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Power Monitoring in Home Area Network using Smartmote

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Abstract: Smart home energy management system (SHEMS) is the essential requirement of home area network (HAN) in smart grid communication technology. This paper presents the design and implementation of smart wireless sensor node for HEM system. The developed smartmote is used to monitor electrical parameters such as voltage, current etc. and transmits these parameters to the network coordinator to calculate the power consumption of the residential load. The developed smartmote is without microcontroller and capable to receive the controlling command from the network coordinator. This paper also discusses the use of xbee Series 2 module in the development of smartmote.

Keywords: Smart Home Energy Management System (SHEMS), Home Area Network (HAN), Smart Grid, Smartmote, Power Ratio Facto**r (P.R.F).**

I. INTRODUCTION

The wireless sensor networks (WSNs) has many applications areas such as industry, military healthcare etc. One of its applications is in smart grid. Smart grid is modernized electric grid which uses computer and other information technologies to improve the system efficiency and reliability [1]. The smart grid communication architecture is divided into three hierarchical networks: the neighborhood area network (NAN), building area network (BAN) and home area network (HAN). The home area network efficiently manages the on demand power requirements of the end users with the help of energy management system.

The electrical appliances used in the HAN have features of M2M devices. Major network communication technologies such as Bluetooth, IEEE 802.11(WiFi), ultra wideband (UWB), IEEE 802.15.4 ZigBee, 6LoWPAN are used to establish a communication between M2M devices in HAN. Among these, UWB technology can be used for sensor network but it has high power requirements. The IEEE 802.11 (WiFi) protocol is suitable for HAN as it has support for IPv6 addressing. But the drawback of this technology is high power requirement. So it is unsuitable for HAN M2M communication.[2]

IEEE 802.15.1 (Bluetooth) protocol supports voice, data and audio applications over short range. It also supports IPv6 addressing. But the Bluetooth network supports up to only eight devices communicating simultaneously. Communication latency also increase as each node will communicate through master device of the piconets. The node wake up time is approximately 3 seconds. These features make Bluetooth protocol unsuitable for M2M communication in HAN. IEEE 802.15.4 (ZigBee) protocol was developed for WSNs. It has low power requirement and simple network configuration. The wake up time of the end devices in the network is in milliseconds. The ZigBee provides communication range of 1-100m. Therefore ZigBee protocol is most suitable for HAN.[2]

In this paper, the low cost, simple in architecture smartmote is presented which can be easily used with home energy management system. The designed smart mote has the following features

(1) It provides a smart solution to monitor electrical parameters such as voltage, current of residential load.
(2) It is based on IEEE 802.15.4 standard (ZigBee protocol).
(3) It supports low data rate (250 kbps) Wireless Personal Area Networks.
(4) It consumes low power.
(5) It does not require any microcontroller as a processing element.
(6) It has hot line switching circuit based on Triac and opto-isolator to turn ON/OFF the residential load.

This paper is organized into V sections. In section II, various motes platforms available in the market are discussed. In section III, hardware architecture of the smart power monitoring node is presented. In section IV, experimental analysis is done with X-CTU software. Paper is concluded in section V.

II. RELATED WORK

The basic building block of any wireless sensor network is a Mote. Various application specific motes are available in the market. In this section we discuss the different architectures of the motes.

The Mica Mote [5] has single chip architecture. It consists of atmega103L microcontroller and TR1000 radio transceivers. The direct connection between application controller and transceiver enables flexibility in meeting application demands. It also has expansion board connector which is used for add on sensor card to interface sensors to the processor.

The TelosB [6] is ultra low power IEEE 802.15.4 based wireless sensor module for use in sensor networks and monitoring applications. It has integrated humidity,

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temperature and light sensors. Two chip architecture of TelosB built with a MSP430 microcontroller and CC2430 radio. The two chip architecture reduces the overhead on processor. The processor can be in sleep mode to reduce power consumption. The epic is similar to that of TelosB.
The lotus is based on the NXP LPC1758 and the RF231 IEEE 802.15.4 radio transceiver from atmel. The 51 pin expansion connector is used to interface sensor and data acquisition boards.
The Tiny node [7] module is ultra low power module. It built with MSP430 microcontroller and ultra low power wireless transceiver semtech sx1211. It consumes only 3mA in receiving mode. This mote supports switching the power sources between the super capacitor and lithium battery. The on board expansion connector is used to interface various external modules as per application requirement.

III.ARCHITECTURE

The complete architecture of the smart power monitoring node is divided into five subsystems like main power supply unit, voltage measurement unit, current measurement unit, XBEE module (RF subsystem) and actuator Unit. The node is used to monitor the power consumption of the residential load. Voltage and current are the key parameters for the power measurement. The output signal from the voltage measurement unit and current measurement unit are given to the xbee module. Xbee module can be configured as router /end device or coordinator. Depending upon the power consumption, the router/end device receives a command from the coordinator to turn on/off the residential load. The Fig.1 shows the functional block diagram of smart node to monitor electrical parameters and control residential load based on power consumption.

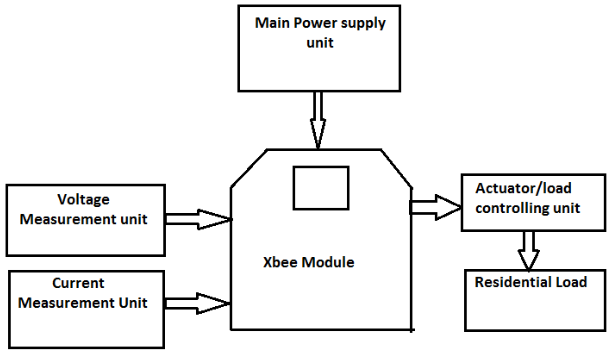

Fig.1. Functional block diagram of smart node.

A. Main Power supply unit.

The power supply unit is connected to mains 230V/50 Hz supply. Fig. 2 shows the circuit diagram of power supply unit. Power supply unit provides fixed 5Vdc output voltage. The step down voltage transformer is used to convert 230V to 10 V_{RMS} AC signal. The AC signal is then rectified by the rectifier. The rectified dc signal is passed through the filter capacitor to get the dc voltage.
The IC 7805 voltage regulator is used to get fixed regulated 5 V_{DC}.

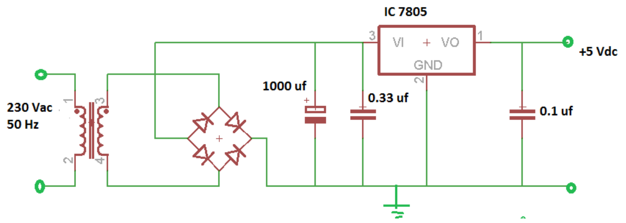

Fig.2. Power Supply Unit.

B. Voltage Measurement Unit

The design of voltage measurement scheme is shown in fig.3. The voltage (potential) transformer is used for voltage measurement. The transformer is step down type transformer. The step down transformer is used to convert 230 V to 10 VRMS ac signal which is then applied to rectifier to get the D.C signal. The rectifier output is then passed through the filter to get the ripple free D.C signal. A voltage divider is used to set the D.C voltage within the measurement level of 3.3 V of the XBEE Module. This signal is applied to the analog input channel of XBEE Module. The Measured D.C signal is directly proportional to the input supply voltage.

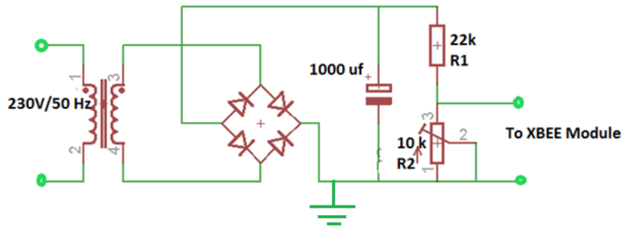

Fig.3 Voltage Measurement Circuit.

C. Current Measurement Unit

Current sensors are the essential part of any power measuring circuit. The common types of current sensors are current transformers, Hall Effect devices, differential currentsense resistance (DCR), and low side FET sensing. Current transformer is the most widely used current sensor. It is based on transformer action to reflect the current flowing from its primary to secondary circuits. A burden resistor across the current transformer is used to convert the current into voltage. They required minimum number of external components and are inexpensive. The fig .4 (a) shows a circuit that gives a D.C output voltage proportion to the supply current.

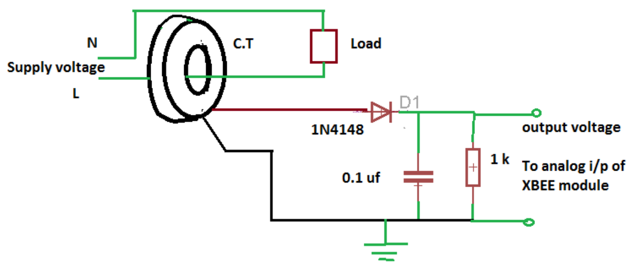

Fig.4 (a) Current Measurement using Current Transformer
Another way to measure the supply A.C current is using Hall Devices. Many Hall Effect based current sensors are available in the market such as ACS 712, WCS 2705 with 2 Amp, 5 Amp, 10 Amp current range. The Hall Effect based devices are operated by sensing the magnetic field

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generated by the current carrying conductor. They are small in size but tend to have low bandwidth and high cost. The fig. 4(b) shows the circuit diagram for current sensing using ACS 712 current sensor. When there is no supply current, the ACS 712 gives D.C output voltage of 2.5 Volts if VCC is 5 volts. The capacitor at the output of the ACS 712 is used to block the D.C voltage. The remaining A.C signal is amplified and rectified. The gain is decided by R2 and R1. The filtering is provided by the RC filter connected at the output of the amplifier. The output of the circuit is fed to any analog input channel of the Xbee module. The D.C output voltage is directly proportional to the A.C supply current.

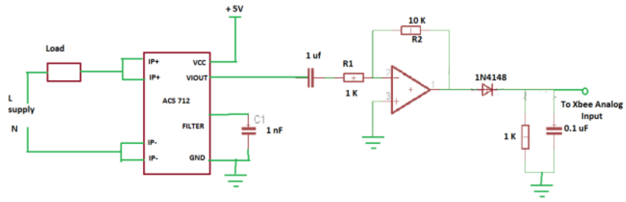

Fig.4 (b) Current Measurement using ACS712 Current sensor.

D. Actuator / Load controlling unit

The load controlling unit shown in fig.5 is used for switching on/off of the residential load. It consists of a BT138 Triac, MOC 3061 optocoupler and a transistor. It provides an easy control of residential load.

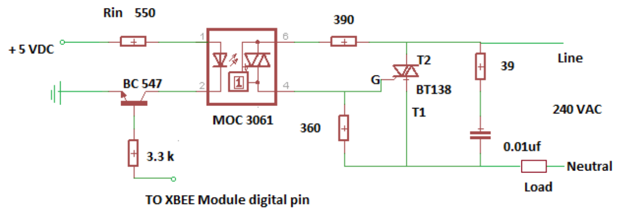

Fig.5 Actuator/ Load Controlling Unit.

E. Xbee RF module

The Xbee RF module is designed to operate within the ZigBee protocol. It supports low power, low cost wireless sensor networks. It has 4 analog input and 13 digital input/output lines. The Xbee S2 modules can be configured in AT or API Modes. It supports point-to-point, point-to-multipoint and peer-to-peer topologies.

Fig.6 XBee RF Module

IV. EXPERIMENTAL ANALYSIS.

X-CTU software is used to configure the sensor node XBee module as router in AT command mode and another Xbee module as coordinator in API command mode. PAN ID, operating Channel is set same for both the XBee modules. AD0 and AD1 analog input pins are enabled and set digital DIO4 pin as output pin. We generate a Remote AT Command frame with ATIS command. In response to Remote AT Command Frame the sensor node response back with Remote AT Command response Frame. The received frame has sampled value of voltages available on both analog input channels. The fig.7 (a, b) shows the scaled voltages for supply voltage and load current.

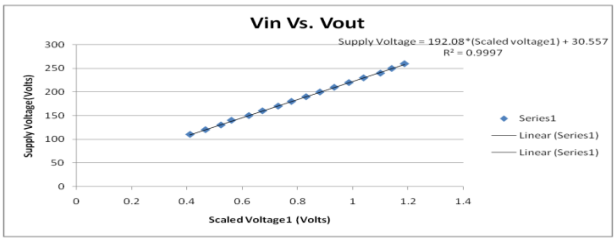

Fig.7 (a) Scaled Voltage for Supply Voltage.

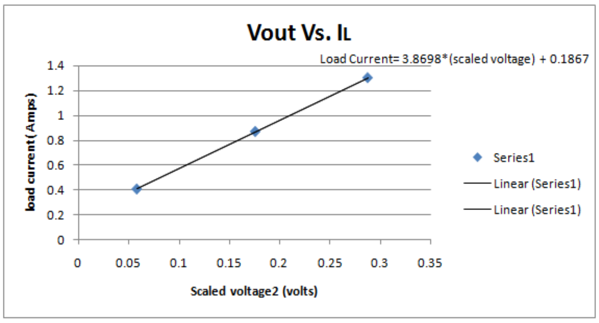

Fig.7 (b) Scaled Voltage for Load Current.

Power is calculated by following eq. (1)

$$P = (V_1 * I_L) * (P.R.F) \quad (1)$$

Where,
P = Power consumed by the load.
V_1 = Supply Voltage.
I_L = Load Current.
P.R.F = Power Ratio Factor.

The Power Ratio Factor is the ratio of measured power to the reference power. Supply voltage and load current is calculated by following eq. (2), (3).

$$V_1 = 192.08*(Scaledvoltage1)+30.557 \quad (2)$$
$$I_L = 3.8698 * (scaled\ voltage2) + 0.1867 \quad (3)$$

V.CONCLUSION

Smart mote for power monitoring and control of residential load is implemented and tested using X-CTU software. The implemented sensor node is very useful in low cost, low power wireless sensor network. The node can be easily integrated with home energy management system. The system is tested with different loads to

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calculate the power consumed by the load. The calculated power is approximately equal to the measured power.

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