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GSM Based Smart Energy Meter

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ABSTRACT

Wireless energy management and analysis is an embedded system implemented for smart metering. In country like India, energy management is done mostly with door –door billing system or user have to pay online at only gram panchayat or municipality where authorized person will do payment procedure for user and take the amount. Here prepaid scheme is implemented for the user-end. User will get the electricity equivalent to balance in his account. All the activity done by server implemented over a here and sum illegal activity at the user to end like meter box lock broken can be determined etc

KEYWORDS: *Microcontroller, Arduino, Meter Box, Prepaid Scheme, GSM modem.*

I. INTRODUCTION

It has become a trend to integrate automatic systems via wireless applications over network. Along with the advancement of technology development, research on wireless applications and remote control has become significant and popular today. An electricity meter, electric meter, or energy meter is a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. A smart energy meter (SEM) is electric device having energy meter chip for electric energy consumed measurement, wireless protocol for data communication (such as GSM Modem) and peripheral devices for security purpose, data showing, meter controlling etc. Energy meter systems [1-2] can be incorporated with embedded controllers such as GSM modem to transmit the data over the mobile network. Such data can be then fed and integrated into existing Energy Management Systems located at power companies and organizations. The problem of efficiently collecting data from a large number of distributed GSM Modems in the energy meters is still a challenging problem. GSM modem should needs the terminal to control that part. Our Embedded controller interfaced with energy meter reading systems and GSM modem to control both.

The Energy Monitoring System is appropriate for Industries, manufacturing plants, commercial buildings or any situation where an electrical system is used. The system provides the centralized energy monitoring and control. The Energy Management System leads to savings in the overall cost. These savings may be come from better utilization of manpower, servicing cost, savings in the energy consumption, and non-Break down in the system. The smart energy meter contains an energy meter, a GSM modem, a microcontroller (Arduino) and a relay circuit, which is connected between the energy meter and the load. The proposed smart energy meter is able to provide all the metering and billing services like counting the consumed energy, sending the generated bill by the SMS (short message service) over the GSM network as well as the security services. Factually at present, the metering and billing system of our country is totally conventional and it is very much slowed, faulty and corrupted so our proposed smart energy meter is highly

deserved for national implementation. The overall operation of the proposed system is discussed in the next section.

II.Energy Metering Systems

A. Conventional Systems

Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) to give energy used (in joules, kilowatt-hours etc.). The meters fall into two basic categories, electromechanical and electronic. The most common type of electricity meter is the electromechanical induction watt-hour meter. The electromechanical induction meter operates by counting the revolutions of a non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter. The number of revolutions is thus proportional to the energy usage.

Electronic meters display the energy used on an LCD or LED display, and some can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours.

There are many flaws and errors in conventional billing. Some human mistakes may also occur in manual billing [3]. Analyzing the conventional billing some of the common observed errors and mistakes are:

- It's a time consuming procedure.
- There is always a chance of human error while taking the manual meter reading.
- There is no check and balance and verification procedure of this meter reading.
- There is always a chance of theft and corruption.
- Extra human power is required.
- Consumer is not updated of his usage.
- Consumer may not get the bill slip within due date.

B. Proposed System

A smart meter works by communicating directly with wireless data protocol with your energy supplier, so the company will always have an accurate meter reading and there's no need for you to take a meter reading yourself. Smart meters can work in a variety of different ways, including using wireless mobile phone type technology to send data. There are many benefits of smart energy meter such as:

Your smart energy monitor shows you how much energy you're using in money. So you can see what you're spending by the minute. Knowing more about how much energy things use, will help you choose the way you use them.

Your smart meters send us accurate, regular information about your energy use. So your bills will be accurate and there will be an end to having to submit meter readings [5]

If you want to get the most out of being a smart meter customer, let us know and we'll update your smart meters to record readings for every half-hour. Your smart meters will continue to only send one 'batch' of readings through to us each day but this will enable us to provide you with a Smart Energy Report a week after your bill.

The proposed system consists of digital energy meter, an Arduino (microcontroller) and GSM modem. After switching power on the Arduino and the GSM modem, turn on the relay and connects the energy meter to load via relay. Then read the EEPROM and display the current data. Arduino checks the impulse from energy meter I.e. If impulse occurs increase the data and display current data. GSM modem checks the new SMS. If there is a new SMS and read it. If the SMS is "DATA", send data to the specific number. If the SMS is "LINE CUT", turn OFF the relay, so load will disconnect. Again the SMS is "LINE OK" and then turn ON the relay so load will connect. If there is any other SMS in any other formats, then delete the SMS. Any tampering attempt occurs in the metering unit; Arduino turns OFF the relay, turns ON the buzzer and sends SMS to the service provider.

III. SYSTEM ARCHITECTURE

The system architecture of Arduino and GSM based smart energy meter is shown in the Fig. 1. The energy consumption is being calculated using the energy meter IC and Arduino(Uno 3). In order to prevent a tampering, detection program is present in the Arduino. Arduino and GSM based smart energy meter can be divided into several parts as Energy Meter IC, LCD, Arduino, GSM modem [11], Relay, Optocoupler, Control Unit, Display Unit and Power Supply Unit etc. The hardware description of different parts is separately introduced as follows:

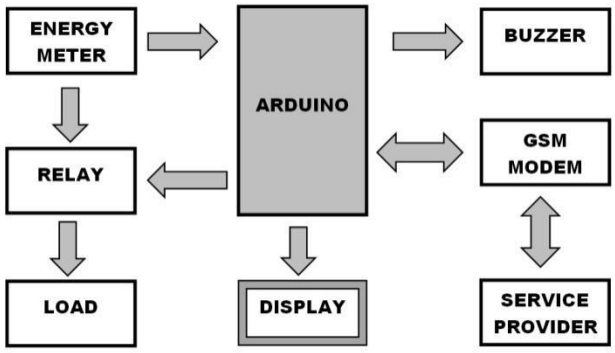

Fig. 1. Block Diagram of Proposed System

A. Energy Meter

In BL6503 [10], the two ADCs digitize the voltage signals from the current and voltage transducers. These ADCs are 16-bit second order sigma-delta with an oversampling rate of 900 kHz. This analog input structure greatly simplifies transducer interfacing by providing a wide dynamic range for direct connection to the transducer and also simplifying the anti- aliasing filter design. A programmable gain stage in the current channel further facilitates easy transducer interfacing. A high pass filter in the current channel removes any dc component from the current signal. This eliminates any inaccuracies in the real power calculation due to offsets in the voltage or current signals.

The real power calculation is derived from the instantaneous power signal. The instantaneous power signal is generated by a direct multiplication of the current and voltage signals. In order to extract the real power component (i.e., the dc component), the instantaneous power signal is low-pass filtered. This scheme correctly calculates real power for non sinusoidal current and voltage waveforms at all power factors. All signal processing is carried out in the digital domain for superior stability over temperature and time. The low frequency output of the BL6503 is generated by accumulating this real power information. This low frequency inherently means a long accumulation time between output pulses. The output frequency is therefore proportional to the average real power. This average real power information can, in turn, be accumulated (e.g., by a counter) to generate real energy information. Because of its high output frequency and hence shorter integration time, the CF output is proportional to the instantaneous real power. This is useful for system calibration purposes that would take place under steady load conditions.

B. Arduino

Arduino is an open-source platfonn used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on our computer, used to write and upload computer code to the physical board. The Arduino [12] platfonn has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board - you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package [14]. The Uno is one of the more popular boards in the Arduino family and a great choice for beginners.

C. Arduino GSM Shield

The GPRS Shield is based on SIM900 module from SIMCOM and compatible with Arduino and its clones. The GPRS Shield provides you a way to communicate using the GSM cell phone network. The shield allows you to achieve SMS, MMS, and GPRS and Audio via UART by sending AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands). The shield also has the 12 GPIOs, 2 PWMs and an ADC of the SIM900 module (They are all 2V8 logic) present onboard [11]. The Arduino GSM Shield connects your Arduino to the internet using the GPRS wireless network. Just plug this module onto your Arduino board, plug in a SIM card from an operator offering GPRS coverage and follow a few simple instructions to start controlling your world through the internet. You can also make/receive voice calls (you will need an external speaker and microphone circuit) and send/receive SMS messages.

D. Optocoupler

An optocoupler is a device commonly used to galvanic ally separate microcontroller electronics from any potentially dangerous current or voltage in its surroundings. Optocoupler usually have one, two or four light sources (LED diodes) on their input while on their output, opposite to diodes, there is the same number of elements sensitive to light (phototransistors, photo-thyristors or

phototriacs). The point is that an optocoupler uses a short optical transmission path to transfer a signal between the elements of circuit, while keeping them electrically isolated. This isolation makes sense only if diodes and photosensitive elements are separately powered. In this way, the microcontroller and expensive additional electronics are completely protected from high voltage and noises which are the most common cause of destroying, damaging or unstable operation of electronic devices in practice. The most frequently used optocouplers are those with phototransistors on their outputs. When it comes to the optocouplers with internal base-to-pin 6 connection (there are also optocouplers without it), the base can be left unconnected

E.Rlay

A relay is an electrically operated switch. 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. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

F. Power Supply Unit

A power supply is an electronic device that supplies electric energy to an electrical load. As all know any invention of latest technology cannot be activated without the source of power. All the electronic components starting from diode to Intel IC's only work with a DC supply usually 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 to convert it into suitable DC voltage. In our project the required voltage is +5V & +6V to run Energy meter IC, Microcontroller and the display unit.

IV. Circuit Connections and Power Calcultions

The complete circuit diagram has shown in Fig. 2. Energy meter we have used is based on the energy meter IC BL6503. In energy measure, the power information varying with time is calculated by a direct multiplication of the voltage signal and the current signal. The energy meter IC is producing impulses according to real power consumption. It calculates lKWh for 1600 impulses. For this the meter is rated as 1600imp/KWh. For every impulse the LED will blink. We have connected an Optocoupler high voltage side to this LED so that the Optocoupler will switch for every impulse. The direct connection from energy meter IC may dangerous for high voltage and make error for ac component to the Arduino. The pin 6 of the Arduino is connected to the Optocoupler switching side for detecting the impulse of the energy meter. While an impulse occurs the Optocoupler is switched, a pin 6 detects a digital O. On the other hand when the Optocoupler is not active the pin 6 will go in undefined state, then the Arduino may detect many pulses on this pin. So, to avoid this

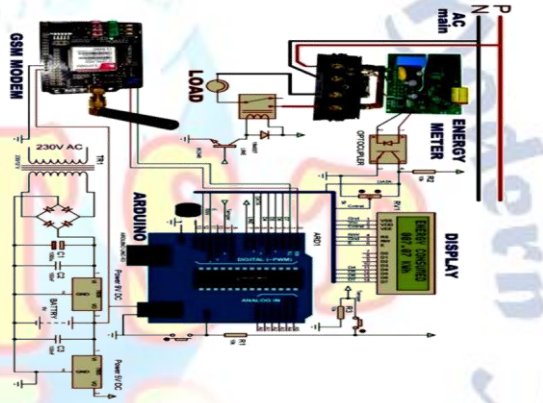

Fig. 2. Circuit Diagram of Proposed Energy Meter

Situation we have connected a lOKQ pull-up resistor with this pin so that on the inactive state of the Optocoupler the pin 6 of the Arduino will detect digital 1. Therefore the pin 6 of the Arduino will detect digital 0 when the Optocoupler is switched on otherwise the pin will detect digital 1. The change of state of the pin from digital 1 to digital 0 will count 1 to the data. For 1600 impulse it has to show lKWh and as the meter display format is as it has to show two digits after radix point. So that data will increase in the display after 16 impulses on the pin 6 of the Arduino [8].

We have used Arduino GSM shield for interfacing GSM modem with Arduino. It is a complete board contains all necessary pins and ports. The data communication pins are TX and RX. We have to connect TX pin of Arduino with RX pin of GSM modem and RX pin of Arduino with TX pin of GSM modem so that data communication may occur. All ground pin GND must connect together. As it is an Arduino GSM shield the pin configuration is so made that we have to just put

the GSM shield on the Arduino board. It will get power from the Fig. 2 Circuit diagram of the proposed smart energy meter. Arduino board... After power ON of the GSM shield the network light will blinking fast until the network coverage has got. When the network coverage has got, then the NET light will blinking slower than the previous. Sending the AT command to the modem it will response 'OK' after execution of every AT command that mean that the modem is connected and interfaced successfully [7].

V. SOFTWARE SIMULATION

We have simulated the project in PROTEUS 8.0 which one of best simulation software for electronic design. The simulated view of the project is shown in Fig. 3. First we have designed the counter using the Arduino where pulse on the pin is given by signal generator then the data will be displayed in the LCD. We have connected the GSM shield using a 'USB to Serial Converter' at USB port of the Pc. The modem is connected to Pc. The connection of the Arduino with GSM modem can establish using 'COMPIM' of the proteus. The component 'COMPOM' contains all serial connection pin. We have also used 'Virtual Terminal' of proteus to see the data exchanging between the GSM modem and Arduino. The virtual terminal shows everything that occurring or exchanging in the GSM modem and Arduino. We have to set all BAUD rate of virtual erminal and COMPIM port to 9600 kbps because of the GSM modem will communicate at this BAUD rate. Otherwise garbage value will show in the virtual terminal. Before RUN the software, the '.hex' file of the associated project i.e. the program should give to the Arduino otherwise it will show error. We have connected button for tampering attempt detect. When any one try to open the meter cover the button will

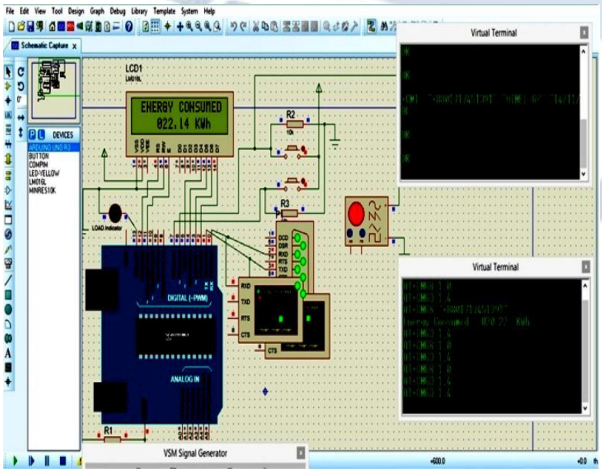

Fig. 3. Simulation Diagram with Result in Proteus Software

Released and send information to the service provider. We used LED as load; when it is glowing the load is connected. The program is written in Arduino IDE software will generate a hex code when verify. This hex code should load to the Arduino before compiling. Internal EEPROM will store data permanently. After stop the simulation if we start again data will not lost. Two GSM mobile SIM number is used for demo operation over GSM network, where one as customer and another as service provider.

VI. HARDWARE IMPLEMENTATION

According to the simulation connection, we have connected all the circuit parameters and parts of the project in a project board as shown in Fig. 4. We have established all the equipment in a board and connected the energy meter, Optocoupler and Arduino on a project board. We direct connected GSM shield with Arduino through male connector. Relay placed on the project board control the circuit board contain a socket and a bulb holder.

Fig. 4 Hardware Implementation of the Proposed System

The load can be connected through the socket though the bulb also is a load but low power. While connecting all the elements one matter must be keep in mind that leakage flux of the 230V AC component may interfere data communication of the Arduino and GSM modem. So high voltage equipment have to keep appropriate place where it may not interfere. All the connection has to connect carefully with good quality male connector. The power of the GSM modem has to take from the Arduino board. The Arduino board should supply with 9V DC and the current ratting must not be bellow lOOOmA. A 9V lOOOmA adapter may use for power supply. A 9V rechargeable battery may connect in parallel with power supply will work in case of power fail.

Two mobile phone set with GSM SIM, where one is used as customer end and another is used as service provider end for demo operation. As the

Arduino has been burned via PC using programming with predefmed functions i.e. energy meter reading code, SMS reading, checking and sending code, A T commands for SMS and security services, it will work on the following process. After powering ON the Arduino goes to its initial condition and powering ON the GSM modem and delete all the SMS. After a short delay the Arduino will read the EEPROM and calculate the data then display the data to the LCD. After that relay will ON and load will connect via relay from the energy meter. If there is any impulse occurs from energy meter IC, the Arduino will count it, increase the data and show in the LCD. Arduino will continuously check the new SMS indication from GSM modem. If there is new SMS, then Arduino will send related AT command to read the SMS. While reading SMS, Arduino will cheek the instruction in the SMS body. If there is valid instruction such as SMS body contain 'D A T A' then Arduino will send the current data showing in the LCD via GSM modem to the specific number i.e. service provider as
'Consumer ID: ... ...
ENERG Y Consumed ... KWh '.
If there is SMS body contain 'LINE CUT' then Arduino will turn OFF the relay so load will disconnect and a conformation message will send to service provider that line has been cut. If there is SMS body contain 'LINE OK' then Arduino will turn ON the relay so load will connect and a conformation message will send to service provider that line

VII. CONCLUSION AND FUTURE WORK

Arduino and GSM based Smart Energy Meter for advanced metering and billing system is built which is able to read and send data via wireless protocol using GSM technology through GSM modem, capable of manage the meter as well as the line connection. However this project needs more modification for more reliable and higher degree of satisfaction and safety. For GSM module the network coverage of the SIM used is one of the important facts. The network strength should strong so that the GSM module can work well.
One of the most important facts for this project is high cost of the component so that the overall cost of this project is high. Due to educational purpose and for research the equipment is provided with all pin connection, features and all possible events. As a result the manufacture cost is high. But when we implement this project commercially the cost may reduce by two or three times or more than the demo project. In commercial production for this project all the necessary component should provide only necessary pin connection and features. As a result overall cost may reduce more. In spite of being high cost at first time that mean when buy or install the overall cost of the system will reduce for this meter. The human labor that is taking data from energy meter in present day has to pay a good amount of salary for every month. Comparing this case Smart Energy Meter saves enough money for every month. In case of line cutting present system is very complex, time consuming and need much labor. Labor come to the pole from where the line taken, ride on the ladder and cut the line through pliers. This process is dangerous and risk of high voltage and high current electric shock. In case of line reconnect have to follow same procedure. For this system also need labor cost. But a Smart Energy Meter can easily do these tasks only by sending SMS. So a Smart Energy Meter saves money, labor and time.

This project is very important for modem time. If this project is implementing commercially it will be benefited us in many ways. If we can implement this project in our country, Bangladesh will go ahead one step. Here we used one GSM modem for one meter but in future work of this project one GSM modem may use for more than one which make it more cost effective.

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