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IOT Based Automatic Energy Theft Detection & Prepaid Energy Meter

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Abstract - Due to rapid increase in human population and the human's dependency towards electrical energy, the demand for electricity has increased many folds, causing deficit of electrical energy during peak hours. In order to cope up with the energy challenges, it is necessary to modernize the electrical system. Internet of Things (IoT) technology can be employed to energy consumption and distribution in different scenarios. This paper mainly focuses on automatic billing, power card facility, theft detection, power optimization and providing the relevant energy consumption information to user. IOT based smart energy meter system basically consists of three major components namely controller, Wi-Fi and Theft detection device. Whenever there is any theft or fault, the theft detector sensor detects the error and responds accordingly. The controller plays a vital role in keeping all the components in working state. In this system energy meters are connected to the internet i.e., using IoT concept, eliminates the human intervention in electricity maintenance. In the proposed work, IoT based meter reading system is designed to continuously monitor the meter reading and service provider can disconnect the power source whenever the consumer does not pay the monthly bill and also it eliminates the human intervention, delivers effective meter reading, prevent the billing mistakes.

Key Words: Internet of Things (IoT), smart energy meter, automatic billing, Power theft detection.

1. INTRODUCTION

At present, Electricity is the essential commodity in the world for human life.Today every home, offices, companies, industries requires electricity connection for their functioning. Due to rapid increase in human population and the human's dependency towards electrical energy, the demand for electricity has increased many folds, causing deficit of electrical energy during peak hours. In order to cope up with the energy challenges, it is necessary to modernize the electrical system [1, 2]. Internet of Things (IoT) technology can be employed to energy consumption and distribution in different scenarios [3, 4]. Latest development in IoT and digital technology, the concept of smart city is becoming smarter compared to earlier years [5].Therefore it is necessary to switch over to innovative and better alternatives such as smart grid, smart metering and zero energy building that will assist to minimize reliance on these assets by minimizing energy consumption and improving usage of renewable energies. This will in turn increase the efficiency of power and energy manages system [6].

Accurate metering, detection of theft and implementation of proper tariff and billing system would manage the consumption of electrical energy. Collecting meter reading is one of the most difficult procedures in billing. The traditional electrical energy meter data collection is such that a person from the utility provider visits the consumer sites periodically to note the meter reading. This procedure has lot of drawbacks such as, it is time consuming, tiresome, requires more human resource, human error and even corruption is probable. The process may be interrupted due to bad weather conditions, also if the consumer is not available, the billing will be pending and human operator needs to revisit. India is facing energy deficit during peak hours. Low voltage during peak hours has been reported as a major power quality issue. Load shedding is a common power management practice followed by the utility providers [7]. Energy conservation has great significance in this scenario of increasing electrical energy demand.

The present system of energy billing is error prone, time consuming and laborious. Errors get introduced at every stage of energy billing like errors with electro-mechanical meters, human errors while noting down the meter reading. These errors can be overcome by using the smart energy meter. The main objective of the proposed work is to develop a smart energy meter. The Arduino takes the pulse from the energy meter, calculate units and displays the reading on the LCD. The reading is stored in built in EEPROM so, in case of power failures it continues the computation. The reading of the energy meter is also sent to the cell phone of the user in the form of a message through Wi-Fi modem [8]. The proto type system is powered by external power supply that takes the ac power and converts it into dc power and is fed to Arduino and WiFi.

This paper mainly focuses on automatic billing, power card facility, theft detection, power optimization and providing the relevant energy consumption information to user. Here the user can monitor the energy consumption units from a web page by providing device IP address. Theft detection unit connected to energy meter will notify company side when meter tampering and theft detection occurs in energy meter through PLC modem and theft detected will be displayed on the terminal window. In this system energy meters are connected to the internet i.e., IoT concept and it eliminates the human intervention in electricity maintenance. This paper is presented in six sections including introduction section. Section II presents the details of proposed prototype IoT based smart energy meter system. The hardware details of the proposed approach are given in section III. Software details are discussed in section IV. The experimental results observed are presented in section V and finally the conclusions are presented in section VI.

2. Proposed Prototype IoT based smart energy meter System

IOT based energy meter system basically consists of three major components namely controller, Wi-Fi and Theft detection device. Whenever there is any theft or fault, the theft detector sensor detects the error and responds accordingly. The controller plays a vital role in keeping all the components in working state [9].

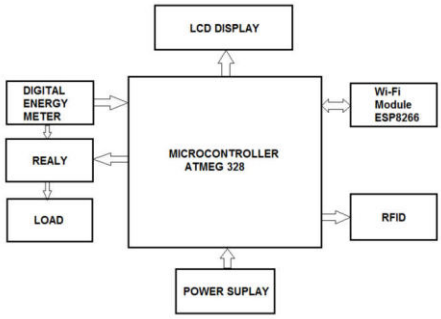

Fig. 1 Block diagram of proposed prototype smart energy meter

In this system energy meters are connected to the internet i.e., using IoT concept. This system eliminates the human intervention in electricity maintenance. The block diagram of the system is shown in Fig.1. Major components used in the system are Arduino micro controller, energy meters (main energy meter and sub energy meter), interfacing circuit (optocoupler), relay and relay driver circuit, LCD display and a Personal Computer. The energy meter is connected to the Arduino microcontroller using an interfacing circuit [8]. The interfacing circuit consists of an optocoupler. The basic design of an optocoupler consists of an LED and LDR. If LED blink for 3 times then LDR will count 1 unit, if again LED blink for 3 times the LDR will count 2units. After the completion of 3 units the bill will be generated. The real time readings from the energy meters are collected by the microcontroller. This can be viewed through an LCD display which is connected to the micro controller. The LCD display shows the readings of the energy meters and the theft status. Once the bill is generated, it is sent to the consumer mobile through the Wi-Fi module. The payment option is done by RFID card. The RFID reader reads the cards ID and sends it to the microcontroller. The microcontroller receives the information and takes an action based on it. For example, if the card is credited for 100units the credit will be decreased when the consumer uses power. When it reaches 30% of the total units, controller will send the message to the costumer that 30% current has been used and so on for 60% and 90% also controller sends the message to the consumer.

3. Hardware Details

In this section hardware details are described, first design module is explained then brief description about each hardware components are given one after the other in the following section.

3.1. Designed Model

In the prototype system the power utility maintains a server and each consumer are provided an energy meter. The server, power sim meters and Wi-Fi module are used to communicate with each other using Wi-Fi network. Fig 2 shows prototype power sim energy management system. The energy meter consists of a microcontroller (ATmega32), energy measuring chip (AAE7751), GSM module (simensA62), mobile phone, Current transformer, potential transformer, LCD display and a relay. The energy consumption by counting the output pulses of the EM chip on an interrupt basis. The Microcontroller uses AT command set to communicate with the Wi-Fi module [10]. The Embedded C programming language has been used to program the microcontroller and to connect the server respectively.

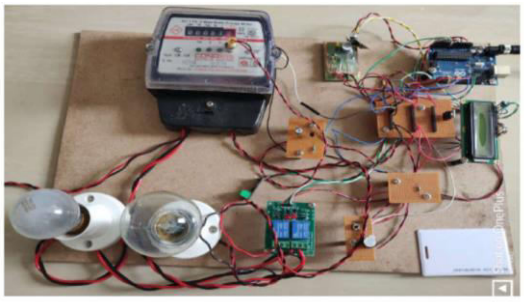

Fig. 2. Designed proto type smart energy meter model

3.2. Digital Electronic Energy Meters:

Digital signal processor or high performance microcontrollers are used in digital electric meters. Similar to the Analog meters, voltage and current transducers are connected to a high resolution ADC. Once it converts Analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.

Microcontroller also calculates phase angle between voltage and current, so that it also measures and indicates reactive power. It is programmed in such a way that it calculates energy according to the tariff and other parameters like power factor, maximum demand, etc. and stores all these values in a non-volatile memory EEPROM.

It contains real time clock (RTC) for calculating time for power integration, maximum demand calculations and also date and time stamps for particular parameters. Further it interacts with liquid crystal display (LCD), communication devices and other meter outputs. Battery is provided for RTC and other significant peripherals for backup power.

3.3. Arduino

Current Arduino boards are programmed via Universal Serial Bus (USB), implemented using USB-to-serial adapter chips such as the FTDI FT232 is shown in figure 3. Some boards, such as later-model Uno boards, substitute the FTDI chip with a separate AVR chip containing USB-to-serial firmware, which is reprogrammable via its own ICSP header. Other variants, such as the Arduino Mini and the unofficial Boarding, use a detachable USB-to-serial adapter board or cable, Bluetooth or other methods, when used with traditional microcontroller tools instead of the Arduino IDE, standard AVR in-system programming (ISP) programming issued.

Fig.3. Arduino

3.4. LCD display

A liquid-crystal display (LCD) shown in figure 4, is a flat-panel display or other optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in colour or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as pre-set 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.

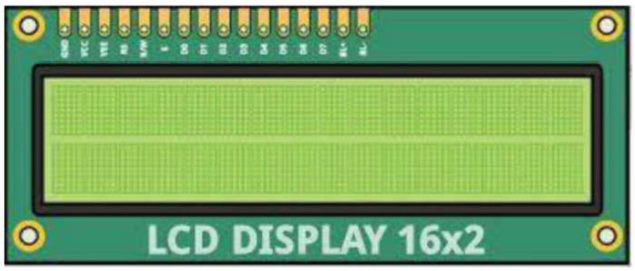

Fig.4. LCD Display

3.5. RFID Interrogators (Reader)

An RFID interrogator shown in figure 5, acts as a bridge between the RFID tag and the controller and has a few basic functions to perform:

- Read the data contents of an RFID tag
- Write data to the tag (in the case of smart tags)
- Relay data to and from the controller
- Power-up the tag (in the case of passive tags).

RFID interrogators are composed of roughly three parts: an antenna, an RF electronics module, responsible for communicating with the RFID tag, and a controller electronics module, responsible for communicating with the controller. A number of factors can affect the distance at which a tag can be read (the read range). The frequency used for identification, the antenna gain, the orientation and polarization of the reader antenna and the transponder antenna, as well as the placement of the tag on the object to be identified will all have an impact on the RFID system‘s read range. The reader either continuously (in case of fixed readers) or on demand (as in handheld readers) sends out electromagnetic waves to inquire the presence of any tags in its active read field. On receiving the signals from the tags, the reader decodes the signal and forwards it to the host information processing system

Fig. 5. RFID reader

3.6. Regulated power supply

Today almost every electronic device needs a dc supply for its smooth operation and they need to be operated within certain power supply limits. This required dc voltage or dc supply is derived from single phase ac mains. A regulated power supply can convert unregulated an ac (alternating electric current or voltage) to a constant dc (direct electric current or voltage). A regulated power supply is used to ensure that the output remains constant even if the input changes. A regulated DC power supply is also called as a linear power supply; it is an embedded circuit and consists of various blocks. The regulated power supply will accept an ac input and give a constant dc output. Figure 6 shows a typical regulated dc power supply.

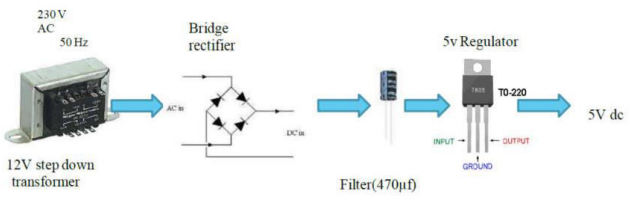

Fig. 6. Regulated power supply

3.7. Wi-Fi Module (ESP8266)

ESP8266 is Wi-Fi enabled system on chip (SoC) module developed by Espressif system is shown in figure 7. It

is mostly used for development of IoT (Internet of Things) embedded applications. It employs a 32-bit RISC CPU based on the TensilicaXtensa L106 running at 80 MHz (or over clocked to 160 MHz). It has a 64 KB boot ROM, 64 KB instruction RAM and 96 KB data RAM. External flash memory can be accessed through SPI.ESP8266 **module is low** cost standalone wireless transceiver that can be used for end-point IOT developments.

To communicate with the ESP8266 module, microcontroller needs to use set of AT commands. Microcontroller communicates with ESP8266-01 module using UART having specified Baud rate.

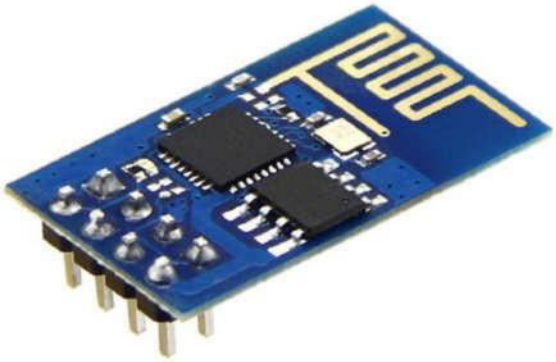

Fig. 7. WiFi Module

3.8. Current Sensor

In the present work ACS712 current sensor shown in figure 8 operates from 5V and outputs analog voltage proportional to current measured on the sensing terminals. Microcontroller along with ADC is used to read the values.Fig.8 shows the current sensor.

Fig.8.0 Current sensor

3.9. RELAY

5V Relay Module is a relay interface board; it can be controlled directly by a wide range of microcontrollers such as Arduino.

3.10. HARDWARE IMPLEMENTATION.

The connections are established on a board and the energy meter is connected to the Arduino. Wi Fi module is connected with Arduino through male connector. The load can be connected through the socket though the bulb. All the connections are to be made carefully with the good quality male connector. The power of the Wi Fi modem to the Arduino board should supply with 9V DC and the current rating must not be below l000 mA. A 9V l000mA adapter is used for power supply. Mobile phone set with Wi Fi, is used at the customer end for demo operation. The Arduino is burnt via PC using programming with predefined functions i.e. energy meter reading code, SMS reading, checking and sending code, AT commands for SMS and security services. After powering ON the Arduino and Wi Fi modem, goes to its initial condition. After a short delay the Arduino reads the EEPROM and calculates the data and later displays the data on the LCD. The data on the LCD includes the pulse count, usage of the units and the cost consumed for the respective units. Wi Fi modem sends these data to the consumer mobile number.

4. SOFTWARE DETAILS

This section explains the software used for the integration of hardware with firmware.

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

Working of the flow chart shown in figure 9 is explained using the following steps:

• Step 1: Start
• Step 2: Initializing the hardware pins like LCD, Wi Fi, Relay pins etc.
• Step 3: Initial condition checking-Relay and theft detection module should be ON. Initialize unit and count to zero.
• Step 4: Check if count==3,

If count<3, go to step 3
If count>3, increment unit by 1: go to step 3
Simultaneously if the theft is detected then the relay will off if not it will under normal condition.

• Step 5: Increment unit by1 and go to step 3.
• Step 6: When unit become 3, bill is generated
• Step 7: Scan the card for bill payment, if the payment is done relay will be on or else relay will be off.

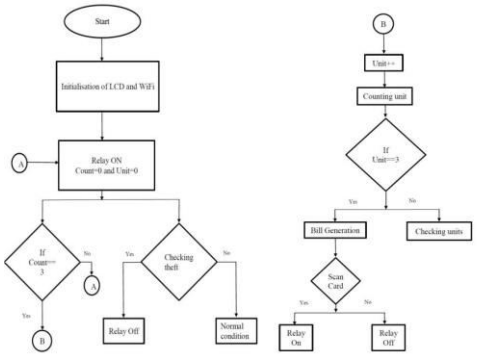

Fig. 9. Flow chart for software implementation

5. RESULTS AND DISCUSSION

The developed hardware is integrated with the software. The prototype module is tested in online real time system and the following results are presented as shown in figure 10.

Fig. 10. LCD display

5.1. Message module:

The screen shot shown in figure 11 sends a SMS message from an Arduino or Genuino board equipped with a Wi Fi. Using the serial monitor of the Arduino Software (IDE), further enter the mobile number of the consumer to forwad the information with respect to the status of the meter reading, current consumption and theft detection and disconnection of power.

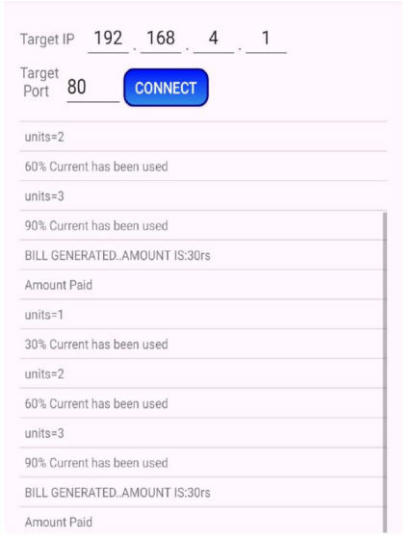

Fig. 11 Message module

The Project has achieved following objectives:-
1. Ease of accessing information for consumer from energy meter through IoT.
2. Theft detection at consumer end in real time.
3. LCD displays energy consumption units and temperature.
4. Disconnection of service from remote server.

6. CONCLUSIONS

The In the era of smart city, smart grid advancement, prototype smart energy meter is a step forward and it mainly focusses on the connectivity & networking factor of the IoT. In this system, an energy consumption calculation based on the counting of calibration pulses is designed and implemented using Arduino Uno MCU in embedded system domain. In the proposed work, IoT based meter reading system is used to continuously monitor the meter reading, current energy consumption, theft detection and service provider can disconnect the power source whenever the consumer does not pay the monthly bill.All these information are sent in the form of message alerts to the consumer mobile phone.Also it eliminates the human intervention, delivers effective meter reading, prevent the billing mistakes.

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