the consumer incase of nonpayment of bill within stipulated time. The planned door lock feature enable the user to turn off the meter relay during out of station or whenever premises is not requiring any power supply. This is very useful to avoid theft of electricity by someone during door lock. The remote command from the user unit can do it or on receipt of unexpected usage of power by any one by theft mode. Fig 2 to 5 show the practical implementation of the concept. To detect the occurrence of power theft, current and voltage sensors are used at the input and output port of the energy meter and a comparator is used to compare the power in both the ports. If the comparison turns out in equal measurement of power then it indicates a power theft and hence a relay should be tripped and intimation should be sent to the electric board (cloud) for further necessary actions.

3. RESULTS AND DISCUSSION

The model is making use of standard energy meter for the reference to verify the lamp energy consumption. It is producing 3200 pulses per KWh consumption. For the purpose of implementation of IoT based energy meter we have calibrated the gain factor such that to observe 1 unit consumption in faster rate for the demo purpose before using lamp loads, the lamps were tested with the standard energy meter zig and results of that test are shown in Table 1 and 2. Table 2 gives the record for different load levels in comparison with standard meter. The time taken for the reading of 1 unit consumption for the lamp load of 60W is read from the standard meter as 1000 min but from the developed energy meter it is 992 min an error of 0.8% lag is observed from this trial. Table 1 provides the comparative study of time taken for 1 unit of energy for different lamp loads using standard energy meter and implemented IoT based energy meter. For the ease of observation from the experimental setup to reduce observatory time for the comfort, a multiplying factor of 320 is used in the program with which 1 unit of consumption for a lamp of 60W is reduced 3min 7 sec. After the multiplication of constant it works to 997.33 min. Therefore in a short time it is experimented. Similarly other lamp load combinations are recorded in Table 2 with error details and the readings are self explanatory. This provides the comparative study of readings of IoT based energy meter for different lamp load combinations with standard meter.

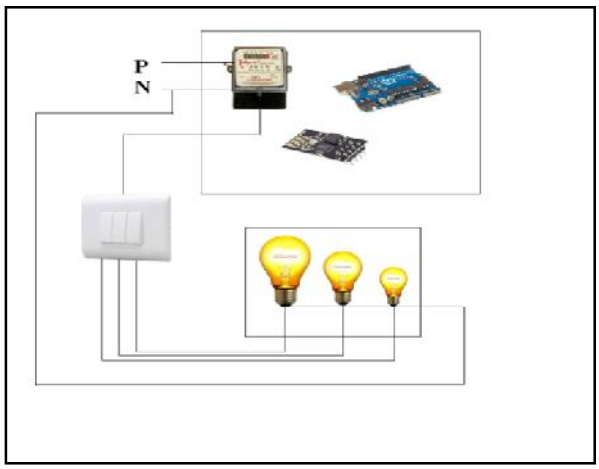


Figure 2 Overall Interconnection diagram

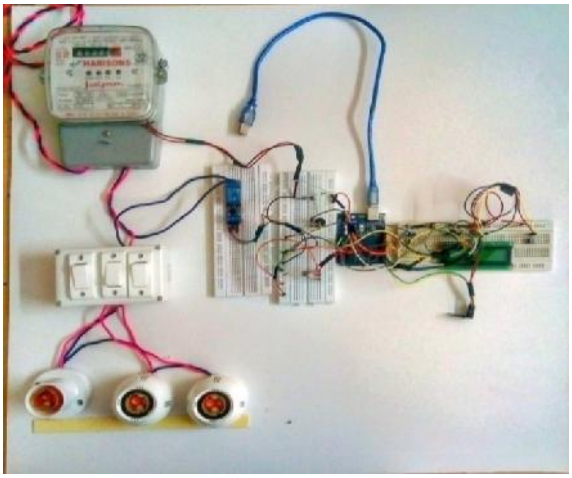


Figure 3 Hardware view of the Energy meter

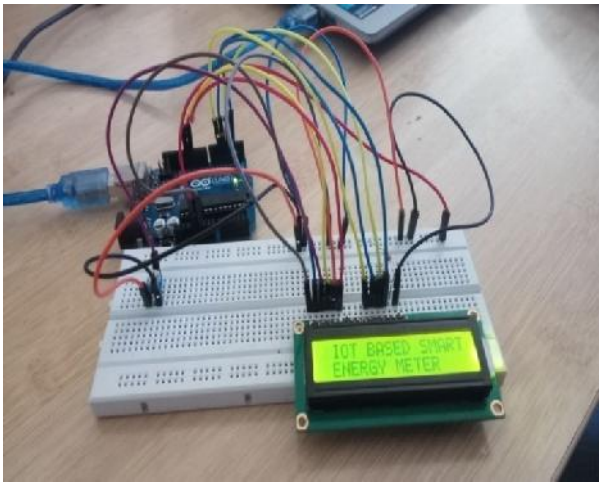


Figure 4 LCD –Arduino interface

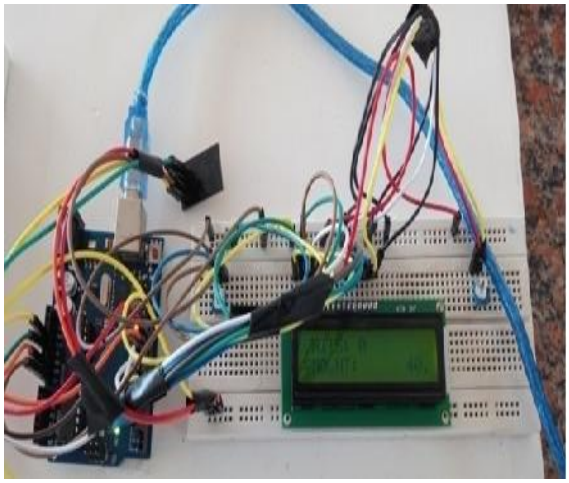
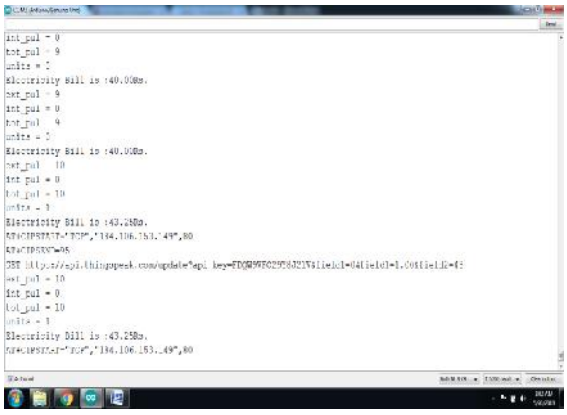


Figure 5 WiFi module interface to the Ardunino



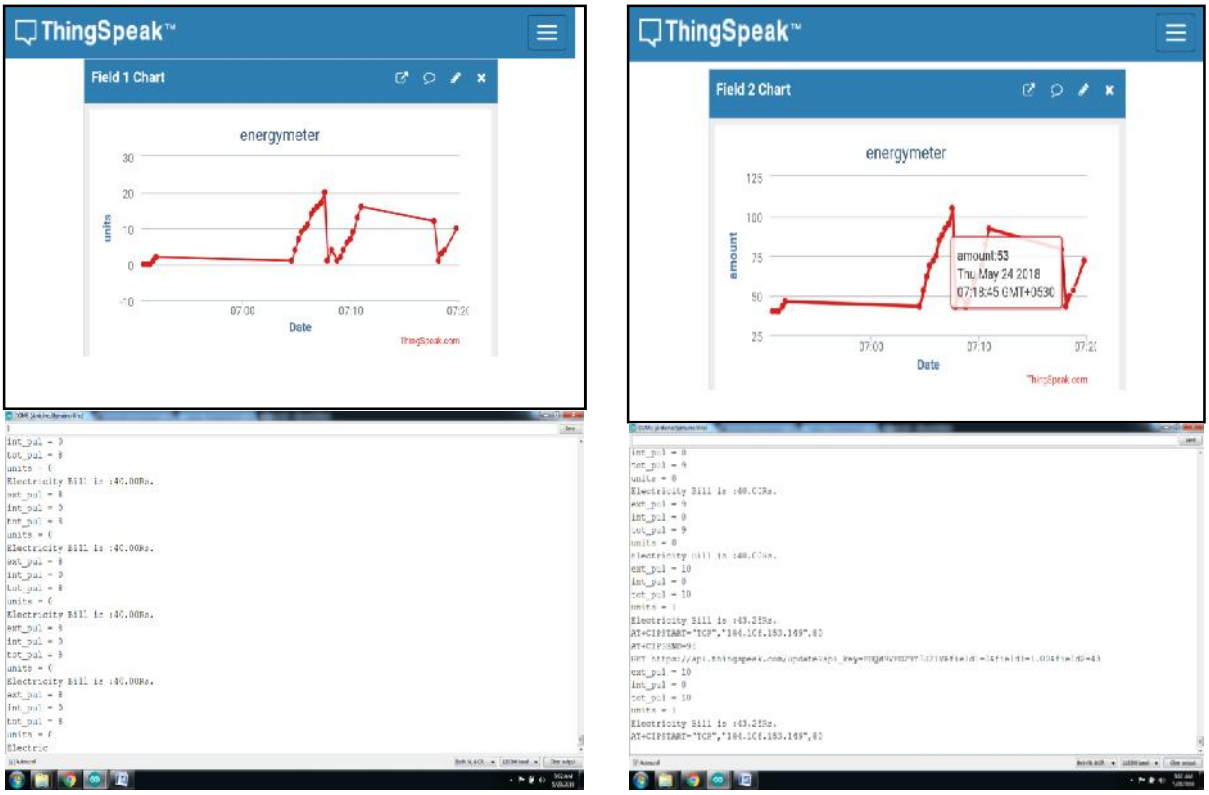


Figure 6 Different outputs viewed from screen and web port

Table 1 Comparison of IoT based smart energy meter with the standard energy meter

Sl. no	Wattage of bulbs (watts)	Time taken by Standard Energy Meter for 1unit consumption	Time taken by Implemented Energy Meter for 1unit consumption	Percentage Error
1	60	1000 min or 16.67 hr	992 min or 16.53 hr	-0.8%
2	100	600 min or 10 hr	595 min or 9.41 hr	-0.8%
3	200	300 min or 5 hr	298 min or 4.96 hr	-0.6%

Table 2 Record of energy consumption for different loads

200 Watt Bulb	100 Watt Bulb	60 Watt Bulb	Total Load (watts)	Time taken for 1 unit consumption	Time taken *multiplier factor	Expected time as per std meter	Percentage Error
OFF	OFF	ON	60	3min 7sec	997.33min	1000 min	-0.26%
OFF	ON	OFF	100	1min 52sec	597.33min	600 min	-0.45%
ON	OFF	OFF	200	56sec	298.66min	300 min	-0.44%
OFF	ON	ON	160	1min 10sec	373.33min	375 min	-0.44%
ON	OFF	ON	260	43sec	229.33min	230.77 min	-0.63%
ON	ON	OFF	300	37.75sec	201.33min	200 min	-0.66%
ON	ON	ON	360	31.06sec	165.66min	166.67 min	-0.61%

A view of bill amount for the consumed energy is displayed and captured in Fig 6. A wave form of energy consumption over the observatory time is plotted and is displayed on mobile of the consumer and in the web portal for the ease of by the consumer. List of such continuous messages sent from the meter are also recorded and displayed. The units consumed and time details are recorded. The meter found good in its working.

4. CONCLUSION

Energy Monitoring using IoT is an low cost innovative application of internet of things developed to control appliances remotely over the cloud from anywhere in the world for the smart grid applications.The development in technology about electrical distribution system is a non-stop process. In the present work, wireless meter reading system is calculated to endlessly monitor the meter reading and cost. It avoids the human intervention and probable errors, billing mistake and reduces man power. The advantages of this project are it reduces the manpower and cost. It also displays the consumed units on LCD as well as energy control center website. The IoT Based Smart Energy Meter is implemented using Arduino controller and used to display the energy consumption of the household and make the energy unit reading to be handy and wireless. Hence it reduces the wastage of energy and brings awareness among all. The door lock feature avoids the misuse of power by theft or by someone and turn off of the relay to ensure the safety or conservation remotely found working satisfactorily.

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