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Smart energy meter with economic alert system

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ABSTRACT

At present the electronic bill of our home is generated by noting down the reading manually and this needs man power. This requires more time and this will lead for the extra charges for the customer as the tariff rate varies for different units. Every management system is trying to make automatic, portable and remote control. This work presents a novel smart energy meter for an automatic and superior metering and billing system. The integration of the PIC microcontroller and GSM Short Message Service (SMS) provide the meter reading system with some automatic functions that are predefined. Firstly, we have simulated the paper in PROTEUS 8.0 then successfully implemented on the circuit board in laboratory. The proposed energy meter system can incorporate with embedded controller and GSM modem to transmit the data like consumed energy in kWh, generated bill over GSM mobile network such as data can be then fed and integrated into existing energy management systems located at power companies or organizations to provide the services among the customers without man-power. This paper is able to provide all required services remotely for metering and billing with high fidelity.

Keywords: Smart Energy Meter (SEM), Peripheral Interface Controller (PIC), Global System for Mobile (GSM), Short Message Service (SMS)

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 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.

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-

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breakdowns in the system. The smart energy meter contains an energy meter, a GSM modem, a microcontroller (PIC). 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. 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. We also did not know about the usage details and we do not have any alert regarding the cost of the units so that we can use the energy economically by minimising the usage. This will help us in reducing the electric bill as the user will be informed when the cost increases as per the tariff table.

Conventional system

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.

There are many flaws and errors in conventional billing. Some human mistakes may also occur in manual billing system. 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 always a chance of theft and corruption.
- Extra human power is required.
- Consumer is not updated of his usage.
- Consumer will not be intimated to use the energy economically as per the tariff table.

Proposed system

This paper is aimed to design a circuit which helps the consumer to monitor the electrical energy consumption and protect him/her from the extra charges incurred due to minor changes in slab categories, since even small changes can affect the bill at a high rate. In this paper, electricity usage is updated periodically that is read from the energy meter and then sent to PIC microcontroller. The energy values once taken from the energy meter are digitized and processed with the help of a micro controller. The micro controller that we use here is PIC microcontroller. The cost value for the corresponding energy value is determined and the threshold cost value is fixed for which the consumption level increase is notified to the user. Daily consumption cost will be updated to the user through SMS. The problem of overload can also be monitored. When the circuit is overloaded, the difference in consumption is also analysed. This deviation from the normal value is notified to customer to prevent tripping of the breakers or blowing of fuses.

BLOCK DIAGRAM

The Figure 2.1 shows the block diagram of the proposed system. It consists of a PIC microcontroller which is interfaced with GSM and LCD to send and show the status of the usage. The meter which is used for measuring the energy utilities by the electric load is known as the energy meter. The GSM is a digital mobile network used by mobile phone users around the world. GSM digitises and compresses the data, then sends it down a channel with two other streams if user data, each one on its own time slot.

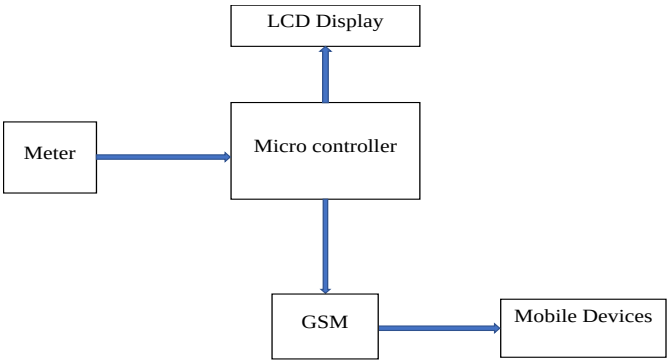

Figure 2.1 Block diagram

Energy meter

The energy is the total power consumed and utilised by the load at a particular interval of time. It is used in domestic and industrial AC circuit for measuring the power consumption. The meter is less expensive and accurate. The energy meter has the aluminium disc whose rotation determines the power consumption of the load. The disc is placed between the air gap of the series and shunt electromagnet. The shunt magnet has the pressure coil, and the series magnet has the current coil. The pressure coil creates the magnetic field because of the supply voltage, and the current coil produces it because of the current.

The field induces by the voltage coil is lagging by 90º on the magnetic field of the current coil because of which eddy current induced in the disc. The interaction of the eddy current and the magnetic field causes torque, which exerts a force on the disc. Thus, the disc starts rotating. The force on the disc is proportional to the current and voltage of the coil. The permanent magnet controls their rotation. The permanent magnet opposes the movement of the disc and equalises it on the power consumption. The cyclometer counts the rotation of the disc.

GSM (Global System for Mobile communication)

GSM (Global System for Mobile communication) is a digital mobile network that is widely used by mobile phone users in Europe and other parts of the world.

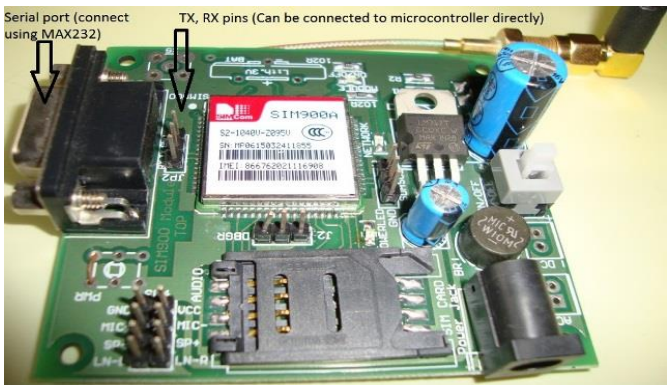

Figure 2.2 GSM module

The Figure 2.2 shows the GSM module. GSM uses a variation of time division multiple access (TDMA) and is the most widely used of the three digital wireless telephony technologies: TDMA,

GSM and code-division multiple access (CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 megahertz (MHz) or 1,800 MHz frequency band. GSM, together with other technologies, is part of the evolution of wireless mobile telecommunications that includes High-Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS), Enhanced Data GSM Environment (EDGE) and Universal Mobile Telecommunications Service (UMTS).

Liquid crystal display

16×2 Character LCD is a very basic LCD module which is commonly used in electronics papers and products. It contains 2 rows that can display 16 characters as shown in the below Figure 2.3. Each character is displayed using 5×8 or 5×10 dot matrix. It can be easily interfaced with a microcontroller. In this tutorial we will see how to write data to an LCD with PIC Microcontroller using Hi-Tech C Compiler. Hi-Tech C has no built in LCD libraries so we require the hardware knowledge of LCD to control it. Commonly used LCD Displays uses HD44780 compliant controllers.

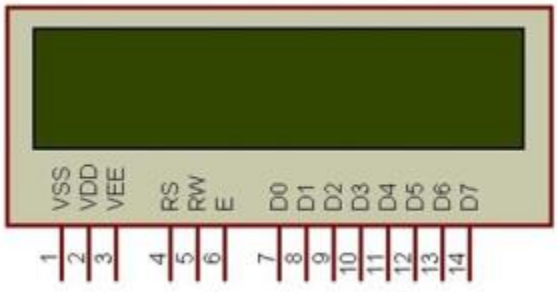

Figure 2.3 16×2 LCD Pin Diagram

This is the pin diagram of a 16×2 Character LCD display. As in all devices it also has two inputs to give power Vcc and GND. Voltage at VEE determines the Contrast of the display. A 10K potentiometer whose fixed ends are connected to Vcc, GND and variable end is connected to VEE can be used to adjust contrast. A microcontroller needs to send two information to operate this LCD module, Data and Commands. Data represents the ASCII value (8 bits) of the character to be displayed and Command determines the other operations of LCD such as position to be displayed. Data and Commands are sent through the same data lines, which are multiplexed using the RS (Register Select) input of LCD. When it is HIGH, LCD takes it as data to be displayed and when it is LOW, LCD takes it as a command. Data Strobe is given using E (Enable) input of the LCD. When the E (Enable) is HIGH, LCD takes it as valid data or command. The input signal R/W (Read or Write) determines whether data is written to or read from the LCD. In normal cases we need only writing hence it is tied to GROUND in circuits shown below.

The interface between this LCD and Microcontroller can be 8 bit or 4 bit and the difference between them is in how the data or commands are send to LCD. In the 8bit mode, 8bit data and commands are send through the data lines DB0 – DB7 and data strobe is given through E input of the LCD. But 4bit mode uses only 4 data lines. In this 8bit data and commands are splitted into 2 parts (4 bits each) and are sent sequentially through data lines DB4 – DB7 with its own data strobe through E input. The idea of 4bit communication is introduced to save pins of a microcontroller. You may think that 4bit mode will be slower than 8bit. But the speed difference is only minimal. As LCDs are slow speed devices, the tiny speed difference between these modes is not significant. Just remember that microcontroller is operating at high speed in the range of MHz and we are viewing LCD with our eyes. Due to

Persistence of Vision of our eyes we will not even feel the speed difference.

Interfacing of LCD with PIC microcontroller

The LCD Sis interfaced with the PIC microcontroller as per the below Figure 2.4.

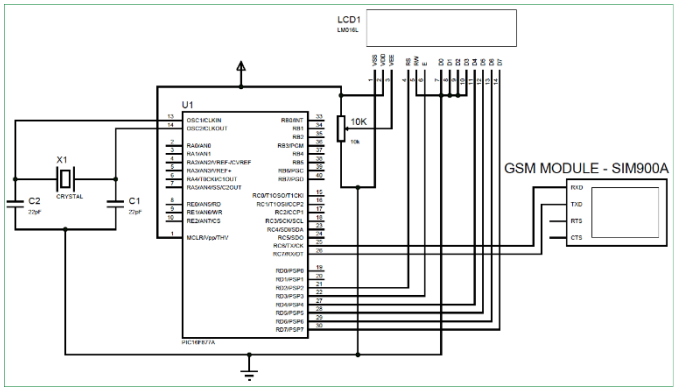

Figure 2.4 LCD interface

The Liquid Crystal Display will also display the status of the units consumed and the cost for the units consumed. At the first day it displays "SMART ENERGY METER". Then at the end of each day it displays the status. After sixty days the system sends a SMS to the user's mobile and the service provider.

PIC microcontroller

PIC is a family of microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to Peripheral Interface Controller, then it was corrected as Programmable Intelligent Computer. Early models of PIC had read-only memory (ROM) or field-programmable EPROM for program storage, some with provision for erasing memory. All current models use flash memory for program storage, and newer models allow the PIC to reprogram itself. Program memory and data memory are separated. Data memory is 8-bit, 16-bit, and, in latest models, 32-bit wide. Program instructions vary in bit-count by family of PIC, and may be 12, 14, 16, or 24 bits long. The instruction set also varies by model, with more powerful chips adding instructions for digital signal processing functions. The hardware capabilities of PIC devices range from 6-pin SMD, 8-pin DIP chips up to 144-pin SMD chips, with discrete I/O pins, ADC and DAC modules, and communications ports such as UART, I2C, CAN, and even USB. Low-power and high-speed variations exist for many types.PIC devices are popular with both industrial developers and hobbyists due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, serial programming, and re-programmable Flash-memory capability.

Advantages

- Small instruction set to learn.
- RISC architecture.
- Built-in oscillator with selectable speeds.
- Easy entry level, in-circuit programming plus in-circuit debugging PIC kit units available for less than $50.
- Inexpensive microcontrollers.
- Wide range of interfacesincluding I²C, SPI, USB, USART, A/D, programmablecomparators, PWM, LIN, CAN, PSP, and Ethernet.
- Availability of processors in DIL package make them easy to handle for hobby use.

PIC 16f877a

The PIC microcontroller PIC16f877a is one of the most renowned microcontrollers in the industry. This controller is very convenient to use, the coding or programming of this controller is also easier.

Figure 2.5 PIC microcontroller

One of the main advantages is that it can be write-erase as many times as possible because it uses FLASH memory technology. It has a total number of 40 pins and there are 33 pins for input and output as shown in the Figure 2.5. PIC16f877a finds its applications in a huge number of devices. It is used in remote sensors, security and safety devices, home automation and in many industrial instruments. An EEPROM is also featured in it which makes it possible to store some of the information permanently like transmitter codes and receiver frequencies and some other related data. The cost of this controller is low and its handling is also easy. Its flexible and can be used in areas where microcontrollers have never been used before as in coprocessor applications and timer functions etc.

CIRCUIT DIAGRAM AND CONNECTIONS

The PIC microcontroller is interfaced with the energy meter, GSM and the LCD display. The PIC microcontroller gets information from the meter. The analog signal is converted to digital form and the reading is compared with the tariff table. Accordingly, the SMS alert is sent to the user and at the end of the month the bill is calculated and it is sent to the user and the service provider. The LCD is interfaced and the current status is displayed at the display.

SOFTWARE SIMULATION

Proteus

Proteus is software for microprocessor simulation, schematic capture, and printed circuit board (PCB) design. It is developed by Lab center Electronics. PROTUES combines advanced schematic capture, mixed mode SPICE simulation, PCB layout and auto routing to make a complete electronic design system. The PROTUES product range also includes our revolutionary VSM technology, which allow you to simulate micro-controllerbased design, complete with all the surrounding electronic.

Simulation results

We have simulated the paper in PROTEUS 8.0 which is one of best simulation software for electronic design.

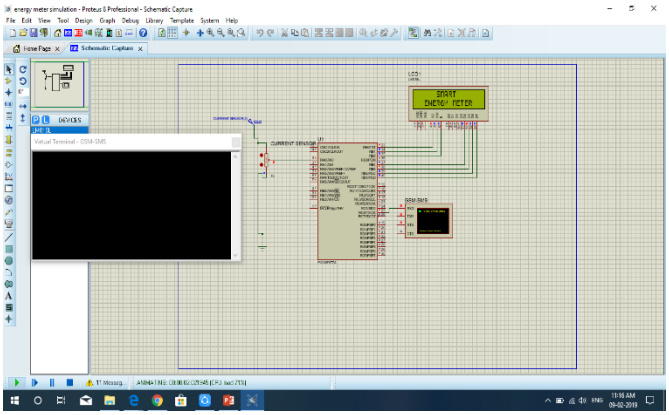

Figure 4.1 Simulation Results

First, we have designed the counter using the PIC microcontroller where pulse on the pin is given by signal generator then the data will be displayed in the LCD as shown in the Figure 4.1. We have connected the GSM shield using a 'USB to Serial Converter' at USB port of the PC. We have also used 'Virtual Terminal' of proteus to see the data exchanging between the GSM modem and PIC microcontroller. The virtual terminal shows everything that occurring or exchanging in the GSM modem and PIC microcontroller.

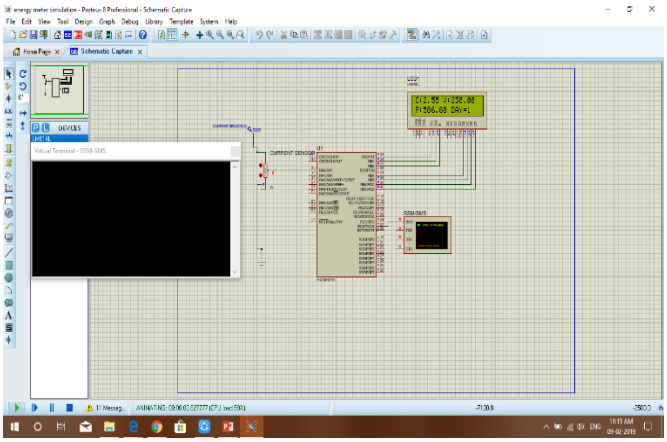

Figure 4.2 Simulation Result Day one Units and cost

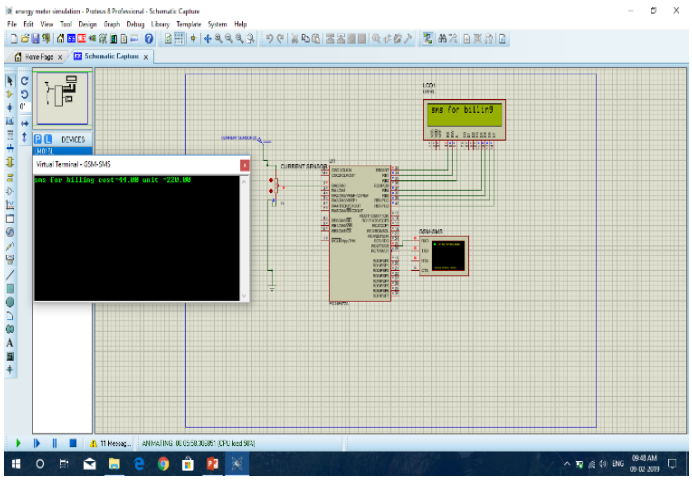

Figure 4.3 Simulation Result

We have to setall BAUD rate of virtual terminal port to 9600 kbps because of 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 paper i.e. the program should be loaded to the PIC microcontroller otherwise it will show error. We have connected button for tampering attempt detect. 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. At the first day the LCD will display smart energy meter. Then at the end of each day it displays the cost and the units consumed. After sixty days the cycle starts again as from the first day. This display will help us to see the status from the home and the SMS will help us to know the usage details even if we are not at the home.

At the end of day 1 it shows the consumption details and the day at the display as in Figure 4.2. The SMS will be sent to the user through the GSM modem. In the simulation, the message sent is shown with help of virtual terminal as given in the Figure 4.3.At the end of the sixty days the total bill is calculated and then it sends SMS to the user and the service provider. The virtual terminal shows the content of the message to be sent and the LCD shows that the message is being sent to the user and the service provider as in the Figure 4.4.

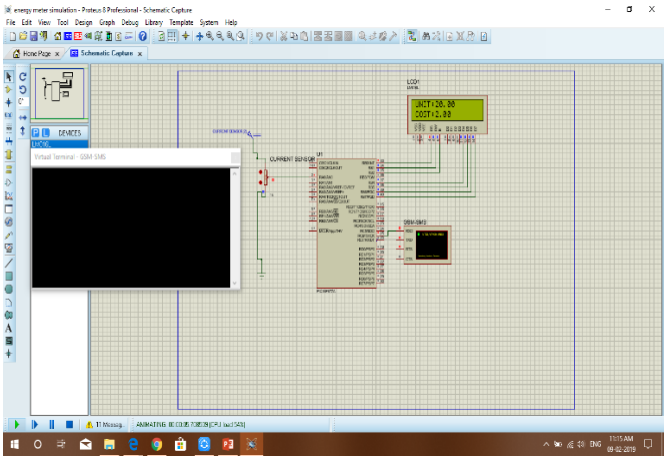

Figure 4.4 Simulation Result

CONCLUSION

In this paper, we have automated the bill generation without using the manpower. This paper will help us to use the energy economically as it alerts the user with respect to the tariff table. The LCD will display the status and the GSM will send the SMS to the user's mobile and thus creates an awareness among the users about their energy usage. At the end of the sixty days it sends the bill to the users and the service provider. In future this paper can be integrated with the complete automation of home appliances. The power consumed by every appliance can be calculated and monitored. The device which consumes more power can be found and alternatives can be made. This can be incorporated with the prepaid meters as it is going to be implemented. The complete automation can be achieved and the user will also know everything about his energy usage which will help to save the energy.

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