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RESEARCH ARTICLE

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AUTOMATIC ENERGY MONITORING SYSTEM

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ABSTRACT

Energy monitoring gives early warning of unexpected consumption of electrical energy in both domestic and industrial aspects. The purpose of monitoring is to relate the energy consumption data to the weather, production figures or other measures in such a way that the better understanding of how energy is utilized can be achieved. In the existing system, the billing process will be pending if the consumer is not available and human operator again needs to revisit. Going to each and every consumer's house and generating the bill is a laborious task and requires lot of time. The main objective of this work is to measure the energy consumed, estimate the cost towards it and to convey the same to both service provider and consumers over wireless communication. Conveying of information through very quickly and efficiently. So the main feature is to collect the data of energy consumption, cost then stores the information in database for analysis and sends the cost to the consumer phone. There is no chance of human error and corruption in the entire process as there is no human intervention. The verification of data at any time and displaying of the total loads are the main advantages of this project. The energy meter has been fabricated, tested and the outputs has been verified.

INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

With the rapid developments in the wireless communication technology by the use of microcontrollers, there are many improvements in automating various industrial aspects for reducing manual efforts. The traditional manual meter reading was not suitable for longer operating purposes as it spends much human and material resource. It brings additional problems in calculation of readings and billing manually. Now-a-days the number of electricity consumers is increasing in great extent. It became a hard task in handling and maintaining the power as per the growing requirements. Presently maintenance of the power is also an important task as the human operator goes to the consumer's house and produces the bill as per the meter reading. If the consumer is not available, the billing process will be pending and human operator again needs to revisit. Going to each and every consumer's house and generating the bill is a laborious task and requires lot of time. It becomes very difficult especially in rainy season. So the problem which arises in the billing system can become inaccurate and inefficient. The availability of wireless communication media has made the exchange of information fast, secured and accurate.

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The digital implementation caused the rapid utilization of devices such as computers and telecommunication devices. Communication media like the internet, GSM networks, etc exists everywhere. Wireless meter reading puts more control into the hands of both utilities and consumers by giving them more detailed information about power consumption. This allows utilities to better regulate supply. So, a wireless meter reading system and management kind of network technologies has become a trend now. In the work presented here, a technique has been developed to read electricity meter readings from a remote server automatically using the existing GSM networks for cellular phones. The meters send the meter readings like kilo-watt-hour (kWh), voltage, current, bill, etc. by SMS to a central server. The central server then stores the information in database for analysis and sends the bill to the customer mobile phone. The SMS based data collection can be done very quickly and efficiently. Data can be collected after any desired time interval such as hourly, daily, weekly, or monthly basis. As there is no human intervention in the entire process, there is no chance of human error and corruption. In the extremely bad weather conditions like heavy snow, rain, storm, etc the system will not hamper on collecting data as long as GSM networks are stable. The development cost of the SMS based remote meter will be higher than conventional meter but the electric supplier revenue will increase in the successive months because it will eliminate the possibility of corruption done by the customer or as of a reader.

1.2 ENERGY METER

An energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device. Electric utilities use electric meters installed at customers' premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour. They are usually read once each billing period.

When energy savings during certain periods are desired, some meters may measure demand, the maximum use of power in some interval. "Time of day" metering allows electric rates to be changed during a day, to record usage during peak high-cost periods and off-peak, lower-cost, periods. Also, in some areas meters have relays for demand response load shedding during peak load periods.

1.2.1 DIRECT CURRENT ENERGY METER

As commercial use of electric energy spread in the 1880s, it became increasingly important that an electric energy meter, similar to the then existing gas meters, was required to properly bill customers for the cost of energy, instead of billing for a fixed number of lamps per month.

Figure 1.1 Direct Current Energy Meter

An Aron type DC electricity meter in which the calibration was in charge consumed rather than energy as shown in Figure 1.1. Many experimental types of meter were developed. Edison at first worked on a direct current electromechanical meter with a direct reading register, but instead developed an electrochemical metering system, which used an electrolytic cell to totalise current consumption. At periodic intervals the plates were removed and weighed, and the customer billed. The electrochemical meter was labor-intensive to read and not well received by customers.

1.2.2 ALTERNATING CURRENT ENERGY METER

AC Energy meter is an Electronic meter with 1 Ø and 3 Ø input wire system and used for measuring the single and three phase A.C active energy which is shown in Figure 1.2. It's a Wall or panel mountable three phase dual source meter which integrates energy from either DG or EB based on the sense input provided to it. The measurement is by the 3 phase 4 wire system. The auxiliary supply to the meter is derived from one of the phases and the sense input to enable the meter to sense whether DG or EB is the input source. The meter individually totalizes the EB and DG KWH and also increments the run hours. The meter is integrated with RS485 communication interface which is galvanically isolated. Energy meters are the basic part to measure the power consumption. It is used everywhere, no matter how big or small consumption it is. It is also known as watt-hour meter.

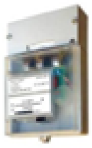

Figure 1.2 AC Energy Meter

The measurement of electrical energy is completely dependent on power which is measured in watt, kilowatts, Megawatts, gig watts, and time which is measured in hour. Joule is the smallest unit of energy. But for some bigger calculation, some better unit is required. So, the unit used for electrical energy is watt-hour. Watts are basic unit of power in which electrical power is measured or we can say that rate at which electric current is being used at a particular moment.

1.3 METERS USED IN ENERGY MONITORING

1.3.1 Standard meters

Standard meters are known in technical terms as electromechanical induction meters. These count the number of revolutions on an aluminium disc which rotates at a speed that is proportional to the power used. Therefore, the number of revolutions indicates the energy used.

1.3.2 Dial meters

A dial meter usually comprises of six dials. These read from left to right. There is only need to read the first five dials - starting with the 10,000kWh dial on the left and stopping after the 1 kWh dial. Ignore a final red dial if it is present. If the needle on the dial is positioned between two figures then it is the figure it has just past that should be recorded.

If the pointer on a dial falls between 9 and 0, reduce the reading already taken for the dial immediately on the left by one - for example, if your original recorded 5, reduce this to 4.

1.3.3 Economy 7 meters

These are for people who are on Economy 7 tariffs, where charges for electricity are lower at night than they are in the day. Using storage heaters to capture energy during the specified 7-hour period means the overall cost of energy can be reduced.

1.4 UNIT OF MEASUREMENT

The most common unit of measurement on the electricity meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Some electricity companies use the SI mega joule instead. Demand is normally measured in watts, but averaged over a period, most often a quarter or half hour.

Reactive power is measured in "thousands of volt-ampere reactive-hours". By convention, a "lagging" or inductive load, such as a motor, will have positive reactive power. A "leading", or capacitive load, will have negative reactive power. Volt-amperes measures all power passed through a distribution network, including reactive and actual. This is equal to the product of root-mean-square volts and amperes.

Distortion of the electric current by loads is measured in several ways. Power factor is the ratio of resistive to volt-amperes. A capacitive load has a leading power factor, and an inductive load has a lagging power factor. A purely resistive load exhibits a power factor of 1. Current harmonics are a measure of distortion of the wave form. For example, electronic loads such as computer power supplies draw their current at the voltage peak to fill their internal storage elements. This can lead to a significant voltage drop near the supply voltage peak which shows as a flattening of the voltage waveform. This flattening causes odd harmonics which are not permissible if they exceed specific limits, as they are not only wasteful, but may interfere with the operation of other equipment. Harmonic emissions are mandated by law in EU and other countries to fall within specified limits.

1.5 ORGANIZATION OF THE REPORT

Chapter 1 deals with the introduction of the project and brief explanation of energy meter with its types.

Chapter 2 deals with the literature review of the project in which the merits and demerits of the project reference papers are mentioned.

Chapter3 deals with the existing method of energy monitoring system and its drawbacks.

Chapter 4 deals with the proposed system, its advantages and components used in the project.

Chapter 5 deals with implementation of the proposed method.
Chapter 6 describes the Result and Discussion of the proposed system.
Chapter 7 describes the conclusion of the project work

LITERATURE REVIEW

P.K. Lee and L.L. Lai, Fieee (Jun 2007) have proposed a paper. In this paper, the authors discuss the way to adopt the cost effective GPRS applications. Although there have been lots of theories and concepts on the GPRS applications but the real applications applying to a large network, distributed power generation or building energy/power distribution monitoring are limited. The authors focus the application of the GPRS to this on line system application and the techniques. A practical scheme is proposed and its use to real life system will be introduced. A practical implementation for a wireless GPRS online Power Quality Monitoring System will be illustrated. Results and benefit to the end users in some practical Applications will be discussed.

H.G.Rodney Tan, C.H. Lee, V.H.Mok (Dec 2007) have presented a paper titled “The development of a GSM automatic power meter reading (GAPMR) system”. The GAPMR System is consists of GSM digital power meters installed in every consumer unit and an electricity E-billing system at the energy provider side. The GSM digital power meter is a single phase IEC61036 standard compliance digital kWh power meter with embedded GSM modem which utilize the GSM network to send its power usage reading using short messaging system back to the energy provider wirelessly. At the power provider side an E-billing system is used to manage all received SMS meter reading, compute the billing cost, update the database, and to publish billing notification to its respective consumer through SMS, email, Web portal and printed postage mailing. A working prototype of the GAPMR system was build to demonstrate the effectiveness and efficiency of automatic meter reading, billing and notification through the use of GSM network.

Bhushan D. Sawarkar1, Mrs. Snehal S. Golait2 M.E. Student, Department of Computer Technology, Priyadarshini College of Engineering, Nagpur, India 1 Assistant Professor, Department of Computer Technology, Priyadarshini College of Engineering, Nagpur, India has proposed a project titled Automatic Meter Reading and Instant Billing. The existing systems are either an electronic energy meter or an electro-mechanical meter which are currently in use is limited to record up to kWh units. The kWh units recorded by meter readers monthly, on foot which need to be processed by a meter reading company. For processing the meter reading, company needs to link each recorded usage data to the particular account holder and then determine the amount owed by means of the specific tariff in use. On basis of various platforms researchers proposed many system for Automatic Meter Reading There are various wire-based AMR systems like Power Line Carrier (PLC) and Telephone Line Network (optical/ cable) and wireless AMR systems such as E-metering systems based on GPRS, Bluetooth, GSM. Design of an Electric Energy Meter for long-distance data information transfers which based upon GPRS, but this system can’t be implemented so easily because the regular use of GPRS is still a dream to the common man. A GSM based Energy meter with instant billing facility is introduced is efficient, but still the problem of missing SMS will degrade the accuracy and performance. A more reliable and user friendly system by creating web portal for multiple access using the advanced Visual studio .net frame work which will manage the data efficiently even if there is loss of SMS. It makes the design different from the previous proposals and also increases the throughput. The GSM/GPRS channel is a very useful means of communication as sending data as SMS turns out to be a very handy tool, due to its good area coverage capability and cost effectiveness. The front end web portal is User friendly and any employee with minimum knowledge of computers can work on this software. Employees can read the meter by sitting in their office.

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Engineering.S.Arun1, Research Scholar CMJ University, Shilliong, Dr, Sidappa Naidu2 , Principal Veltech Multitech Engineering College, Chennai. Designing and implementing commercial as well as industrial systems based on Wireless communication has always been a prominent field of interest among many researchers and developers. This paper presents an implementation methodology for a wireless automatic meter reading system (WAMRS) incorporating the widely used GSM and Zigbee network. In many countries GSM and GPRS network is widely known for its vast coverage area, cost effectiveness and also for its competitive ever growing market. Using GSM as the medium for WAMRS provides a cost-effective, wireless, always-connected, two-way data link between utility company and WAMRS, the WAMRS sends information of utility usage, power quality and outage alarm to utility company, tampering detection to the utility servers. In this paper we suggest a method where we utilize telecommunication systems for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS, Email.

Tanvir Ahmed , MD Suzan Miah , MD. Manirul Islam and MD. Rakim. Uddin have presented a paper titled Automatic Electric Meter Reading System. Energy meter reading is a monotonous and an expensive task. Now the meter reader people goes to each meter and take the meter reading manually to issue the bill which will later be entered in the billing software for billing and payment automation. If the manual meter reading and bill data entry process can be automated then it would reduced the laborious task and financial wastage. “Automatic Electric Meter Reading System” is a metering system that is to be used for data collecting from the meter and processing the collected data for billing and other decision purposes. In this paper we have proposed an automatic meter reading system which is low cost, high performance, highest data rate, highest coverage area and most appropriate for Bangladesh perspective. In this AMR system there are four basic units. They are reading unit, communication unit, data receiving and processing unit and billing system. For reading unit we identified the disk rotation of the energy meter and stored the data in microcontroller. So it is not required to change the current analog energy meter. An external module will be added with the current energy meter. In the communication unit Wimax transceiver was used for wireless communication between meter end and the server end because of its wide coverage area. In the data receiving and processing unit meter reading will be collected from the transceiver which is controlled by another microcontroller. There will be a computer application that will take the data from the microcontroller. This will also help to avoid any tampering or break down of energy meter. There are various AMR system exists all over the world. Those systems were analyzed and we found they are not feasible for Bangladesh. Our proposed system is completely new and is appropriate for Bangladesh perspective. The study was conducted at the Electrical Circuit Laboratory, American International University, and Dhaka, Bangladesh during October 2009 to November 2010.

K.Ashna & Sudhish N George have proposed a project titled “GSM based automatic energy meter reading system with instant billing”. 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 system. This paper presents the design of a simple low cost wireless GSM energy meter and its associated web interface, for automating billing and managing the collected data globally. 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. A new interactive, user friendly graphical user interface is developed using Microsoft visual studio .NET framework and C#. With proper authentication, users can access the developed web page details from anywhere in the world. The complete monthly usage and due bill is messaged back to the customer after processing these data.

Pablo Corral, Beatriz Coronado, Antonio Cezar de Castri Lima & Oswaldo Ludwig have presented a paper on "Design of Automatic Meter Reading based on Zigbee". This paper describes the study about Automatic Meter Reading (AMR) in indoor environments, implementing a WSN-Wireless Sensor Network based on Zigbee technology. Automatic Meter Reading is used for remote collection of the utilities data. And these utilities may means electricity, gas, water consumption data or any other. Our concentration will be on Electricity power monitoring system which can monitor power quality, can remotely control power service which will enable prepaid billing.

S.B. Sanukrishnan has proposed a paper titled "Cognitive Energy Monitoring System using Arduino". This is a complete automated solution for the existing energy distribution and monitoring system. It can monitor the meter readings continuously and take necessary actions to maintain the power grid stable. A Power Line Communication based modem is integrated with each electronic energy meter. Through PLC the meters communicate with the coordinator. Coordinator makes use of GPRS modem to upload/download data to/from internet. A personal computer with an internet connection at the other end, which contains the database acts as the billing point. Live meter reading sent back to this billing point periodically and these details are updated in central database. An interactive, user friendly graphical interface is present at user end. All the energy logs, notices from the Government, billing details and average statistics will be available here. The system splits the loads into two: critical loads and non critical loads. This makes the distribution system more intelligent. More over prior information about the power cuts can be done. We can easily implement many add-ons such as energy demand prediction, real time dynamic tariff as a function of demand and supply and so on.

2.1 INFERENCE

From the literature survey , it have been stood that the energy monitoring has been done by various methodology in which the power consumed and the cost for that are displayed and viewed only at the energy provider premises.

In the proposed system, the power consumption and the cost according to it are displayed and viewed at both energy provider and consumer premises.

EXISTING SYSTEM

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. According to the maximum demand, the consumer will purchase a cash card of amount depending on the consumption of energy and after the full consumption, the consumer again has to purchase another cash card or recharge the same and thus the hassle related to go to the billing office, to stand in a long queue and to submit the bill, can be avoided. Also this system helps to eliminate the draw backs of billing management system, such as to take the reading from the meter, to create the bill, to print the bill, to send the bill to the proper address and to collect the amount for the bill. This paper presents the results of an investigation which show that the development of the GSM network as a low cost, global carrier of digital telecommunications signals provides exciting opportunities for novel applications such as the handling of power system metering and load management telemetry. As the use of GSM for telephony becomes more widespread, it is inevitable that costs will be driven lower. It is also inevitable that this medium will become very important to the electricity supply industry in the next few years. One major issue which will require to be addressed as this development takes place is the security protection

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of data being transferred, particularly in the radio link paths of the network.

A power load management system based on ARM7 microcontroller and GPRS is presented in this paper. The proposed system consists of electronic KWH meter, intelligent management terminal (IMT) and management centre. The intelligent terminal is sued to acquire information from KWH meter, control the energy consuming device and communicate with management centre via GPRS network.

3.1 COMMON METER READING INSTRUMENT

The Common Meter Reading Instrument (CMRI) is a portable battery operated instrument applicable for viewing, downloading, and uploading meter data to BCS. In the context of electricity metering applications, it is also referred as MRI or HHU.CMRI has been in use for more than a decade in the Indian power sector. The present CMRI's has a hardware/ software that runs different communication protocols as provided by various manufacturers to download data from the meters of respective manufacturers, all of which are generally supplied with their own data exchange formats or protocols. Now for Indian power sector "IEC62056 Electricity metering – Data exchange for meter reading, tariff and load control" is adopted for implementation in meters as the open protocol for meter data exchange. This series of IEC standards are supported by the Indian Companion Specification as IS 15959. When the meters complying with ICS are deployed and become part of an AMR network the meter data would be read by the HOST system. Under certain circumstances if any of the meters was not readable the data of those meters shall be possible to download in to a CMRI and uploaded to the HOST/BCS. Hence, new CMRI is to be designed to meet the requirements of IS 15959. These new CMRI shall also support security features as per the ICS. This Functional Requirements for Common Meter Reading Instrument is prepared by the committee comprising of members from CEA, CPRI and System Integrators, CMRI manufactures, Meter manufactures and utilities.

3.1.1 CMRI Connectivity Scheme

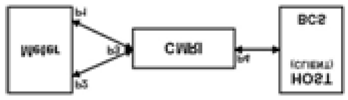


Figure 3.1 CMRI Connectivity Diagram

Figure 3.1 shows the connectivity scheme between server (meter) and host (BCS). The meter block in above diagram may be an ICS meter. In the case of ICS meter P1 is hard ware port and P2 is optical port. The CMRI shall connect and read data from any of these ports.

3.1.2 CMRI Passwords

CMRI server shall support Low Level Security and High Level Security. The LLS secret and HLS key shall be handled using appropriate association objects in a way similar to that of ICS.

3.1.3 Meter Passwords

The Passwords corresponding to each shall be stored in Meter passwords table object in MLD. This object is modelled as Utility table (IC=26) and the "buffer" attribute shall be of the format.**3.1.4 DRAWBACKS OF CMRI IN EXISTING SYSTEM**

The high-performance Atmel picopower 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, a 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.

3.2 General Packet Radio Service (**GPRS**)

It is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications GPRS was originally standardized by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD anti-mode packet-switched cellular technologies. It is now maintained by the 3rd Generation Partnership Project.

GPRS usage is typically charged based on volume of data transferred, contrasting with circuit switched data, which is usually billed per minute of connection time. Usage above the bundle cap is charged per megabyte, speed limited, or disallowed.

The offered CMRI compatible to read minimum 60 meters for billing & tamper data with 35 days load survey and CMRI shall be able to display phase / vector diagram of phase current, phase voltage with respective phase angles and phase sequence of voltage at side when these data are read from the meter. 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. The voltage coil consumes a small and relatively constant amount of power, typically around 2 watts which is not registered on the meter. The current coil similarly consumes a small amount of power in proportion to the square of the current flowing through it, typically up to a couple of watts at full load, which is registered on the meter.

The disc is acted upon by two sets of coils, which form, in effect, a two phase induction motor. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees, due to the coil's inductive nature, and calibrated using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current, voltage and phase angle i.e power factor between them. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power or rate of energy usage. The disc drives a register mechanism which counts revolutions, much like the odometer in a car, in order to render a measurement of the total energy used.

The type of meter described above is used on a single-phase AC supply. Different phase configurations use additional voltage and current coils.

3.3 PARAMETERS MEASURED IN EXISTING SYSTEM

(i) Rms values of voltages and currents
(ii) Active, reactive and apparent power
(iii) Energy delivered into a load
(iv) Phase shift, power factor
(v) Frequency spectrum of the power network signals.

3.4 TYPES OF ENERGY METERS

3.4.1 Electronic meters

Electronic meters display the energy used on an LCD or LED display as shown in Figure 3.2, 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.

Figure 3.2 Electronic meter

3.4.2 SMART METER

A smart meter is usually an electronic device that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing.

3.4.2.1 PURPOSE

Since the inception of electricity deregulation and market-driven pricing throughout the world, utilities have been looking for a means to match consumption with generation. Traditional electrical and gas meters only measure total consumption, and so provide no information of when the energy was consumed at each metered site. Smart meters provide a way of measuring the site-specific information, allowing utility companies to introduce different prices for consumption based on the time of day and the season which is shown in Figure 3.3.

Utility companies propose that from a consumer perspective, smart metering offers potential benefits to householders. These include, a) an end to estimated bills, which are a major source of complaints for many customers b) a tool to help consumers better manage their energy purchases - stating that smart meters with a display outside their homes could provide up-to-date

Figure 3.3 Smart Meter

information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills. Electricity pricing usually peaks at certain predictable times of the day and the season.

In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online. Proponents assert that billing customers at a higher rate for peak times will encourage consumers to adjust their consumption habits to be more responsive to market prices and assert further, that regulatory and market design agencies hope these "price signals" could delay the construction of additional generation or at least the purchase of energy from higher price sources, thereby controlling the steady and rapid increase of electricity prices.

There are some concerns, however, that low income and vulnerable consumers may not benefit from intraday time-of-use tariffs. An academic study based on existing trials showed that homeowners' electricity consumption on average is reduced by approximately 3-5%.

The ability to connect/disconnect service and read meter consumption remotely is major labour savings for the utility and can result in large layoffs of meter readers.

3.4.3 Prepayment meters

The standard business model of electricity retailing involves the electricity company billing the customer for the amount of energy used in the previous month or quarter using prepayment meter as shown in Figure 3.4. In some countries, if the retailer believes that the customer may not pay the bill, a prepayment meter may be installed.

Figure 3.4 Prepayment meter

This requires the customer to make advance payment before electricity can be used. If the available credit is exhausted then the supply of electricity is cut off by a relay. In the UK, mechanical prepayment meters used to be common in rented accommodation. Disadvantages of these included the need for regular visits to remove cash, and risk of theft of the cash in the meter.

Modern solid-state electricity meters, in conjunction with smart cards, have removed these disadvantages and such meters are commonly used for customers considered to be a poor credit risk. In the UK, customers can use organisations such as the Post Office Ltd or Pay Point network, where rechargeable token scan be loaded with whatever money the customer has available.

PROPOSED SYSTEM

The energy meter is newly designed for energy monitoring with cost estimation for energy consumed in the domestic household and industrial purpose.It will provide

a) Total load

b) Load from each meter

c) Cost for energy consumed

The meters will send the data to the master controller through the wireless communication. GSM receives the message and get displayed and it is sent to the consumer mobile. In this system, the power wastage in the equipments after shut down can be monitored and controlled. The power sharing between each section in an Industry can be monitored using this system. Power demand for each section can be calculated. The load used can be viewed at any time and also the cost consumed for each unit will be displayed through the gsm communication. The master controller can receive all the data which is being processed Point-to-Multipoint service: point-to-multipoint multicast and point-to-multipoint group calls.If SMS over GPRS is used, an SMS transmission speed of about 30 SMS messages per minute may be achieved. This is much faster than using the ordinary SMS over GSM, whose SMS transmission speed is about 6 to 10 SMS messages per minute.

4.2 TECHNICAL DESCRIPTION

The technical description for all the parameters as shown in Figure 4.1 & 4.2 are explained below.

4.2.1 GSM MODULE

SIM900A is a dual band GSM modem being able to operate only in 900,1800MHzbands and it can only be works in India .The operating range is maximum when compared to sim900.It is a small in dimension and cost effective solutions. Since SIM900A is cheaper and compact it is chosen in the hardware. The 230V supply is converted to 12V ac where the output voltage is given to the potential divider circuit which as resistors(470kΩ, 100kΩ,33Ω,10kΩ) and capacitors. The function of potential divider is to reduce 12V to 6V where it is directly fed to the arduino processor.

4.2.2 ATMEGA 328

Due to the simplicity, low power consumption and low cost ATMEGA328 microcontroller is chosen.

4.2.3 RTC (DS1307)

Energy meter use a real time clock for wireless communication with other devices and use to perform more accurate time. It provides low cost method of evaluating real time clock functionality in certain developed platforms.

4.3 BLOCK DIAGRAM OF PROPOSED SYSTEM

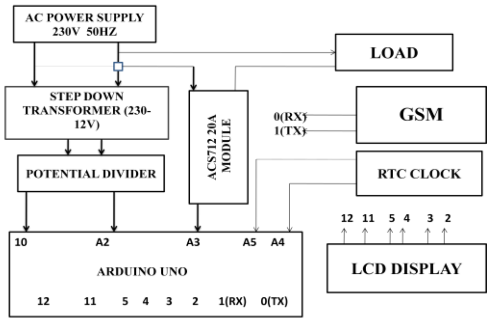


Figure 4.1 BLOCK DIAGRAM OF PROPOSED SYSTEM

Figure 4.1 shows that the block diagram of automatic energy monitoring system which consists of two units. Each unit consists of one energy meter and GSM.

4.4 HARDWARE DESCRIPTION

4.4.1 ABOUT ATmega 328

The Atmega 328 is a single chip micro-controller created by Atmel and belongs to the mega AVR series. The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter, programmable watchdog timer with internal oscillator, and five software selectable power saving modes. Figure 4.1 shows the block diagram of proposed system.. The device operates between 1.8-5.5 volts. The device achieves throughputs approaching 1 MIPS.

The AVR is a modified Harvard architecture 8-bit RISC single-chip microcontroller, which was developed by Atmel in 1996. The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to one-time programmable ROM, EPROM, or EEPROM used by other microcontrollers at the time.

4.4.1.1 PIN DIAGRAM OF ATMEGA 328

Figure 4.2 shows the Pin Diagram of ATMEGA 328 through which inputs and outputs are connected.The ATMEGA 328 microcontroller resembles as shown in Figure 4.3 which is the outlook of the controller.

4.4.1.2 KEY PARAMETERS OF ATMEGA 328

The Key Parameters including speed, frequency, I/O Pins of the
ATmega 328 controller is shown in Table 4.3.

4.4.1.4 APPLICATIONS

Today the ATmega328 is commonly used in many projects and Autonomous systems where a simple, low-powered, low-cost micro-controller is needed. Perhaps the most common implementation of this chip is on the popular Arduino development platform, namely the Arduino Uno and Arduino Nano models.

4.4.2 GSM

Global System for Mobile Communications, originally **Group Special Mobile**, is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation digital cellular networks used by mobile phones, first deployed in Finland in July 1991. As of 2014 it has become the default global standard for mobile communications - with over 90% market share, operating in over 219 countries and territories.

2G networks developed as a replacement for first generation analog cellular networks, and the GSM standard originally described a digital, circuit-switched network optimized for full duplex voice telephone. This expanded over time to include data communications, first by circuit-switched transport, then by packet data transport via GPRS and EDGE."GSM" is a trademark owned by the GSM Association. It may also refer to the most common voice codec used, Full Rate.

The development of UMTS introduces an optional Universal Subscriber Identity Module (USIM) that uses a longer authentication key to give greater security, as well as mutually authenticating the network and the user, whereas GSM only authenticates the user to the network. The security model therefore offers confidentiality and authentication, but limited authorization capabilities, and no non-repudiation. New attacks have been observed that take advantage of poor security implementations, architecture, and development for Smartphone applications. Some wiretapping and eavesdropping techniques hijack the audio input and output providing an opportunity for a third party to listen in to the conversation.GSM uses General Packet Radio Service for data transmissions like browsing the web. The most commonly deployed GPRS ciphers were publicly broken in 2011.The researchers revealed flaws in the commonly used GEA/1 and GEA/2 ciphers and published the open-source "gprs decode" software for sniffing GPRS networks. They also noted that some carriers do not encrypt the data in order to detect the use of traffic or protocols they do not like, leaving customers unprotected. GEA/3 seems to remain relatively hard to break and is said to be in use on some more modern networks. If used with USIM to prevent connections to fake base stations and downgrade attacks, users will be protected in the medium term, though migration to 128-bit GEA/4 is still recommended.

4.4.3 LIQUID CRYSTAL DISPLAY

A **liquid-crystal display** is a flat-panel display or other electronic visual display that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly. LCDs are available to display arbitrary images or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube displays in nearly all applications. They are available in a wider range of screen sizes than CRT and plasma displays, and

Figure 4.4 LIQUID CRYSTAL DISPLAY

since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence. The LCD screen is more energy-efficient and can be disposed of more safely than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment more efficiently than CRTs. It is an electronically modulated optical device made up of any number of segments controlling a layer of liquid crystals and arrayed in front of a light source or reflector to produce images in colour or monochrome. Liquid crystals were first discovered in 1888.By 2008, annual sales of televisions with LCD screens exceeded sales of CRT units worldwide, and the CRT became obsolete for most purposes.

4.5 SOFTWARE DESCRIPTION of ATmega 328

Performance

- Improved speed for build process.
- Hardware serial improvements.
- Upgrades to tools and tool chains.
- Increased USB stability and performance.
- Serial monitor improvements, including a faster serial library, backed by modern jSSC, compared to the previous RX TX Usability.
- Upgrades to the command line interface.
- Scrollable menus for multiple entry display.
- Definable sub-menus with board configuration.
- Addition of line numbers to the editor.
- Ability to find and replace over multiple tabs.
- Auto save capabilities while compiling or uploading sketches.
- Enhancements to IDE reports, including sketching of size and static RAM usage libraries.
- Improvements to the Arduino API libraries, including the String, Serial, and Print libraries.
- Improved support for transactions in the SPI library for better interoperability with multiple SPI devices.
- Debugged and improved bundled libraries, specifically the Bridge, TFT, Ethernet, Robot Control, Software Serial, and GSM libraries.

Arduino programs may be written in any programming language with a compiler that produces binary machine code. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio.

The Arduino project provides the Arduino integrated development environment, which is a cross-platform application written in Java. It originated from the IDE for the Processing programming language project and the Wiring project. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and provides simple one-click mechanism for compiling and loading programs to an Arduino board. A program written with the IDE for Arduino is called a "sketch".

The Arduino IDE supports the C and C++ programming languages using special rules of code organization. The Arduino IDE supplies a software library called "Wiring" from the Wiring project, which provides many common input and output procedures. A typical Arduino C/C++ sketch consists of two functions that are compiled and linked with a program stub main () into an executable cyclic executive program:setup (): a function that runs once at the start of a program and that can initialize settings.loop (): a function called repeatedly until the board powers off.

After compilation and linking with the GNU tool chain, also included with the IDE distribution, the Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal coding that is loaded into the Arduino board by a loader program in the board's firmware.

4.5.1 DEVELOPMENT

Arduino is open-source hardware: the Arduino hardware reference designs are distributed under a Creative Commons Attribution Share-Alike 2.5 license and are available on the Arduino Web site. Layout and production files for some versions of the Arduino hardware are also available. The source code for the IDE is available and released under the GNU General Public License, version.Although the hardware and software designs are freely available under copy left licenses, the developers have requested that the name "Arduino" be exclusive to the official product and not be used for derivative works without permission. The official policy document on the use of the Arduino name emphasizes that the project is open to incorporating work by others into the official product. Several Arduino-compatible products commercially released have avoided the "Arduino" name by using "-duino" name variants.

4.5.2 APPLICATIONS

- Xoscillo, an open-source oscilloscope.
- Scientific equipment such as the Chemduino.
- Arduinome, a MIDI controller device that mimics the Monome.
- OBDuino, a trip computer that uses the on-board diagnostics interface found in most modern cars.
- Ardupilot, drone software / hardware.
- ArduinoPhone, a do-it-yourself cell phone.
- GertDuino, an Arduino mate for the Raspberry Pi.
- Water quality testing platform.

IMPLEMENTATION AND EXECUTION

5.1 PLATFORM USED IN THE PROJECT

In this project, the platform which is used to perform the automation is Embedded system.

5.1.1 EMBEDDED SYSTEM

An **embedded system** is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and software.

One of the very first recognizably modern embedded systems was the Apollo Guidance Computer, developed by Charles Stark Draper at the MIT Instrumentation Laboratory. At the project's inception, the Apollo guidance computer was considered the riskiest item in the Apollo project as it employed the then newly developed monolithic integrated circuits to reduce the size and weight. An early mass-produced embedded system was the Automatics D-17 guidance computer for the Minuteman missile, released in 1961. When the Minuteman II went into production in 1966, the D-17 was replaced with a new computer that was the first high-volume use of integrated circuits. This program alone reduced prices on quad nand gate ICs from $1000/each to $3/each, permitting their use in commercial products.Since these early applications in the 1960s, embedded systems have come down in price and there has been a dramatic rise in processing power and functionality. An early microprocessor for example, the Intel 4004, was designed for calculators and other small systems but still required external memory and support chips. In 1978 National Engineering Manufacturers Association released a "standard" for programmable microcontrollers, including almost any computer-based controllers, such as single board computers, numerical, and event-based controllers As the cost of microprocessors and microcontrollers fell it became feasible to replace expensive knob-based analog components such as potentiometers and variable capacitors with up/down buttons or knobs read out by a microprocessor even in consumer products. By the early 1980s, memory, input and output system components had been integrated into the same chip as the processor forming a microcontroller. Microcontrollers find applications where a general-purpose computer would be too costly.

5.1.1.1 USER INTERFACE

Embedded system text user interface using MicroVGA. Embedded systems range from no user interface at all, in systems dedicated only to one task, to complex graphical user interfaces that resemble modern computer desktop operating systems. Simple embedded devices use buttons, LEDs, graphic or character LCDs with a simple menu system. Some systems provide user interface remotely with the help of a serial or network connection. This approach gives several advantages: extends the capabilities of embedded system, avoids the cost of a display, simplifies BSP and allows one to build a rich user interface on the PC. A good example of this is the combination of an embedded web serverrunning on an embedded device or a network router. The user interface is displayed in a web browser on a PC connected to the device, therefore needing no software to be installed.

5.1.1.2 PROCESSOR IN EMBEDDED SYSTEM

Embedded processors can be broken into two broad categories. Ordinary microprocessors use separate integrated circuits for memory and peripherals. Microcontrollers have on-chip peripherals, thus reducing power consumption, size and cost. In contrast to the personal computer market, many different basic CPU architectures are used, since software is custom-developed for an application and is not a commodity product installed by the end user. Both Von Neumann as well as various degrees of Harvard architectures is used. RISC as well as non-RISC processors are found. Word lengths vary from 4-bit to 64-bits and beyond, although the most typical remain 8/16-bit. Most architecture comes in a large number of different variants and shapes, many of which are also manufactured by several different companies.

Numerous microcontrollers have been developed for embedded systems use. General-purpose microprocessors are also used in embedded systems, but generally require more support circuitry than microcontrollers.

5.1.1.3 PERIPHERALS

Embedded Systems talk with the outside world via peripherals, such as:

- Serial Communication Interfaces-SCI: RS-232, RS-422, RS-485 etc.
- Synchronous Serial Communication Interface: I2C, SPI, SSC and ESSI (Enhanced Synchronous Serial Interface)
- Universal Serial Bus-USB
- Multi Media Cards-SD Cards, Compact Flash etc.
- Networks: Ethernet, Lon Works, etc.
- Field buses: CAN-Bus, LIN-Bus, PROFIBUS, etc.
- Timers: PLL, Capture/Compare and Time Processing Units
- Discrete IO: aka General Purpose Input/output -GPIO
- Analog to Digital/Digital to Analog
- Debugging: JTAG, ISP, ICSP, BDM Port, BITP, and DB9 ports.
- circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form

5.3.2 Connecting GSM Module

- There are two ways of connecting GSM module to Arduino. In any case, the communication between Arduino and GSM module is serial. So we are supposed to use serial pins of Arduino -Rx and Tx. So if you are going with this method, you may connect the Tx pin of GSM module to pin of Arduino and Rx pin of GSM module to Tx pin of Arduino.GSM Tx –> Arduino Rx and GSM Rx –> Arduino Tx. Now connect the ground pin of Arduino to ground pin of gsm module. So that’s all.Made 3 connections and the wiring is over! Now you can load different programs to communicate with gsm module and make it work. To avoid this difficulty, I am using an alternate method in which two digital pins of Arduino are used for serial communication. need to select two PWM enabled pins of Arduino for this method. So I choose pins 9 and 10 as shown in Figure 5.1.

Serial.read () – Reads all the data available on serial buffer (or incoming serial data if put otherwise). Returns the first byte of incoming serial data.

mySerial.available () – checks for any data coming from GSM module through the Software Serial pins 9 and 10.

Returns the number of bytes available to read from software serial port. Returns a -1 if no data is available to read.

mySerial.read () – Reads the incoming data through software serial port.

Serial.write () – Prints data to serial monitor of Arduino. So the function Serial.write (mySerial.read ()) – prints the data collected from software serial port to serial monitor of Arduino.

These are the functions in which we actually send commands to GSM module from Arduino. These commands to communicate with GSM module are called AT Commands. There are different commands to perform different tasks using the GSM module. The complete AT Commands Library can be read to understand all that is possible with GSM module.

SendMessage () – is the function we created in our Arduino sketch to send an SMS. To

5.4 SENSING VOLTAGE FROM AC MAINS

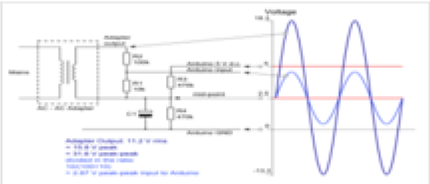
Measure AC voltage (230V 50Hz domestic supply) using Arduino analog pins.

1. Use a transformer of 230V to 12V to step down for safety and send it through a simple bridge to rectify and get the Vout.

2. Then use a voltage divider circuit (using resistors, and may be a cap for smoothing), divide and get suitable voltage for Arduino analog pin. Resistors of 10Ω,100Ω,3.3Ω& 470Ω mains voltage proportional to the input voltage given to Arduino pin.

3. Next get the voltage input of 5V to the Arduino analog pin, and make a coding in the IC to do some math with some constant value, and show theIf mains voltage is 230VAC / then transformer LV side 12C/ after rectifying 10.5VDC / after divider circuit, 5VDC is obtained and it's given to Arduino IC input pin. Finally the voltage is sensed using this method as shown in Figure 5.2.

5.4.1 VOLTAGE CIRCUIT



The resistors are connected to form potential divider is shown in Figure 5.3.

5.5 SENSING CURRENT

1.Current Sensor is used to sense the current from ac mains.

2.The output from the current sensor is given to current transformer 3.Resistors of one 3.3Ω,two 470Ω,

3.Get the current output from transformer and give it to the Arduino analog pin. The current is measured as shown in Figure 5.4.

5.6 SENSING FREQUENCY

Next step is to measure frequency from the voltage of Arduino. The frequency is measuredalongwith the voltage as shown in Figure 5.5. Using FreqCounter library, it can measure frequencies up to several MHz, and is very precise. However, measurement pin is fixed to digital pin 5. Also it may affect Arduino PWM outputs, increasing their duty cycles. In case you don't use PWM and you need to measure frequency of just one signal, FreqCounter is an excellent choice Using pulseIn() function from standard Arduino libraries. The technique I'm suggesting below is free from FreqCounter limitations, so that can use it on any pin. However, it's minimal wave period is 10 uS, with corresponding maximum measurable frequency of 50 kHz. PulseIn function returns the length of the pulse (in microseconds) or 0 if no pulse started before the timeout. To get the frequency you can use f = 1 / T equation, however, that depends on duty cycle of the signal.

5.7 POWER FACTOR MEASUREMEN

Reactive power is power where the current is out of phase with the voltage, and the Volts x amps doesn't do any real work. Current that charges a capacitor, for example or current that creates the magnetic field around a coil for another.

Figure 5.7 Final Module of Proposed Systemigure 5.7 shows the final module of the proposed system which consists of energy meter 1, 2 and GSM communication module.

RESULT AND DISCUSSION

6.1 RESULT

The Voltage from the consumer premises is monitored and the corresponding current, power, power factor and frequency are also monitored. The cost of the power consumed can be calculated and displayed in the Liquid Crystal Display in both energy meter and Monitor side.

6.2 DISCUSSION

The voltage, current, power factor and frequency for different power load is measured.

CONCLUSION AND FUTURE SCOPE

Conclusion

An Automatic Energy Monitoring System is designed by making some improvements in the Existing system of Energy Monitoring System. The cost of the energy consumed can be displayed in the meter and sent to the consumer (industrial person) for their convenience. The Power flow in various sections can be monitored and controlled using Arduino controller.

Future Scope

The energy meter is further developed by inserting the Account Number in the microcontroller and the electric bill payment is done by online.

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APPENDIX

PROGRAM

```
#include <LiquidCrystal.h>
#include "EmonLib.h"
EnergyMonitor emon1;
#include <Arduino.h>
#include <Wire.h>       /
#include "RTClib.h"
#if defined(ARDUINO_ARCH_SAMD)
#define Serial SerialUSB
#endif
#include <SoftwareSerial.h>
SoftwareSerialmySerial(0, 1);
RTC_Millisrtc;
int input=10;
inthigh_time;
intlow_time;
floattime_period;
float frequency;
float cost;
floatsupplyvoltage =0;
floatIrms=0;
constintcurrentPin = 0;
const unsigned long sampleTime = 1000UL;
const unsigned long numSamples = 2500ULconst unsigned long sampleInterval = sampleTime/numSamplesintadc_zero;
LiquidCrystallcd(12, 11, 5, 4, 3, 2);
void setup()
{
Serial.begin(9600);
lcd.begin(20, 4);
emon1.voltage(2, 169.04, 9.0);
emon1.current(1,0.3);
rtc.begin(DateTime(F(__DATE__), F(__TIME__))t
pinMode(input,INPUT);
adc_zero = determineVQ(currentPin); //Quiscent output voltage - the average voltage ACS712 shows with no load (0 A
```

```
}
void loop()
{
emon1.calcVI(20,2000);
emon1.serialprint();
floatrealPower = emon1.realPower; //extract Real Power into variable
floatapparentPower = emon1.apparentPower; //extract Apparent Power into variable
floatpowerFActor = emon1.powerFactor; //extract Power Factor into Variable
floatsupplyVoltage = emon1.Vrms; //extract Vrms into Variable
floatIrms = emon1.Irms;
lcd.print("Energy MonitorI
delay(1000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("V="); */
lcd.print(supplyVoltage);
lcd.print("v");
lcd.setCursor(0,1);
lcd.print("I=");
lcd.print(readCurrent(currentPin),3);
lcd.print(" A");
lcd.setCursor(0,2);
lcd.print("PF=");
lcd.print(powerFActor);
lcd.setCursor(0,3);
lcd.print("power=");
//lcd.setCursor(14,0);
lcd.print(abs(realPower*24)/(3600));
lcd.print("kwh");
high_time=pulseIn(input,HIGH);
low_time=pulseIn(input,LOW);
time_period=high_time+low_time;
time_period=(1 / time_period);
frequency= time_period*970000;
float amount;
intfixedcharge=10;
int charge = 50;
{
if((abs(realPower*24)/(3600))<50)
{amount = fixedcharge;
}
if((abs(realPower*24)/(3600))>200)
{
amount= (abs(realPower*24)/(3600))*3.50+ fixedcharge;
}
if((abs(realPower*24)/(3600))<200>=500)
{
amount = ((abs(realPower*24)/(3600))*4.60)+fixedcharge;
}
if((abs(realPower*24)/(3600))<500)
{
amount = (abs(realPower*24)/(3600))*6.60+ charge
;
}
lcd.setCursor(10,0);
lcd.print("cost=");
lcd.print(amount);
lcd.setCursor(28,0);
lcd.print("Fre=");
lcd.print(frequency);
lcd.print(" Hz");
delay(10000);

DateTime now = rtc.now();
lcd.clear();
lcd.setCursor(1,0);
lcd.print(now.year(),DEC );
lcd.print('/');
lcd.print(now.month(), DEC);
lcd.print('/');
lcd.print(now.day(), DEC);
lcd.print(' ');
lcd.setCursor(0,1);
lcd.print(now.hour(), DEC);
lcd.print(':');
lcd.print(now.minute(), DEC);
lcd.print(':');
lcd.print(now.second(), DEC);
lcd.println();
delay(10);
{Serial.begin(9600); //Baud rate of the GSM/GPRS Module
Serial.println("\r");
delay(1000);
Serial.println("AT+CMGF=1\r");
delay(1000);
```

```
Serial.println("AT+CMGS=\"+918220292160\"\r");
//Number to which you want to send the sms
delay(1000);
 // Serial.print("Haisir,how are u sir\r");    //The text
of the message to be sent
 //delay(1000);
Serial.println("Energy MonitorI\r");
Serial.println("v=\r");
Serial.println(supplyVoltage);
Serial.println("v\r");
delay(1000);
Serial.println("I=\r");
Serial.println(Irms);
Serial.println("A\r");
delay(1000);
Serial.println("Powerfactor=\r");
Serial.println(powerFActor);
delay(100);
Serial.println("power\r");
Serial.print(abs(realPower*24)/(3600));
delay(1000);
Serial.print("Frequency Meter\r");
Serial.println(frequency);
Serial.println(" Hz\r");
delay(1000);
Serial.println("cost\r");
Serial.println(amount);
delay(1000);
Serial.write(0x1A);
Serial.write(0x0A);
Serial.write(0x0D);
delay(10);
 }
}intdetermineVQ(int PIN)
{
 // Serial.print("estimating avg. quiscent voltage:");
long VQ = 0;
 //read 5000 samples to stabilise value
for (inti=0; i<5000; i++) {
   VQ += analogRead(PIN);
delay(1);//depends on sampling (on filter capacitor),
can be 1/80000 (80kHz) max.
 }
 VQ /= 5000;
Serial.print(map(VQ,     0,     1023,     0,
50000));Serial.println(" mV");
returnint(VQ);
}
floatreadCurrent(int PIN)
{
unsigned long currentAcc = 0;
unsignedint count = 0;
unsigned   long   prevMicros   =   micros()   -
sampleInterval ;
while (count <numSamples)
 {
if (micros() - prevMicros>= sampleInterval)
  {
intadc_raw = analogRead(currentPin) - adc_zero;
currentAcc += (unsigned long)(adc_raw * adc_raw);
   ++count;
prevMicros += sampleInterval;
  }
 }
floatrms                                        =
(sqrt((float)currentAcc/(float)numSamples)      *
(5080.7576 / 1024.0))/100;
returnrms;
 //Serial.println(rms);
}
```