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Automatic Meter Reading and Load Management Using Power Line Carrier Communication

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ABSTRACT: Energy crisis is the main problem faced by present day society. A suitable system to control the energy usage is one of the solutions for this crisis. Load shedding, power cut etc. helps to rearrange the available power but they can't be used to prevent the unwanted usage of energy, peak time load control etc. Also a system is needed to monitor the power consumption of an overall area to select the areas to suitably control the energy usage. One of the easiest solutions for this is by using power line communication. PLC is the communication technology that enables sending data over existing power cables. This means that with just power cables running to an electrical device, one can power it up and at the same time control/retrieve data from the device in full duplex manner. The major advantage of PLC is that it does not need extra cables. It uses existing wires. Thus by using power line communication we can monitor and control the usage of devices by providing a control the usage of devices by providing a control circuit at consumer end. In this project we are trying to control, monitor (metering), messaging through power line communication with consumer and to control the load from a centralized control room. Thus flexible load control can be achieved.

KEYWORDS: Automatic Meter Reading, Power Line communication, Electronic meter, Modem

I. Introduction

This project is mainly implemented for the purpose of getting a fully automatic electricity billing system. The aim of this project is to measure and monitor the electricity consumed by consumers in a locality and transmitting the measured reading between the consumer and utility. It also helps in reducing the malpractices and damages of the meter. Using this system the Electricity Board can access all data regarding the consumed power at each home. The system can monitor the power usage and can warn the users when the power usage is getting close to the prescribed energy usage level. It also possesses the capability to automatically turn off the low priority devices when the load limit exceeds threshold level during the peak hour

The concept of Power Line Communication is used for the transfer of data between consumer and utility. Power Line Communication uses the high power line for the communication. The data is transmitted at a higher frequency that of the transmission frequency. The main advantage of this method is that no additional transmission line is required for the transmission of data.

The traditional billing systems are discrete, inaccurate, costly, slow, and lack flexibility as well as reliability. Therefore, several attempts were made to automate the billing systems. Even though accurate and fast readings are obtained, bill payment is still performed based on the old billing procedure. They require an individual/agent to physically come and take down the readings and report to house hold/office the amount one has to pay.

It also acts as a suitable system to control the energy usage. Load shedding, power cut etc. helps to rearrange the available power but they can't be used to prevent the unwanted usage of energy, peak time load control etc. Also a system is needed to monitor the power consumption of an overall area to select the areas to suitably control the energy usage.

II. RELATED WORK

From extremely thorough review of related work and published literature, it is observed that many researchers have done rigorous work on power line communication as a cheap method for communication. It is observed from the careful study of reported work that in the real world PLCC and smart metering can improve the efficiency of power system and can help to analyse the power system.

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The paper by Poonam Barle, Ankitha Saswadhar, Deepali Hiwarkar, Rupali S Kali gave us the basic idea for automatic meter reading, its present methods available, future phase etc. Each method had its own disadvantages and we decided to build something that minimizes these disadvantages. The paper paper by Clien Y Bai, H Chen and C Hung initiated us to club the energy metering and controlling part. It also pointed us the advantages of PLC over traditionally available method.

III. WORKING PRINCIPLE

The whole project can be divided into 4 systems

1) Load Management System

One of the main aims of the project is the effective management of the loads at the consumer side. A microcontroller is provided at each consumer side which controls the load. In this system the peak time is decided by total load connected to the utility and is not fixed. Hence a predetermined peak value is initially set in the microcontroller and if the power consumption exceeds the predetermined value, the microcontroller initially warns the consumer through the LCD module. If no action is performed by the consumer, the controller cuts of the supply to certain devices in a prioritized manner. A priority list of devices can be preset in the microcontroller based on which the cutoff is done.

2) Meter Reading System

This system is kept in synchronizing with the utility. Each and every consumer is provided with a unique address which is stored in the microcontroller as well as the utility data bank. When the meter reading of a particular consumer is to be done, the utility sends the required address through the power line. The required consumer microcontroller is uniquely identified and the microcontroller is instructed to read the meter. The meter reading is taken with the help of the blinking pulses and the reading is returned to the utility. At the utility, the required calculations are done and the bill details are retransmitted and the microcontroller displays this in the LCD module. The information is also saved in the data bank for future use.

3) Graphical user interface

It is the interface that is provided for the load management/billing at the utility side. It helps the utility to properly manage the meter details of each consumer. It is created using a special toolbox called 'GUIDE' in MATLAB software.

4) PLC unit

It is the 'modem' system of the setup. It modulates and demodulates the data that is to be sent through the power line. FSK modulation technique is followed by the unit. It is placed at the consumer as well as utility side for transmission and reception and vice versa. Serial communication method is used for the power line transfer.

IV. METHODOLOGY

A. *Hardware Description*

In this section we will emphasize on detailed overview of each of the block shown in above block diagram. The project setup is divided into 2 sections, namely the Consumer section and the Data Monitoring section.

The consumer section of the automatic electricity billing system has

1) An energy measuring unit consisting of a digital energy meter and a light dependent resister.
2) A switching unit that is working with the help of relays.
3) A control unit used to control the processes taking place. An ATmega 16 microcontroller is used.
4) An LCD module.
5) PLC modem is employed as the wireless communication module.

The Data Monitoring section is present at the utility side. The section consists of

1) A Central Control Unit (CCU) which is mainly a computer. It completely controls the utility using a Graphical User Interface.
2) A Data bank refers to the memory where all the information about the different consumers is stored.

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3) A PLC modem

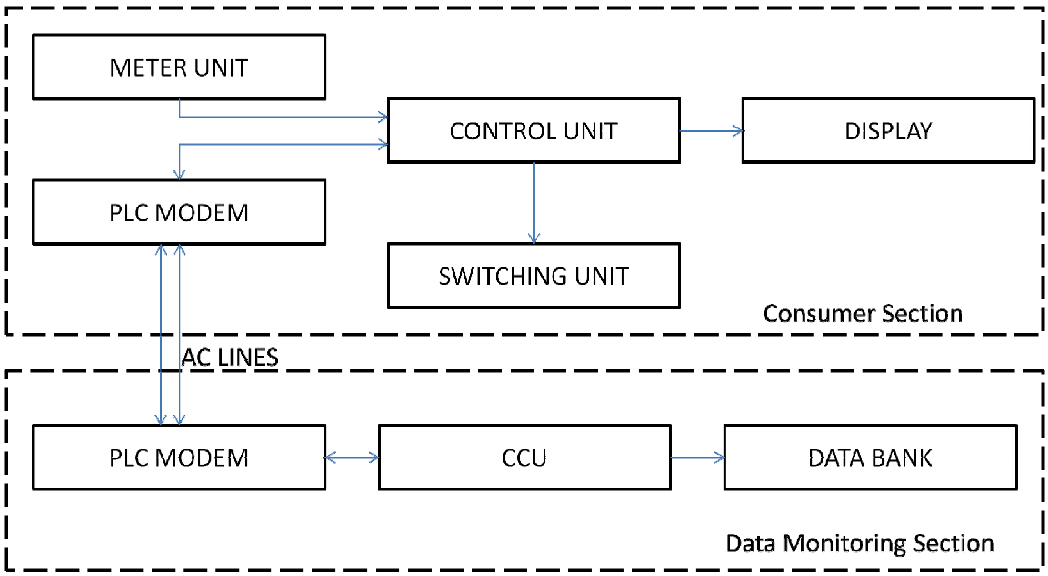

Fig. 1. Block Diagram

The main hardware components used are

i. Energy measuring unit

The energy measuring unit consists of a standard calibrated energy meter and a light dependent resistor (LDR). The IR LDR is placed in the top of the energy meter to sense the blinking of the LED in the energy meter. Digital energy meter works on the basis of the flash made by the LED. This flash is detected using an LDR. It sense the blinking of energy meter led and compare with the reference voltage with help of a comparator. If the output of comparator is high then the number of units counting will be incremented in the microcontroller. The output of comparator is given directly to a pulse counter in atmega16a. It counts the number of pulses. It is proportional to energy consumed.

ii. Energy meter

An electricity meter or energy meter is a device that measures the amount of electric energy consumed by a residence, business, or an electrically powered device. Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. Periodic readings of electricity meters establish billing cycles and energy used during a cycle. Electronic meters display the energy used on an LCD or LED display, and some can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours. For the energy meter used in the project, 3200 led blinking corresponds to 1 unit of energy consumption.

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Fig. 2. Energy Meter

iii. Microcontroller

The microcontroller which we have used is ATmega 16a. Flash, EEPROM, and SRAM are all integrated onto a single chip, removing the need for external memory in most applications. Some devices have a parallel external bus option to allow adding additional data memory or memory-mapped devices. Almost all devices (except the smallest Tiny AVR chips) have serial interfaces, which can be used to connect larger serial EEPROMs or flash chips.

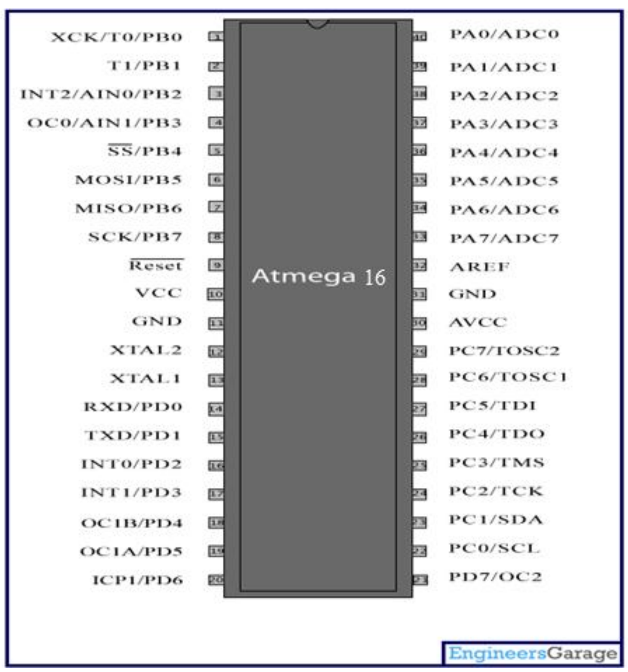

Fig. 3. Pin Diagram of Atmega 16a

iv. PLC Modem

Power line modem is useful to send and receive serial data over existing AC mains power lines of the building. It has high immunity to electrical noise persistence in the power line and built in error checking so it never gives out corrupt data. The modem is in form of a ready to use circuit module, which is capable of providing 9600 baud rate low rate bi-directional data communication. Due to its small size it can be integrated into and become part of the user's power line data communication system. The module provides bi-directional half-duplex communication over the mains of any voltage up to 250V AC and for frequency 50 Hz or 60 Hz. Half Duplex communications means it can either transmit or receive data at a time but not both at same time. Normally module is in receiving mode all the time listening to incoming communication on the power line. Once your application gives serial data to transmit on its RX-IN pin, it switches over to transmit and transmits the data through power line. Once transmit process is complete it switches back to receive mode. The transmission of data is indicated by Red LED. The reception of data by modem is indicated by Green LED which is on TX out pin itself. Data communication of the modules is transparent to user's data terminals and protocol independent; as a result, multiple units can be connected to the mains without affecting the operation of the others. There is no hassle of building interface circuits. Interface to user's data devices is a simple data-in and data-out serial link.

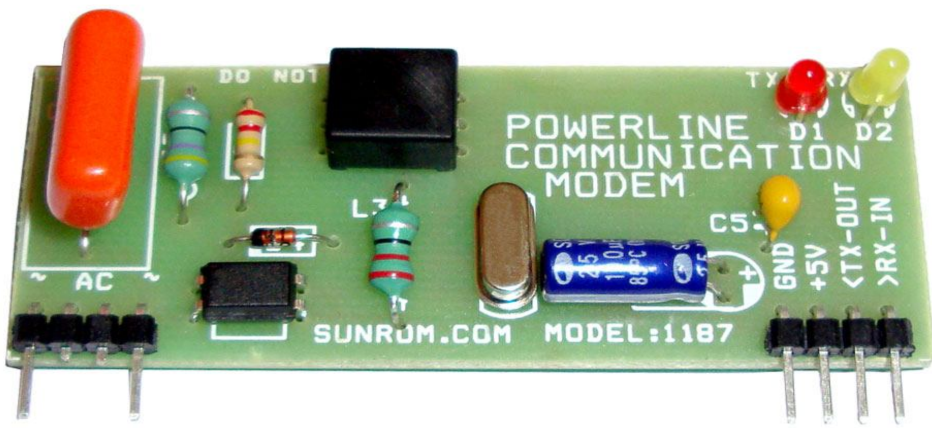

Fig. 4. PLC modem

Transmission is based on byte by byte basis. Once you give one byte to module for transmission, you will have to wait at least 500ms (milli second) before a new byte is given to module again since the module waits for zero crossing of AC mains to transfer a bit. For AC 50Hz system the zero crossing of AC signals happens every 10ms and modem needs 50 zero crossings to transmit one byte with error checking data. That is why it takes 500ms for one byte. For example we want to transmit character "TEST", then we will have to transmit 'T', then wait 500ms, then transmit 'E' and wait 500ms, then transmit 'S' and wait 500ms, then transmit 'T' and wait 500ms. This can be quite slow speed for big data transfer, but the purpose of this module is transfer of small data bytes like sensor readings and remote control for which this speed is ok to implement

v. Utility centre

The Utility Centre or the electricity board resides in the utility company and consists of a PLC modem and a PC using which the details of power consumption from the consumer unit is obtained via communication network. Also a serial to USB convertor is used for level conversion. The software Matlab is used to receive the data and also to send the bill amount to the consumers. We are using Guide toolbox inside the Matlab to make a user friendly Graphical User Interface.

vi. Relay and Relay control

A high power relay is a vital part in the system. It provides the useful functionality of switching the power ON/OFF to the user based on the signal send to it from the controller corresponding to the status of bill payment.

A relay is an electrically controllable switch widely used in industrial controls, automobiles and appliances. The relay allows the isolation of two separate sections of a system with two different voltage sources i.e., a small amount of voltage/current on one side can handle a large amount of voltage/current on the other side but there is no chance that these two voltages mix up. When current flows through the relay coil, a magnetic field are created around the coil i.e., the coil is energized. This causes the armature to be attracted to the coil. The armature's contact acts like a switch and closes or opens the circuit. When the coil is not energized, a spring pulls the armature to its normal state of open or closed. There are all types of relays for all kinds of applications. When a command is received by the microcontroller to disconnect or reconnect the load then by using this relay the operation is performed. A solid-state relay uses a thyristor or other solid-state switching device, activated by the control signal, to switch the controlled load, instead of a solenoid

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Fig. 5.Relay

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A high power relay is a vital part in the system. It provides the useful functionality of switching the power ON/OFF to the user based on the signal send to it from the controller corresponding to the status of bill payment. It consists of a relay and its transistor driving circuit. The transistor used is BC 547. We are also using a 12 volt relay as a switch.

vii. Power supply

- *Step down Transformer*

  A step down transformer is one whose secondary voltage is less than its primary voltage. It is designed to reduce the voltage from the primary winding to the secondary winding. This kind of transformer "steps down" the voltage applied to it. As a step-down unit, the transformer converts high-voltage, low-current power into low-voltage, high-current power. The larger-gauge wire used in the secondary winding is necessary due to the increase in current. The primary winding, which doesn't have to conduct as much current, may be made of smaller-gauge wire.

- *Bridge rectifier and filter*

  Bridge rectifier makes use of four diodes in a bridge arrangement to achieve full-wave rectification. This is a widely used configuration, both with individual diodes wired as shown and with single component bridges where the diode bridge is wired internally

  7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

B) Software Description.

- GUI and MATLAB

A graphical user interface (GUI) is a graphical display in one or more windows containing controls, called *components* that enable a user to perform interactive tasks. The user of the GUI does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the details of how the tasks are performed.

Typically, GUIs wait for an end user to manipulate a control, and then respond to each user action in turn. Each control, and the GUI itself, has one or more *callbacks*, named for the fact that they "call back" to MATLAB to ask it to do things. A particular user action, such as pressing a screen button, or passing the cursor over a component, triggers the execution of each callback. The GUI then responds to these *events*. You, as the GUI creator, write callbacks that define what the components do to handle events. This kind of programming is often referred to as *event-driven* programming.

A MATLAB GUI is a figure window to which you add user-operated components. You can select, size, and position these components as you like. Using callbacks you can make the components do what you want when the user clicks or manipulates the components with keystrokes. You can build MATLAB GUIs in two ways:

1) Use GUIDE (GUI Development Environment), an interactive GUI construction kit. This approach starts with a figure that you populate with components from within a graphic layout editor. GUIDE creates an associated code file

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containing callbacks for the GUI and its components. GUIDE saves both the figure (as a FIG-file) and the code file. Opening either one also opens the other to run the GUI.

2) Create code files that generate GUIs as functions or scripts (programmatic GUI construction).

In this approach, you create a code file that defines all component properties and behaviors. When a user executes the file, it creates a figure, populates it with components, and handles user interactions. Typically, the figure is not saved between sessions because the code in the file creates a new one each time it runs. The code files of the two approaches look different. Programmatic GUI files are generally longer, because they explicitly define every property of the figure and its controls, as well as the callbacks. GUIDE GUIs define most of the properties within the figure itself. They store the definitions in its FIG-file rather than in its code file. The code file contains callbacks and other functions that initialize the GUI when it opens. You can create a GUI with GUIDE and then modify it programmatically.

IV.RESULT

Model of the implemented circuit is shown below. It consist of the control circuit at the consumer side. Each bulb represents different consumer circuit.

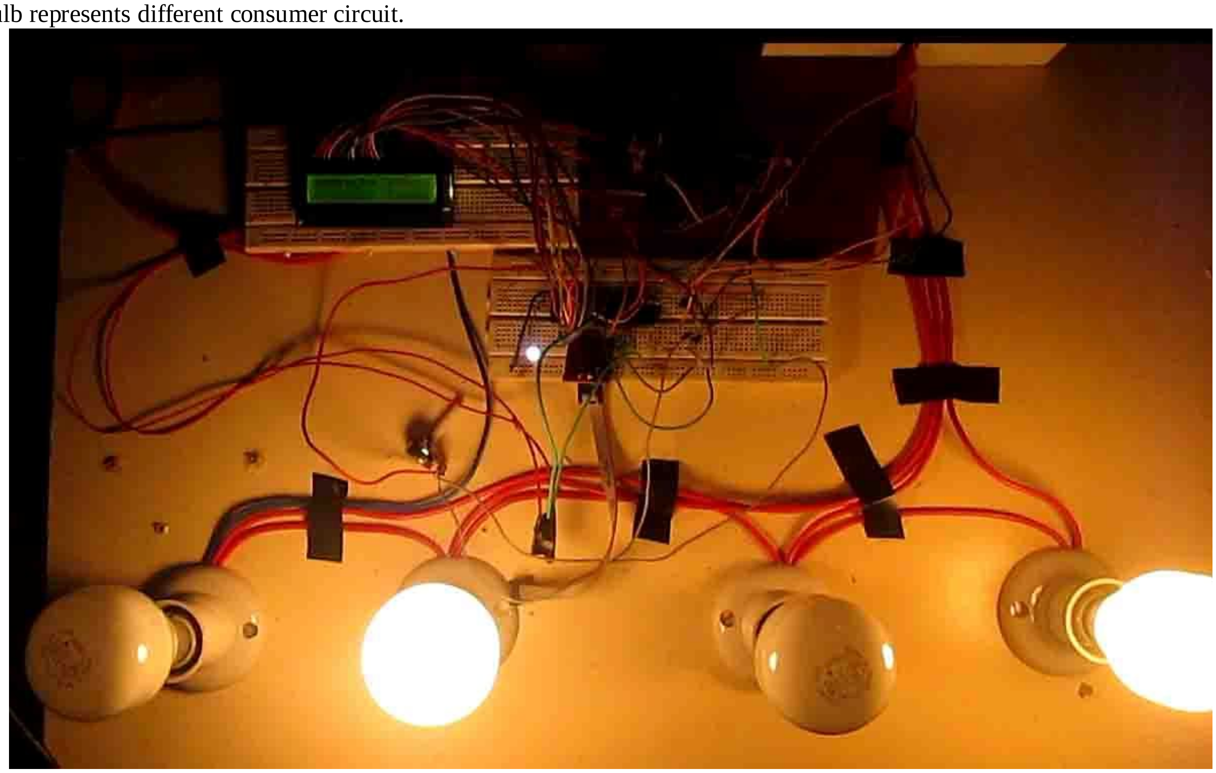

Fig 6: Implemented circuit

- Serial communication

For serial communication between utility and consumer following criteria was decided Baud Rate was determined as 9600. Data contained 8 data bit and one stop bit. No parity was used.

- Graphical User Interface

In this all windows were developed using MATLAB. Desired callback was assigned to each button. Displays were also properly arranged. Functions were used to generate serial communication signal.

- Consumer circuit

The circuit was set up in a dotted PCB. Programming was done using programmers notepad and was entered to the micro controller.

The overall setup of the project was interconnected. Using given address each consumer was identified and meter reading were noted and calculated. Also Load management was done for peak time control. Overall load at consumer

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side was divided into various section and they were assigned priorities. These sections were cut during load shedding according to their priorities.

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