

Design of Smart Energy Meter for Smart Grid with Net Metering & Theft Detection

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Abstract: The demand for reliable smart energy meter (SEM) is increasing now-a-days. The technologies for e-metering are changing very fast. This paper presents design of smart energy meter with net metering using GSM & ZigBee. GSM is used for the purpose of automatic billing & managing the collected data. The proposed system provides the facility of remote monitoring, net metering & remote disconnect in case of electricity theft. Pilferage of electricity can be substantially reduced by incorporating the proposed theft detection & control methods. A PC at electricity board (EB) end acts as a billing point which contains database at meter data management (MDM) software & receives data using GSM. Meter reading from smart energy meter is sent to this billing point periodically & the reading is updated in database of PC. A web page is designed which contains all billing information of each consumer & consumer can access it from anywhere in the world. The meter is also known as bidirectional meter, as it can record reverse power & send it to electricity board for calculation of the net bill. Monthly net bill is messaged back to the customer.

Keywords- *Advanced Metering Infrastructure (AMI); electronic metering (e-metering); Electricity Board (EB); Global System Mobile (GSM); Meter Data Management (MDM) software; Personal computer (PC); Smart Energy Meter(SEM); Short Message Service (SMS).*

I. INTRODUCTION

Electrical power has become one of the basic needs to human survival and progress. Traditional meter reading & billing technique is inefficient & have several disadvantages. Each month a person from the service provider side come and collect meter reading and produce bill to the consumer. This system is problematic as it requires man power, time consuming & causes error also. It is costly when readings have to be collected from scattered rural areas. This method is inefficient for houses at top of higher buildings & there is a chance of missing bill, because of reasons like consumer not at home etc. Power management department cannot get real time data of electricity being used.

Here a new method of metering which utilizes two-way communications with ability to control and monitor meters is introduced which is called as smart energy meter with Advanced Metering Infrastructure (AMI). Smart energy meters read the energy, records these readings continuously, then sends to billing point through GSM & ZigBee network. After calculating monthly bill using meter data management software at service provider side this bill is send back to consumer as SMS. Registered users & service provider can monitor & analyze the generated bill of any month by sitting anywhere in the world.

Electricity theft is a serious & common problem in power sector in developing countries like India. Because of theft a

huge amount of revenue is lost. Due to this loss there is shortage of funds for investments to expand the existing power capacity. In the proposed system measures for controlling electricity theft are added with smart metering. Smart meters are very useful for smart grid. Distributors can get the detailed load flow so that they can manage grid effectively. In this paper a smart meter is designed & developed that uses both GSM & ZigBee. ZigBee is used here to communicate with other devices & GSM network is used because of its SMS capability for data transfer.

II. A LOOKBACK AT ENERGY METERING SYSTEMS

A. Conventional metering systems

The meters come under two basic categories, electromechanical & electronic. The common type of electricity meter is electromechanical watt-hour meter. The meter continuously measures instantaneous voltage & current to give energy used. The electromechanical induction meter operates by counting revolutions of metal disc which is made to rotate at a speed proportional to the energy usage. Electronic meters can transmit readings to remote places in addition to display the energy used. The common drawbacks of conventional metering are:

-Time consuming due to need of human power for collecting meter data from each house.

-More chances of occurrence of electricity theft.

-Consumer cannot track his real time energy use information.

-Consumers producing renewable power and selling it to utility, does not get real time information about power exported to utility.

B. Smart energy meter

There are two types of AMR systems, wire-based and wireless. Power Line Carrier (PLC) & telephone line network (optical/cable) are wire-based AMR system and several related works are available. Many e-metering systems have now been proposed based on GPRS, Bluetooth and GSM which is wireless technology. Numerous amount of research focused on using

GSM based meters. In [1], a GSM energy meter was developed and a database that provides the information to the consumer. In paper [2], a ZigBee-GSM based automatic meter reading system was developed; the meters are equipped with ZigBee that sends the data to a data collector device which uses GSM to communicate with the central computer. In paper [3], GSM network is used effectively in this paper to control the electricity theft. If there is any type of electricity theft occurs then meter is disconnected with the help of relay switch and GSM network. In [6], ZigBee communication technology is used to record outage event data with Advanced Metering Infrastructure. In [7], power meter is designed using Wi-Fi technology for communication. In paper [8], a low cost PLC watt-hour meter is designed. This communication uses existing power line so that building cost is low. In paper [10], GSM network is utilized well for finding the fault location of transmission line. The comparison of various technologies used in smart metering is shown in table 1. It is seen that data rate & range of GSM is highest. ZigBee is low power technology but its range is up to few hundred meters. In this system both ZigBee & GSM are used.

Table 1 Comparison of various communication technologies for smart metering

	Bluetooth	Wi-Fi	PLC	ZigBee	GSM
Range	10m	50m – 100m	15 km	70m – 100m	35Km - 120 Km
Data rate	720Kbps	11 – 54Mbps	576Kbps	250Kbps	100Mbps
Frequency	2480MHz	5GHz	9 – 500 KHz	2.4GHz	900, 1800MHz

III. PROPOSED SYSTEM

In proposed system shown in figure 1 benefits of ZigBee and GSM technology are used and a new system is developed. This architecture is used as a residential bidirectional smart energy meter. Large centralized power

plants are no longer the only source of electricity. The production of renewable electric power is increasing at fast rate. Consumer needs a smart bidirectional meter which can measure power exported to EB, so he would come to know exact payable bill. Power grid is called smart grid when smart meters are used at different points of power grid to collect data & to manage grid. The foundation for smart grid is a smart meter. An overview of proposed system is shown in figure. The system consists of two devices, smart energy meter for consumer side & the receiver for electricity board side.

Residential consumers of metropolitan cities are building solar power system on their rooftop. Many consumers have extra power after their consumption, which they want to export to EB. For this purpose a bidirectional meter is designed, which can record reverse power flowing towards grid. Arduino is programmed to calculate net bill by the formula (Reverse power units) – (forward power units) = Net units consumed.

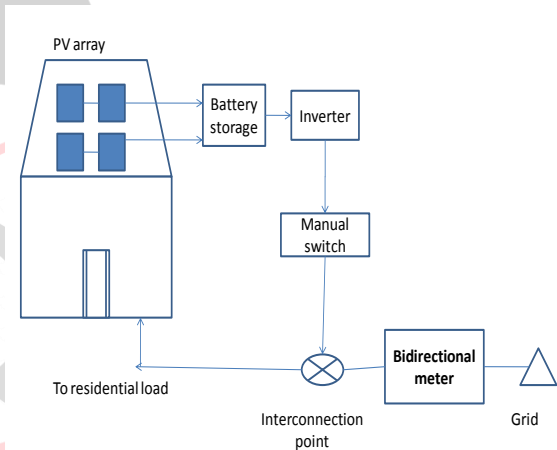


Fig.1. Bidirectional meter for net metering

A. Concept of Smart Energy Meter & Net Metering

Automatic meter reading is a system that utilizes one way communication to collect data. Advanced metering infrastructure is the system that utilizes two way communications to control & monitor the meter. The combination of automatic meter reading (AMR) & two way communication is called smart metering. Smart meter is key component of smart grid. In proposed system smart meter is made more reliable by adding following features to it.

- Remote Monitoring

Customer can monitor power/ energy usage remotely by using website. He can also get SMS of energy usage on mobile phone using an android app downloaded. Consumer come to know which appliance or activity contribute the most towards their bill.

- Remote Disconnect

Supply is disconnected when a theft like bypassing of phase & disconnection of neutral occurs.

- Alerts

When a theft like bypassing of whole meter and tampering of meter occurs, meter gives alert to utility/receiver in the form of a message.

- Regular Update of MDM Software

Meter data management software is updated every 10 minutes. Website is also updated every 10 minutes. This data of each meter can be used for forecasting of demand.

- Net Metering

Net metering is a billing mechanism for solar energy system owners to get credit for the electricity they add to the grid. For example, if a residential customer has a photovoltaic system on the rooftop & it is generating more electricity than the home uses during daylight hours. If the home is having bidirectional meter, the electricity meter will run backwards to measure electricity exported against what electricity is consumed at night or other periods where the home's electricity use exceeds the PV system's output. Customers get billing amount of their net energy use. Exported solar electricity is used by nearby customer loads.

B. Smart Energy Meter: A Solution to Control Electricity Theft

Block diagram of smart energy meter with theft detection measures is shown in figure 2.

- Shorting of Phase Line and Disconnecting the Neutral Line.

To prevent these kinds of theft, two current transformers are used separately in phase and neutral line. The output voltages of CT1 & CT2 are provided to ADC input of Arduino. If phase line is shorted or neutral is disconnected then there will be a difference between output voltages of CT1 and CT2. The Arduino compares the voltages of CT1 & CT2 and if any significant difference is found, it disconnects the load immediately using the relay.

- Whole Meter Bypassing

When whole meter is bypassed, the meter will detect no energy consumption. To prevent this theft, output voltage of PT2 is converted to 5V dc and is given to the interrupt pin of the microcontroller. When whole meter is bypassed, PT2 detects no voltage & an interrupt is sent to the Arduino. Meter immediately send message to utility/ receiver using GSM.

- Tampering of Meter

Many consumers try to tamper or open energy meter for the purpose of electricity theft. To avoid this, two lever switches are used at two sides of proposed energy meter. One terminal of each lever switch is connected to 5V supply and the other is connected to Arduino. In normal operating conditions, two lever switches will be closed & Arduino will detect 5V at its two input pins. If consumer tries to tamper the meter, the lever switches are disconnected and Arduino

will detect 0V at its input pins. Arduino immediately send message to utility/receiver after this using GSM.

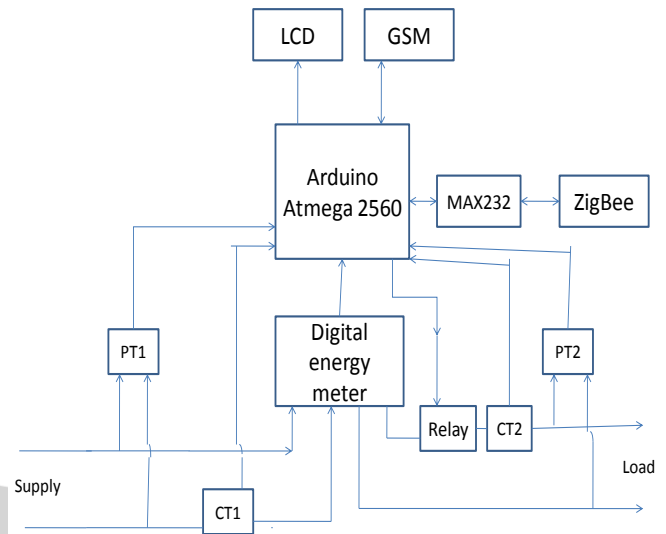


Fig.2. Block diagram of smart energy meter with theft detection measures

IV. HARDWARE COMPONENT DESCRIPTION

- Digital energy meter:

A digital energy meter is used with a meter constant of 3200 impulses per KWhr. The impulses are sent to Arduino using LDR & op-amp circuit.

- Arduino ATmega 2560

The Arduino being used contains everything needed to support the system. The main requirement for our project is that we require multiple UARTS for communication and also even parity for request packet for meter and hence the Arduino Mega 2560 is used.

- GSM modem

The GSM module we are using is SIM900D as it conforms physical condition and required characteristics of the project and it has dedicated voltage supply so we connect constant dc supply of 5V without fluctuations in voltage levels to operate GSM. GSM operates within 900 MHz frequency.

- ZigBee

ZigBee is used in the project for testing purpose. ZigBee is a low-cost, low-power wireless sensor networks. The module requires minimal power 3.3 V and provide reliable delivery of data between devices. The module operates within 2.4 GHz frequency band.

- Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. We used a relay which requires 12V supply. It consists of a relay driver, NPN transistor, freewheeling diode & 270Ω resistor.

- Power supply unit:

Power supply unit provides 5V & 12V supply. It consists of 230V/12V step down transformer, a bridge rectifier, 7805 voltage regulator for 5V regulated voltage, 7812 voltage

regulator for 12 V regulated voltage, capacitors of 1000 μ F & 100 μ F.

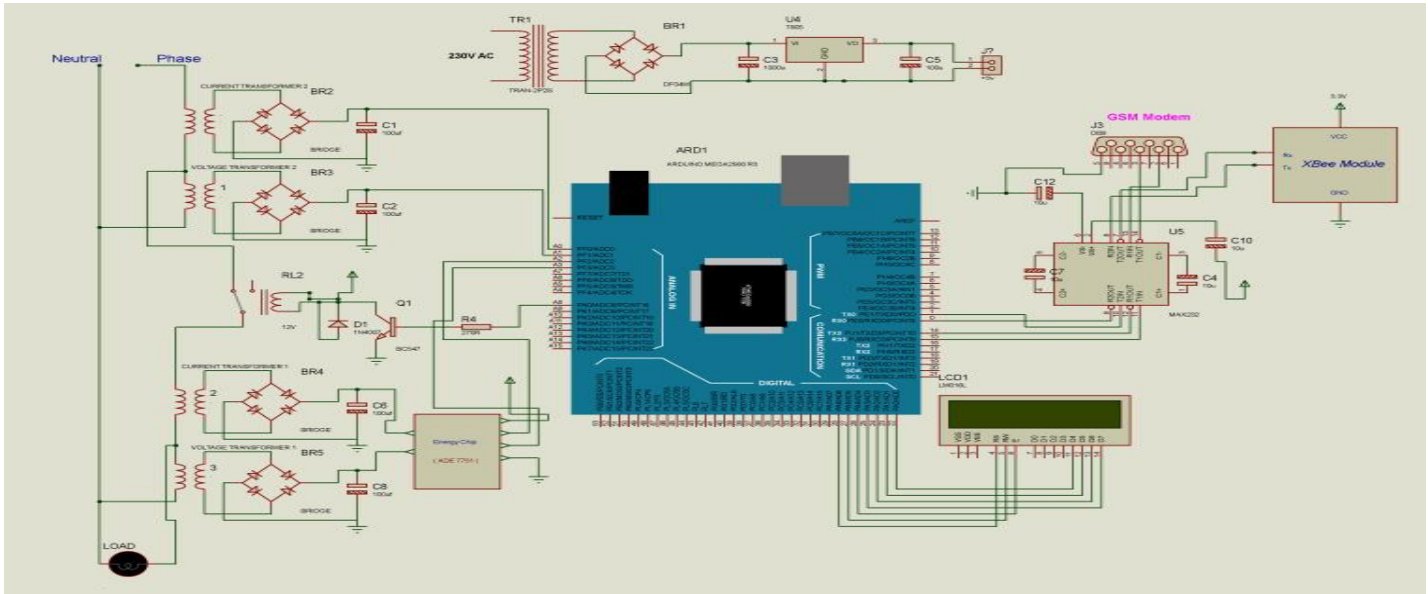


Fig. 3. Circuit diagram of consumer meter

V. CONCLUSION

In the present manuscript, the authors have proposed a smart energy meter which provides better two way communication with no data loss and also ensures security from practices of electricity theft. A net metering concept is also implemented in meter. Net metering policies can create a smoother demand curve for electricity and allow utilities to better manage their peak electricity loads. By encouraging generation near the point of consumption, net metering also reduces the strain on distribution systems and prevents losses in long-distance electricity transmission and distribution. The system has user friendly graphical user interface which makes it easy for user to understand the net energy consumption. The use of web service & SMS service has made it possible to overcome the main limitations of smart meters currently found in market. So data can be easily accessed via the Internet. The feature of ZigBee to communicate with other ZigBee and forming a network can be used to reduce the meter cost, as this will require less GSM modules.

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