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Design and Development of Embedded Energy Meter

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***Abstract*—Now adaysEvery house, Organizations, factories, industries, business establishments, shops, offices etc. need at least one energy meter to calculate Energy consumption. The Discom(Distribution Companies)gives the bill according to the user utilization. And the energy meter shown number of units consumed by the user in digital form in Energy meter. The user can pay the electricity bill as per the predefined tariff. Consumer needs to pay the amount against the bill raised by the supplier .In this paper we are proposing method for billing according power consumption in Time of Day .In this paper we are giving a approach to reduce the power losses, power theft and Tampering problems .In this project we design a new method designing two energy meter one is placed at Street Transformer and another is placed at consumer house.Comare the two energy meters reading we can easily analyze power losses between Street transformer to consumers house. The energy meter at consumer house not gives present month bill it also stores the number units by the user for past six months. According to this we can do load survey .According to load survey we can analyze how to minimize the power consumption and how to bill the energy consumption.**,

Keywords—Load Serveyt; Time of Day; Tampering; Power losses; power theft

I. INTRODUCTION

Traditional electricity meters, whether electromechanical or digital, provide a measurement of the number of kilowatt hours that have been consumed by a customer. To encourage more efficient use of electricity, utility companies would also like to measure, amongst other things, the variations in supply voltage and electricity consumption through the day. From theknowledge of the variation of electricity consumption with the time of day, it becomes possible for the utility companies to analyze customers' behavior, as well as to predict the load demand at a particular time of the day. It may also be emphasized that from the perspectives of both the customers and the utility companies, it is necessary that certain basic quality requirements are met by the electrical energy supplied to the consumer premises. From the customers' perspective, if electrical equipment is to operate correctly, the electrical energy must be supplied at a voltage that is within a specified range around the rated value of the equipment's in operation. Most of the equipment's in use today require good power quality. If quality of power requires ,need a sophisticated Load survey on energy consumption like per day ,per week and per month. The energy consumption user is not same throughout the week .Example the user uses the power 55 kilowatts on Friday but it will increase on Sunday according to like that first we do load survey and TOD.(time of Day).In this paper we are Designing two energy meters one at Street transformer and another is place at consumer house. The first energy meter at transformer note the readings only how much power is coming to that street .The energy meter at consumer house measures the energy consumed by the consumer. Every month check the reading of both meters .The energy coming from the street transformer must be equal to sum of readings shown by the consumers energy in that particular street. If the readings are matched no issue otherwise we can tell power theft and power losses and tampering are happened .In this paper two energy meter s are made with 8051 microcontroller series capable of storing last six months data and how many units consumed by the user. An External memory is added to the 8051 for store the past readings. According that past units the user minimize their power utilization.

II. DESIGN APPROCH

In this paper we propose two Embeddedenergy meters, one is placed at consumers house and second one is placed at street transformer. Consumer end energy meter measures the consumption of electrical energy by the consumer and it records consummated electrical energy of six successive months. The main energy meter which is placed at street transformer records total transferred electrical energy in period of one month. The consumer end energy meter first sense the current and voltages by using sensing devices, the output is given to circuit through ADC.The function of ADC converts analog currents and voltages in to digital form. This energy meter records this digital information for every second and stores for every 15 minutes information in flash memory. Here the Day is divided in four slots and each slot is four hours. Andeach hour having 4 small slots .Each small slot is 15 minutes. Now the consumer end energy records the energy for every 15 minutes and cumulate for every one hours and stores this for every one hour in flash memory. After completion one slot (4

hours)this information is stored separately in flash memory. That means the consumer end energy meter records the units information for every 15 minutes and every one hour and for every 4 hours .For every big slot(4 hours) the energy meter stores the information separately in flash memory. This is repeats for every month. Now the energy meter stores the information for every 15 min,every hour ,every big slot(4 hours) and the day in flash memory. The Consumer end energy meter having the Rs-232 port for Extracting what ever the information is there in energy meter flash memory.

Whenever the billing person comes to the consumer's house he must carry the Laptop that having the IDE software. The billing operator put the RS-232 cable to energy meter and second end to laptop now the IDE asks consumer number .when the consumer number enters in the laptop what information is theirin flash memory that transfer in to the lap top and this information is saved with consumer number in laptop .Now laptop connect to the printer for hard copy of bill. The hard copy of bill shows number of units consumed by the consumer for every 15 minutes ,every hour ,every 4 hours and every day .And finally 30 days billing information is available on bill.

The salient features of the developed smart meter can be summarized as below:

- Records the energy consumption of the connected load with accuracy better than 0.9%.
- Records the Energy consumption profile of the supply system to which the meter is connected.
- Records the Day wise and month wise energy profile.
- Records the average power consumption of the connected load over pre-defined intervalsof time. Detects and records the occurrence of certain power quality events.
- The time interval over which the data are logged is flexible and can be easily modified. Ifa more detailed and accurate data is required, the time span may be reduced without affecting the other features of the meter.

The bill format is as follows :

01/07/2014

Small slot

00.00 am-00.15am……..----10 units

00.16am -00.30am……..----9units

00.31am-00.45am…….. 10units

00.46am-1.00am---------- -32units

.

.

11.45pm-12.00pm----------35units

First big slot(00.00-06.00am)--------500 units

Second big slot(06.00-12.00am)— 900 units

Third Big slot(12.00am—6.pm)---- 955 units

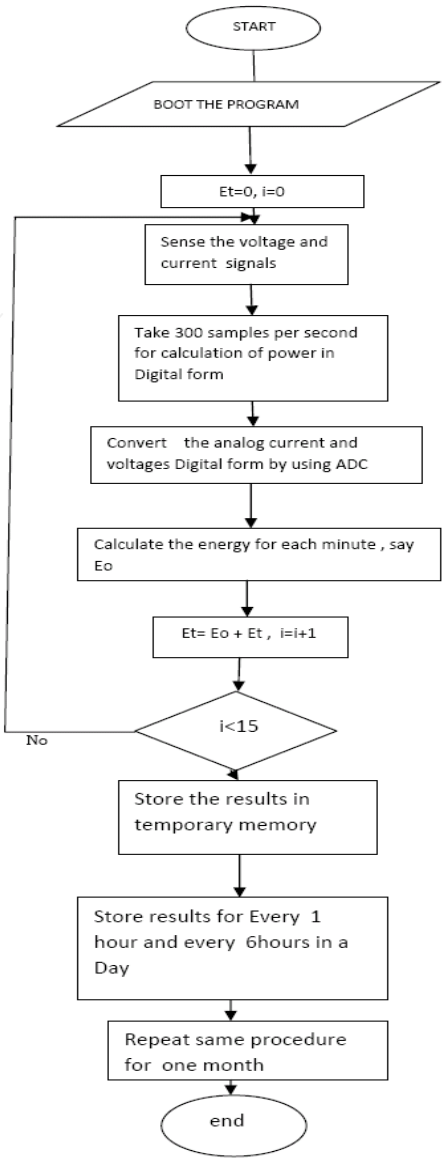
Fourth Big slot(6.00pm---12pm)----600 units

Total Units in 01/07/2014= 2995 units

Gives the number units consumed by the user for every 15 minutes, every 1 hour and every 4 hours in day. We will get same kind of billing procedure for remaining 29 days.

The past 6 months data is stored in flash memory that is perfectly interfaced with microcontroller. This past data is used for control the consumption of electricity and reference for future how the power is utilizing in months, days, and hours.According to this data only the distribution companies send the power or power cut in respective areas.

A. Flow chart:



B. Energy calculation

It is required to make frequent measurements to get an accurate value of energy consumption of an AC system. The sampling rate Fs should be many times that of the supply frequency. If N is total samples in N/Fs seconds, Energy in terms of watt seconds can be obtained by multiplying N/Fs with the average power.

$$Energy = \frac{\sum_{n=0}^{N-1}(V[n]*I[n])}{F_s}$$

Voltage and current calculation

An RMS value is defined as the square root of the mean value of the squares of the instantaneous values of aperiodically varying quantity, averaged over one complete cycle. The discrete time equation for calculating Vrms is

$$V_{rms} = \sqrt{\frac{\sum_{n=0}^{N-1}(V[n]*V[n])}{N}}$$

Apparent Power and Power Factor calculation:

Apparent Power can be calculated by multiplying the instantaneous voltage and instantaneous current as per Equation

$$ApparentPower = V_{rms} * I_{rms}$$

Power factor:

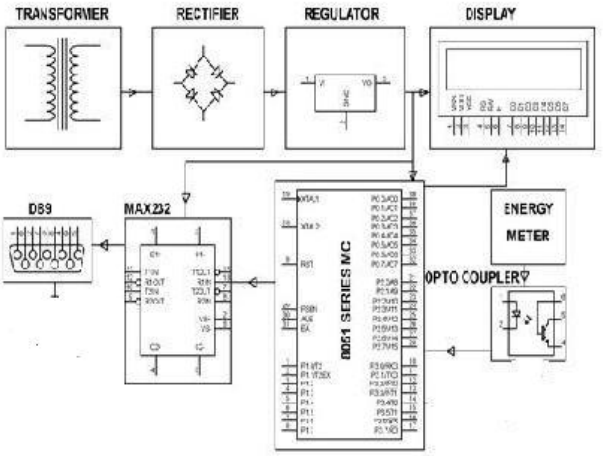
$$PowerFactor = \frac{AveragePower}{ApparentPower}$$

III. HARWARE IMPLETATION

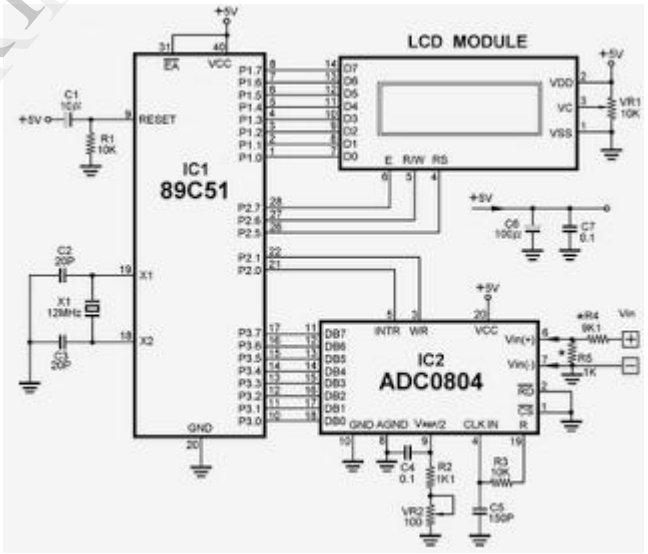
Energy meter mainly consist of the following hardware sections

- Power Supply unit
- 89c51 Micro controller
- ADC Convertor(IC ADC0804)
- LCD Module
- External Memory (Flash memory)

The Power supply unit provides 5v voltage with constant output. And the purpose of Micro controller is used to control all activities of energy meter. Here the micro controller is 89c51 8 bit, 40 pin micro controller ADC Module is used to convert the analog voltages in to digital voltages for manipulation and storage purpose. The LCD module is used to Display the consumption power everytime. External memory is used to store the last 6 months data.First we have to write the code according to our application.



The application program me is store the consumpted energy for every 15minutes and 1 hour andf for every 6 hours in day. Repeat this for month. In this program the controller stores the consumption energy for last 6 sixs in day wise and big slots wise(4 Hours).For this purpose this project need external memory that should be interfaced with 89c51 micro controller.



An energy meter measures the amount of electrical energy supplied to a residential or commercial building. The most common unit of measurement made by a meter is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt in one hour. shows a system block diagram for a single-phase energy meter. As shown the energy meter hardware includes a power supply, an analog front end, a microcontroller section, and an interface section. The analog front end is the part that interfaces to the high voltage lines. It converts high voltages and high currents to voltages sufficiently small to be measured directly by the ADC (Analog/Digital Converter) of the microcontroller. The amount of

amplification required depends on the ADC resolution as well as the Class accuracy required for a single-phase meter.

The heart of the meter is the MCU, which calculates active, reactive and apparent energy based on voltage and current measurement. The ADC samples the analog input voltage, current signals and converts into digital form. The digital samples are given to MCU for calculating energy. The MCU accumulates the products of voltage and current samples over a time. The active power is calculated by dividing this accumulated value by the number of samples. Multiplying the active power by time gives the active energy consumed.

The Microcontroller will update the LCD driver to display the calculated the energy in LCD display for the billing purpose. This readings can send to the places through electrically connected medium like RS232/RS485.

The Microcontroller will also generate the pulse output proportional to the measured active energy with the rate of imp/kWh. This pulse output can be used to measure the accuracy of the measured energy by comparing with the reference meter at short interval of time .The typical energy meter also requires a Real Time Clock (RTC) for tariff information. The RTC for metering application should be very accurate. This involves dividing the day, month and year into tariff slots (Time of Day). Higher rates are applied at peak load periods and lower tariff rates at off-peak load periods. The energy meter needs to be calibrated before it can be used and that is done in a digital domain for an electronic energy meter. Digital calibration is fast, efficient and can be automated, removing the time-consuming manual trimming required in traditional, electromechanical meters. Calibration coefficients are safely stored in an EEPROM.

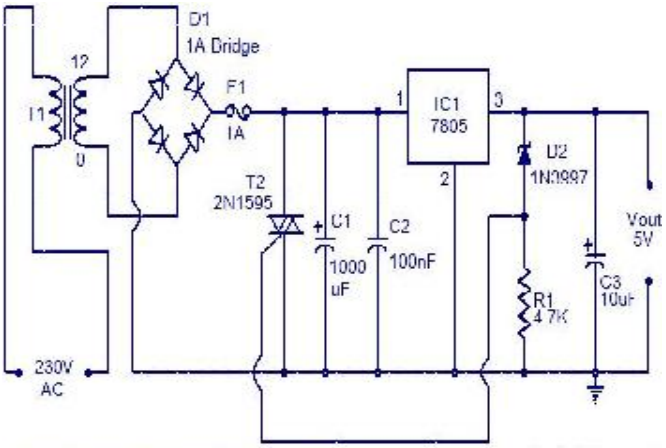
C.power supply unit

Generally the Microcontroller kit is functioning with the help of +5v .The 5volts is generated separately and finally applied to controller.

This power supply unit consist of 4 sections.

- Transformer
- Bridge Rectifier
- Filter Network
- Regulator

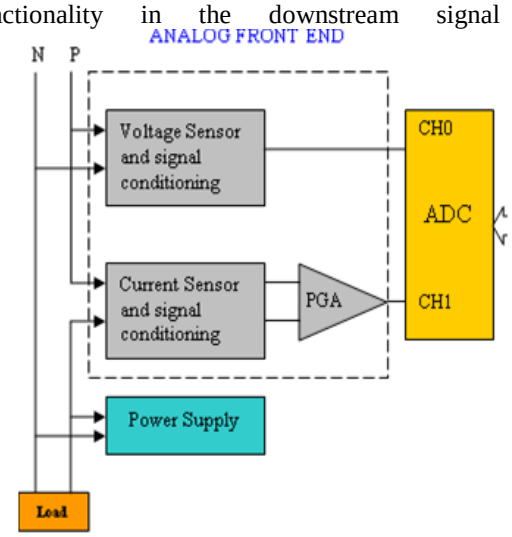
The transformer step-downs the incoming 230v in to low voltages with same frequency. Here the stepdown voltage is 12v .The step-down voltage is applied to Bridge Rectifier that converts a.c signals into pulsated signals. Now this voltage is applied to filters fto remove unwanted A.c from that. But the final out put voltage is not constant it varies with respect to input voltage. We need to maintain output voltage constant irrespective changes in input voltage. The voltage regulator ic 7805 maintains the output voltage constant .That supplied to microcontroller circuit for its functionality of working



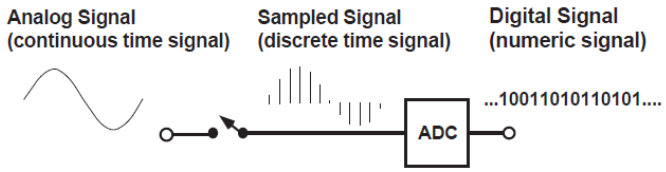
5v power supply with over voltage protection

D .ADC Conversion

There are various methods for sensing current and voltage, each with their own tradeoffs. The voltage is scaled down to the range of the ADC by resistor dividers. The current is measured by current transducer. The current transducer Shunt or CT both have their own advantages and disadvantages. The voltage drop across the shunt in proportional to the current being drawn by the load. This voltage drop is taken as a current input signal. As the shunt is in series with the load, it should be in μΩ. The shunt resistor gives the voltage drop in milli-Volts. In a noisy environment it requires precision filtering and amplification circuitry prior to delivery to the ADC to measure accurately. Current can also be measured by Current Transformers (CT). CT can also provide galvanic isolation from the primary. Current transformers are based on magnetic cores that can saturate and exhibit a nonlinear phase response. This can cause power or energy measurement errors at low currents and large power factors. This requires corresponding phase-correction functionality in the downstream signal chain



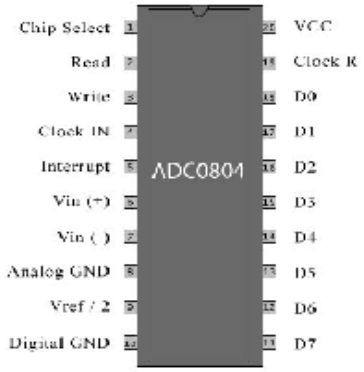
Thelectronic energy meter relies on an analog-to-digital conversion. This is done by Analog to Digital Converter (ADC). The ADC takes samples or “snap shots” of the analog signals at discrete instances of time. These “snap shots” or discrete time signals are in turn converted to numeric values by the ADC as shown in



The ADC requirements for energy metering are:

- The relatively wide dynamic range and the accuracy requirements of the application, the resolution of the ADC
- needs to be high resolution
- A Sampling rate of at least 2 to 4kSPS (kilo Samples Per Second) is required. A basic rule of sampling theory
- states that the rate (frequency) of sampling must be at least twice the highest frequency content of the signal.
- This is called the Nyquist rate. Energy metering specifications call for accurate measurement of frequency
- content up to the 20th harmonic which is 1kHz or 1.2kHz depending on the line frequency
- Low cost. The solution must be low cost because the energy metering application is particularly cost sensitive
- The ADC must not Consume more Power.

In this project we are using ADC0804 ic for analog to digital conversion. This ic has 20 pins and easy to fix and interface with 89c51 microcontroller



The functional description ADC0804 convertor is given below.

- 1Activates ADC; Active lowChip select
- 2 Input pin; High to low pulse brings the data from internal registers to the output pins after conversion: Read
- 3Input pin; Low to high pulse is given to start the conversion: write
- 4 Clock Input pin; to give external clock.: Clock IN
- 5 Output pin; Goes low when conversion is complete: Interrupt
- 6Analog non-inverting input:: Vin(+)
- 7 Analog inverting Input; normally ground: Vin(-)
- 8Ground(0V): Analog Ground
- 9Input pin; sets the reference voltage for analog input: Vref/2
- 10Ground(0V):Digital Ground
- 11 D7
- 12 D6
- 13 D5
- 14 8 bit digital output pins D4
- 15 D3
- 16 D2
- 17 D1
- 18 D0
- 19Used with Clock IN pin when Clock R
  - internal clock source is used
- 20 Supply voltage; 5V VCC

E .89C51 Micro controller

In this project we are using 8 bit microcontroller for computations.Here we used 89c51 controller.This reads the current and voltage informations in digital form and stores in its flash memory for future and billing purpose.The microcontroller is interfaced with flash memory and lcd.The LCD display is used to display the number of units consumed by the consumer on display.89c51 is 40 pin controller

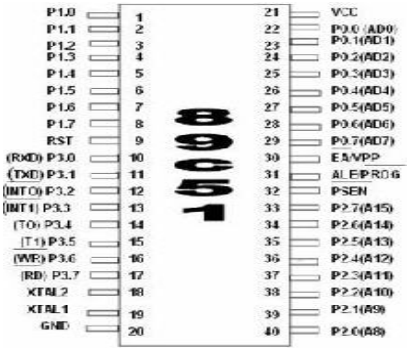
Features of 89c51 micro controller:

- Compatible with MCS-51™ Products
- 4K Bytes of In-System Reprogrammable Flash Memory
  - Endurance: 1,000 Write/Erase Cycles
- Fully Static Operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 128 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Two 16-bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial Channel
- Low-power Idle and Power-down Modes

Description of 89c51 microcontroller:

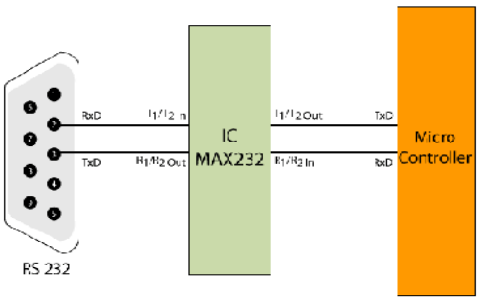
The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4Kbytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a

powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.



F.Rs 232 interface:

The application program develop on host pc and compile it and it generate executable file .Now transfer the executable file into our energy meter flash memory with help of serial communication interface. Now energy meter counts the energy according to our application program. Here the serial communication interface is RS 232 .In this Max 232 acts as Voltage converter.

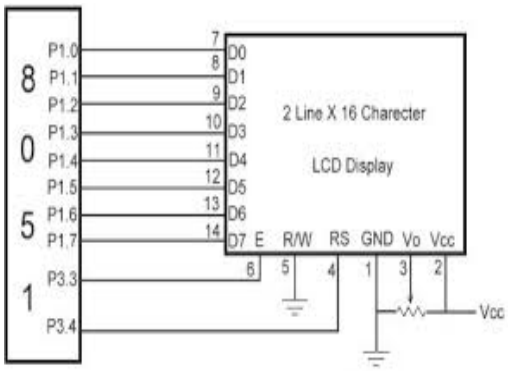


G .Lcd interface

Liquid Crystal Display (LCD) is very commonly used electronic display module and having a wide range of applications such as calculators, laptops, mobile phones etc. 16×2 character lcd display is very basic module which is commonly used in electronics devices and projects. It can display 2 lines of 16 characters. Each character is displayed using 5×7 or 5×10 pixel matrix.

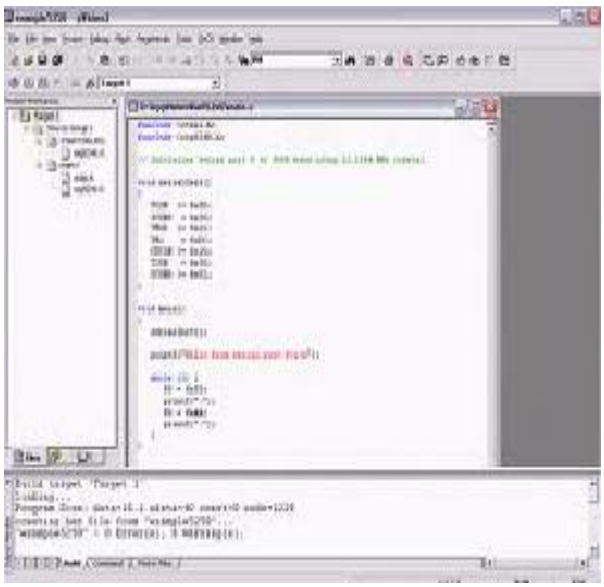
Interfacing 16×2 LCD with 8051 using Keil C is bit complex because there is no powerful libraries in Keil C. To solve this problem we have developed a LCD library which includes commonly used features, you just need to include our header file and use it. You can download the header file at the bottom of this article.

LCD can be interfaced with microcontroller in 4 Bit or 8 Bit mode. These differs in how data is send to LCD. In 8 bit mode to write a character, 8 bit ASCII data is send through the data lines D0 – D7 and data strobe is given through E of the LCD. LCD commands which are also 8 bit are written to LCD in similar way.



H.Software Development Environment:

First Develop the energy meter application in embedded C for 8051 sreies on Pc.Here the PC must and Contain the KEIL IDE(integrated Development Environment).This IDE already having C cross compliler.Thiscompliler generates executable code for enrgy meter not for host.Now this executable is transfer to flash memory which is placed in energy meter with help of RS 232.



IV.Designing of Energy meter at Street Transformer

In this project we Design and develop the energy meter for place at street transformer. This energy meter monitors and records the energy coming to transformer. And it also records the power failure timings. It simply records the time slot between power failuretimings. Thediscom operators comes to line and place the RS 232 to energy meter which is placed at street transformer .This

information and is placed in PC for future reference. The main purpose of placing the energy meter at street is it records the when power is not available to the street Transformer. If the discom operator compare the power failure times with consumer end energy meter the power theft easily found out.

IV. BILLING

I.TOD time of Day:

As per this Method a Full Day is Divided in to

Six slots each one consist of 4-hours From 00.00am to 00.00pm i.e

First slot= 00.00am to 04.00am

Second slot =04.00am to 08.00am

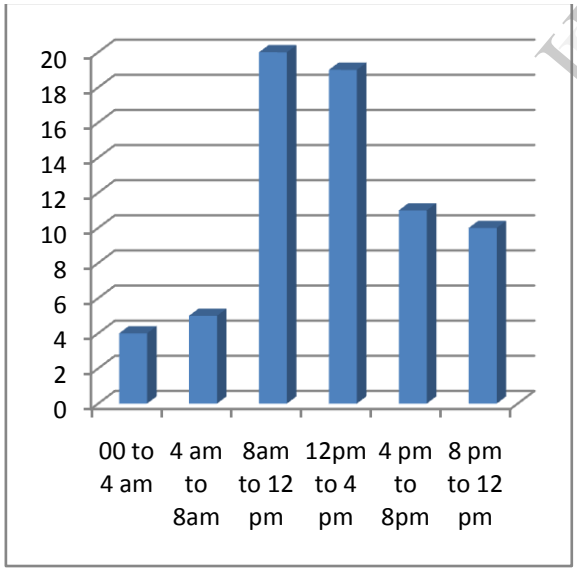
Third slot = 08.00am to 12.00pm

Fourth slot = 12.00pm to 04.00pm

Fifth slot = 04.00pm to 08.00pm

Sixth slot = 08.00pm to 12.00am

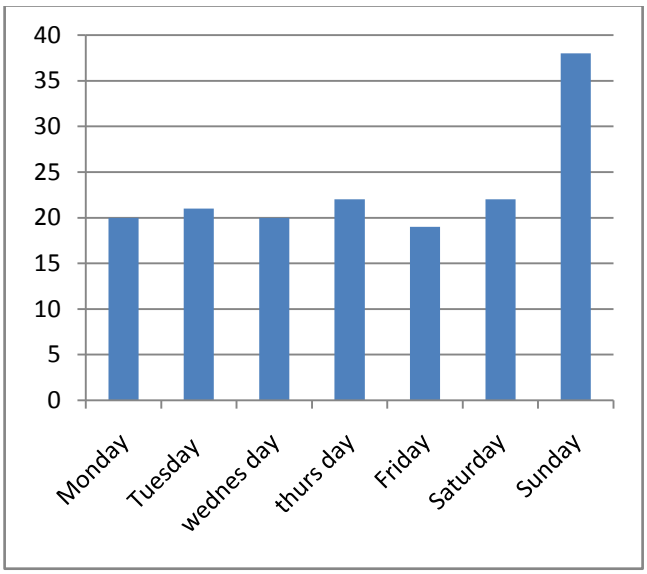
Now the energy meter records energy consumption of each slot and stores it in flash memory and this record is useful to Change the TARIFS and Timings of Power cuts to the distribution companies because the consumption of Electrical energy is not same for all day.



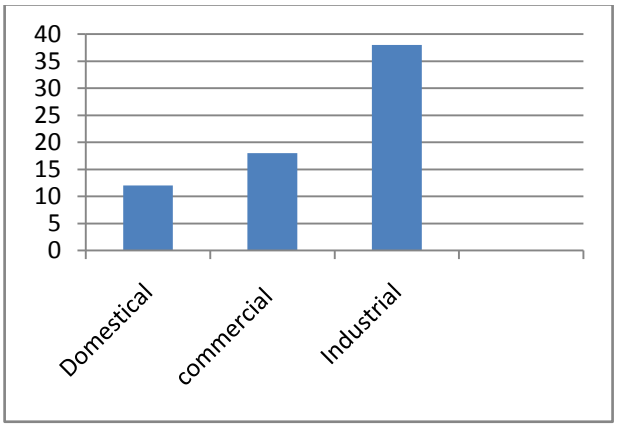
From this data we can easily analyze at what time the energy consumption more and at what time it is less. So Discom companies changes tariffs very easily through this data. And from consumer also aware of power consumption timings .According to this bar chart they can easily understand.

J.Load Survey

The power consumption of each day is not same in aweek. That power consumption varies according working days and holidays.The energy consumption is almost same in a week except Sunday and holiday.The power consumption is more on Sundays for domestic appliances.



The Power consumption in a area Depends on type of loads, Majority loads are Industrial, commercial and domestic type. During working days the power consumption of Domestic loads is less where as onSundays and Holydays it is high. Generally the power consumption is more for industries comparedto commercial and domestic loads. According to this Load survey the Distribution companies are change the energy tariff and power cuts in the day.



VI.CONCLUSIONS

From the concept of Embedded energy meter it gives clear idea about billing and consumption of energy. It also gives information of power tampering and losses in lines

k.Tampering

The Energy meter placed at street transformer is designed with microcontroller,that gives enrgy comes to the street .It also monitors whether the power on or off.When power cut by the Discom at that time no readings are recorded by the Street energy meter and Consumer end Energy meter. Whenstreet energy meter is on and records the consumption at the same time consumer end energy meter not recording any units means the consumer of that particular energy meter holder tampers the power.

L.Losses in lines

The recorded energy at Main energy meter is equal to the Algebraic sum of individual energies consummated at consumer end premises. Hence by this information we can easily analyze the Total consummated energy and losses occurred during in that period. By this information the Discom companies can take the proper and required steps to prevent the power losses

ACKNOWLEDGMENT

The Summarizing the quite broad and active field of Embedded Energy Meter Development for solutions to billing problems research has been a tough challenge. While I remain the only responsible of imprecision's or omissions, there are many people whom I indebted. First with the aim of being as comprehensive and unbiased as possible. Out of the many I invited, I warmly thank for contributing AdiNarayanamallea sr. Project manager in Whirpoolindia. Anoop Kumar Assistanr Engineer in APCPDCL Andhra Pradesh India

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