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Simulation of Smart Meter Using Proteus software for Smart Grid

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Abstract – *With the growing power demand and increasing use of energy, the traditional electricity transmission and distribution network can be improved into an interactive service network or a smart grid. Smart meters are one of the proposed solutions for the smart grid. Wireless smart metering is an integral part of smart grid to realize real-time data acquisition, meter reading analysis, real time monitoring and decision making etc. This project tries to use the new wireless communication technologies to design and implement a ZigBee based smart power meter for reading power consumption and communicates this data to the utility server for power data processing. ZigBee protocol is used for wireless transmissions. Smart meter based on energy consumption budget setting is implemented. Monthly budget of power and billing information are sent to the user through mobile phones and then SMS is received. Power monitoring technique is used in this system. In this way it is possible to manage the power consumption of the power system which leads to an overall reduction in consumption and costs. A unique feature of power theft concept is implemented and user can also ON and OFF the particular appliances based on the power requirement. ARM cortex M4 microcontroller is used for controlling the smart meter. Simulation is done using Embedded C Proteus software along with CCS compiler.*

Key Words: **smart meter, billing service, renewable sources, power theft, Zigbee.**

1. INTRODUCTION

Problem associates with traditional meter reading have been increased day by day due to various reasons such as rapid growth in population, tedious location, environmental conditions etc. But with the help of microcontroller, there are many improvements for reducing manual effects. In traditional meter reading system, utility usages are written on papers by workers, there is lot of chances of human errors which will increase the cost to the users/companies. Also there are chances for unavailability of consumers during the visit of utility workers for meter reading.

In such cases, billing process will be pending and workers need to visit the consumer's house again. Workers going to each and every consumer's house and generating the bill is very laborious task and require lot of time. It is more difficult in future. Moreover it is also difficult for utility workers to find out unauthorized connections or malpractices carried out by consumers manually.

To reduce manual labour, smart meter powered by ARM controller is implemented as described in [2] [4]. With the attached sensors the controller can determine the voltage and current flowing through the transmission line. In addition, the amount of unit consumed by the load is billed simultaneously and if there is any energy theft from the power lines it is also intimated to the consumers. The billing detail parameters are transmitted through Zigbee to remote locations as discussed in [1] [3].

A digital energy meter that measures the consumption of electrical energy and provides other additional information as compared to the traditional energy meter as described in [1]. It is to provide the consumer and supplier an easy way to monitor the energy. Smart meters are considered a key component of the smart grid as these will allow more interactivity between the consumers and the provider. Smart meters will enable two-way and real-time communication between the consumers and the provider. Considering the increase of electricity demand, smart meters can decrease the overall energy consumption as discussed in [7]. This paper presented the development of Zigbee based smart meter. It can measure the energy and send the information to the service provider, who can store this information and notify the consumer through SMS messages or through the internet [8].

For achieving good communication link among them, it is very necessary to find suitable protocol. In this project, different hardware techniques are used for power monitoring, power management and remote power

controlling at home and transmission side. Zigbee protocol is used for wireless communication network. Zigbee has major role in monitoring and controlling of load for efficient power utilization.

This method can eliminate the problems such as manpower requirement for billing and errors during calculation etc., and can provide necessary information such as tariff variation and due date for payment to the consumer through the wireless medium. The wireless technology can be implemented by having a Zigbee enabled transceiver interfaced with the EB section server as well as in the consumer side.

Likewise in order to have different power sources to use alternate energy renewable sources can be used. Natural sources like wind, solar, fuel etc can be used as renewable sources. In this system we use multiple sources which help to select a single source from different sources like EB, solar energy and wind energy.

1. Methodology

2.1 Working Description Of Proposed System

The block diagram of the proposed smart meter using Zigbee for smart grid is given in the Fig 2.1.

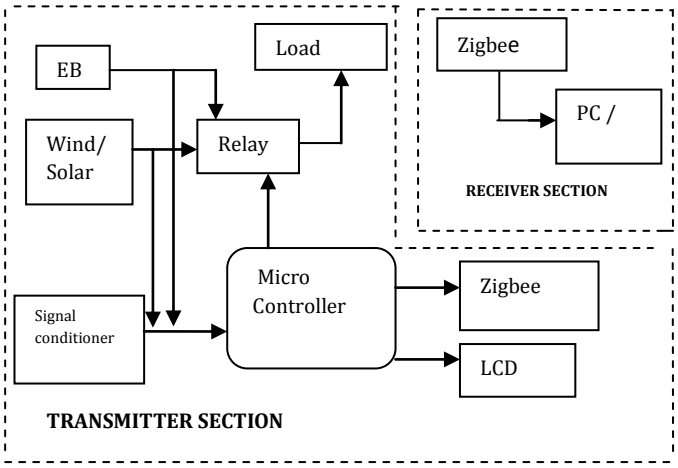

Figure -1 Block diagram of the system

In figure 1, smart meter system using ARM cortex M4 microcontroller and Zigbee transmission is designed. ARM is supplied by the DC voltage of 3.3 V. The system is divided into two segments,

1. Transmission unit

2. Receiver unit

The receiver unit comprises of potential transformer is used to to measure the voltage in power line and current transformer is used to measure the amount of current used by the consumer. The ARM cortex M4 microcontroller is used in the transmission unit which is used to monitor the unit which is used to monitor the power consumption and transfer the value of the power consumption details to the Receiver unit through Zigbee module.

The smart meter is implemented for monitoring the consumed power in home and communicating the value of consumed power to user. In the smart meter, billing information of the consumed power will sent to the user via Zigbee protocol. The consumed power is updated continuously to the user. This entire process is implemented. The relay is used for switching the input supply. The Zigbee is used to update the consumed power to PC or mobile phones. If there is any power theft detection microcontroller will turn off all loads and send the information to monitor section that the theft occurs in some area.

In EB station, the collected information of chargeable power consumption by the user is collected as a database. The demand value and the total chargeable consumed value are compared to find the un-chargeable power consumption. The un-chargeable power consumption is nothing but the power theft in the power line. A thresh hold value is set to analyze the un- chargeable power consumption to eliminate the fake power theft identification due to losses in the transmission line.

Once the power theft is identified, a relay unit is activated in the EB side with warning message about power theft and the theft detected area is disconnected automatically. The monitor section was sent to find the cause of power theft and a release button if the line is cleared from the power theft activity. The Eb section also calculated the charges for the consumed power by the user and transmits the payable amount to the home side for monthly payments.

2.2 Zigbee Technology

Zigbee is a radio frequency (RF) communications standard based on IEEE 802.15.4. It is an open standard. Zigbee is wireless communication technology, representing a wireless sensor network which is highly reliable, secure, low data rate, and low power consumption, low cost and fast reaction. The Zigbee coordinator is responsible for creating and maintaining the network. All communication between devices propagates through the coordinator to the destination device. The Zigbee standard theoretically

provides 250kbps data rate, and as 40kbps can meet the requirements of most control systems, it is sufficient for controlling the system.

The power measurement application encompasses many services and appliances within the home and workplace, all of which need to be able to communicate with one another. Therefore, open standards architecture is essential. Zigbee provides true interoperability between systems. Zigbee also help to future-proof investment made by both utilities and consumers. Zigbee also provides strong security capabilities to prevent mischief, and is extremely tolerant of interference from other radio devices, including Wi-Fi and Bluetooth. Zigbee- enabled meters form a complete mesh network so they can communicate with each other and route data reliably. And the Zigbee network can be easily expanded as new homes are built or new services need to be added. Figure 2 shows Zigbee module.

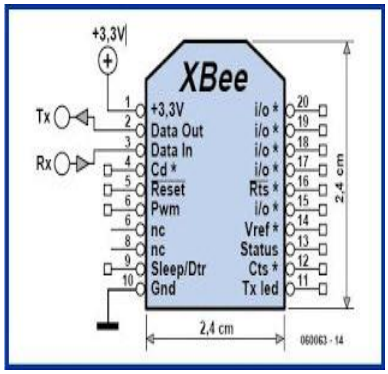

Figure- 2 Zigbee module

2.3 Tarang Module

Tarang module is designed with low to medium transmit power and for high reliability wireless networks. The module requires minimal power and provides reliable delivery of data between devices. The interfaces provided with the module help to directly fit into many industrial applications. The modules operate within the ISM 2.4-2.4835 GHz frequency band with IEEE 802.15.4 baseband.

Features

- Range - Outdoor line of sight: up to 50kms.
- Transmit Power: up to 1 watt / 30 dbm nominal.
- Receiver Sensitivity: up to –107 dbm.
- Direct sequence spread spectrum technology.

2.4 Flow Chart of Smart Meter Operation

Figure 3 shows the flow chart of smart meter operation.

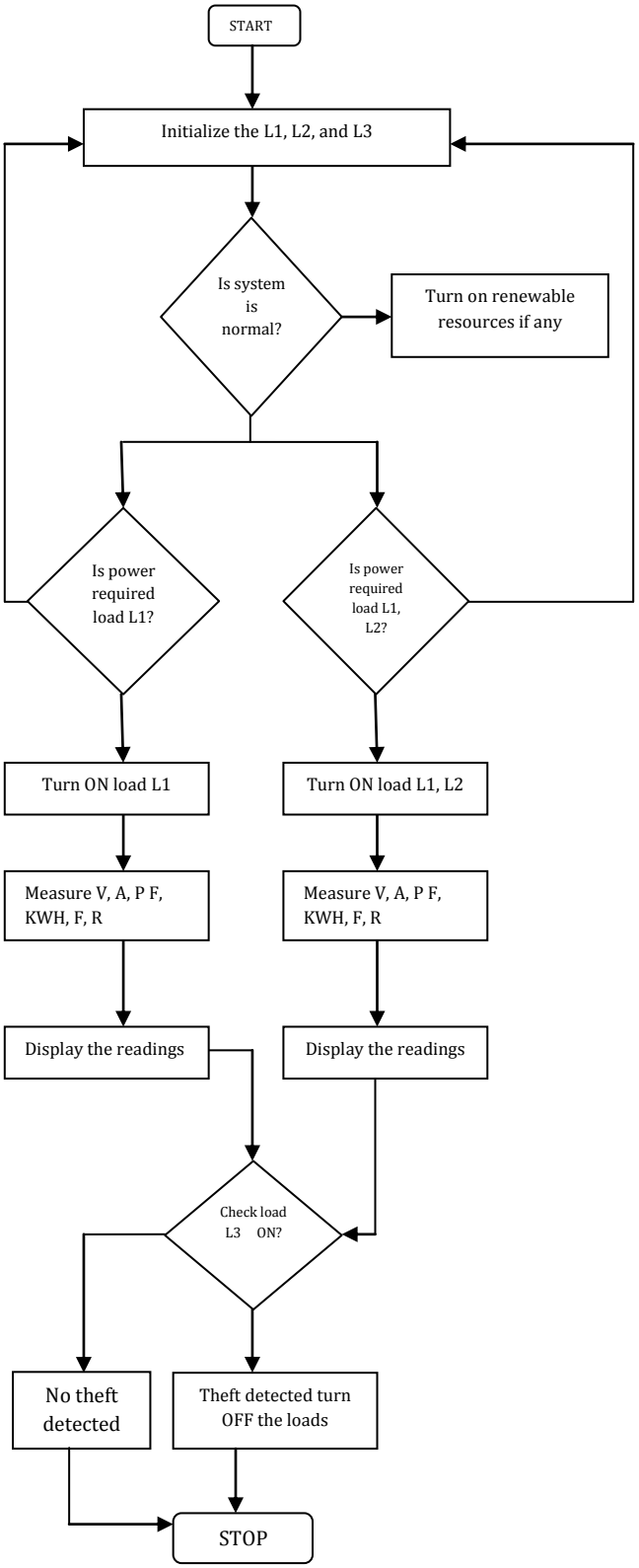

Figure- 3 Flow chart of smart meter operation.

2.5 Smart Grid

Smart Grid is the modern development in electricity grid. Recent electrical grids are becoming weak with respect to the electrical load variation of appliances inside the home. The higher the population, the more load on the grid. Improving the efficiency of grid by remotely controlling and increasing reliability, measuring the consumptions in a communication that is supported by delivering data (real-time) to consumers, supplier and vice versa is termed as Smart Grid. Automated sensors are used in Smart Grids. These sensors are responsible in sending back the measured data to utilities and have the capability to relocate power failures and avoid heating of power lines. It employs the feature of self-healing operation. Literally, the concept of Smart Meter is commenced from the idea of Smart Grid. Figure 4 shows the architecture of smart grid.

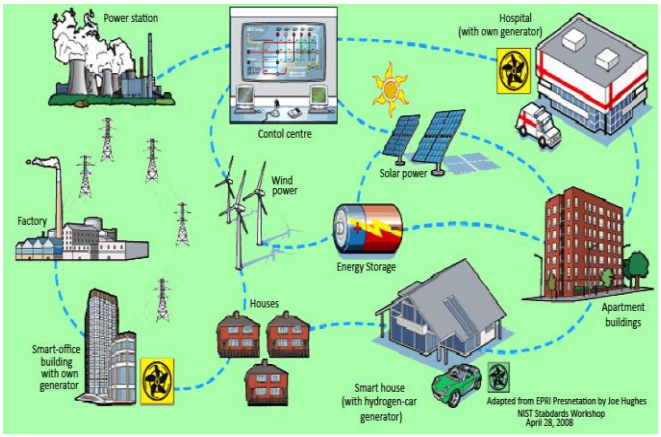

Figure-4 Architecture of smart grid

2.5.1 ***Benefits of Smart Grid***

- Smart grid basically enables better energy management by integrating isolated technology.
- During emergency situations smart grid enables proactive management of electrical network by automatically detecting and accordingly responding to the problems.
- It can exactly determine from where the power has been stolen which was not able in the conventional power grid. It can be able to provide power to the high priority based applications by easily routing the power distribution with less effort and time.
- It improves power reliability, quality and also help reduced the greenhouse gas emissions. The smart grid also provides a helping hand in expanding development of renewable and distributed energy sources.

2.6 Relay Unit

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. Relays are used where it is necessary to control a circuit by a low-power signal or where several circuits must be controlled by one signal. Figure 5 shows the relay circuit.

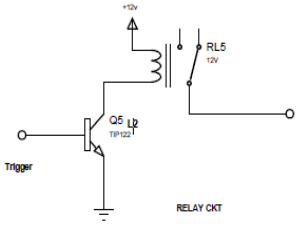

Figure-5 Circuit diagram of relay

2.7 Voltage Transformer

The voltage transformer is one in which the secondary voltage is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections. In an ideal transformer, the secondary voltage vector is exactly opposite and equal to the primary voltage vector, when multiplied by the turn's ratio. In a practical transformer, errors are introduced because some current is drawn for the magnetization of the core and because of drops in the primary and secondary windings due to leakage reactance and winding resistance. Figure 6 shows the circuit diagram of potential transformer.

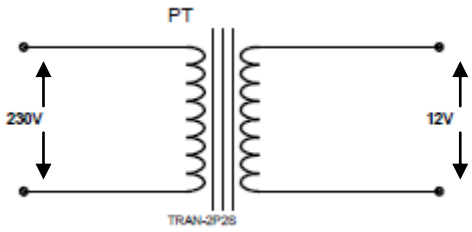

Figure-6 Circuit diagram of potential transformer

2.8 Current Transformer

A current transformer is defined as as an instrument transformer in which the secondary current is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections. This highlights the accuracy requirement of the current transformer but also important is the isolating function, which means no matter

what the system voltage the secondary circuit need be insulated only for a low voltage. The current transformer works on the principle of variable flux. In the ideal current transformer, secondary current would be exactly equal and opposite of the primary current. But, as in the voltage transformer, some of the primary current or the primary ampere-turns are utilized for magnetizing the core, thus leaving less than the actual primary ampere turns to be transformed into the secondary ampere-turns. This naturally introduces an error in the transformation. The error is classified into two-the current or ratio error and the phase error. Thus by considering all these parameters are program into the microcontrollers to calculate the amount of power actually consumed. Figure 7 shows the current transformer.

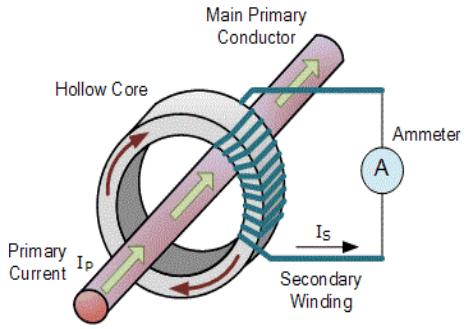

Figure-7 Current transformer

2.9 Smart Meter

Smart Meters are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems. Initially, the use of this technology was applied to commercial and industrial customers due to the need for more sophisticated rates and more granular billing data requirements. The use of electronic meters came into service to the largest customers of the utility and over time gradually expanded to all customers. This migration was made possible by decreasing cost of the technology and advanced billing requirements for all customers. The combination of the electronic meters with two-way communications technology for information, monitor, and control is commonly referred to as Advanced Metering infrastructure (AMI). The main task of the smart meter is to measure the power consumption and report related data to the Distribution Service Operator (DSO), also called Energy Service Provider (ESP) for billing.

2.9.1 Advantages of Smart Metering

Avoidance of manually reading meters as in the case of traditional meters is one of the significant benefits which are possible through remote reading of meters. Any disturbance in the service can be detected easily resulting in faster response times, real time recording of consumption data and accurate billing improves the competence of metering services. This results in low number of customer complaints which is an advantage for the utility providers.

2.9.2 Benefits of Smart Meter

Benefits to the customer:

- Consumers get more information about their energy usage.
- Bills are based on actual consumption.
- Power outages are reduced.
- The necessity of bill estimation is reduced.

Benefits to the utilities:

- Demand peaks are reduced.
- Remote controlling enables better management of billing.
- Automated and remote meter reading.
- Electric systems are monitored more quickly.
- Enabling more efficient use of power resources
- Power outages are reduced.
- Enabling dynamic pricing.

2.10 Liquid Crystal Display

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly. LCDs are available to display arbitrary images such as preset words and digits. Thus it can able to get information by the display. Figure 8 shows the lcd display.

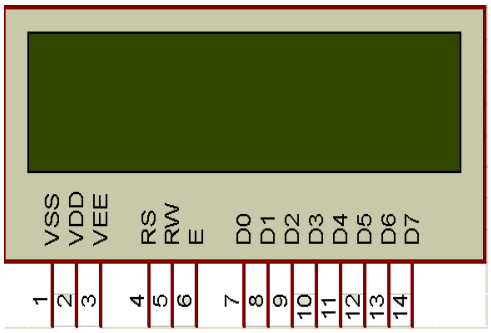

Figure-8 Lcd Display

2.11 Signal Conditioning

Most analog signals require some form of preparation before they can be digitized. Signal conditioning is the manipulation of a signal in a way that prepares it for the next stage of processing. Many applications involve environmental or structural measurement, such as temperature and vibration, from sensors. Signal conditioning can include amplification, filtering, converting, range matching, isolation and any other processes required to make sensor output suitable for processing after conditioning.

3 SIMULATION AND RESULTS

3.1 Software Tools

The corresponding design specification is achieved through the following software.

- ISIS proteus toolkit

3.1.1 ISIS Proteus Toolkit

The purpose of the proteus toolkit is to simulate the creation of a schematic circuits and how to conduct an interactive simulation using proteus VSM. User will concentrate on the use of active components and the debugging facilities of the ISIS editor, the basics of laying out a schematic and general circuit management is also covered in the software.

Proteus toolkit combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. It helps to develop and test such designs before a physical prototype is constructed. The Proteus Design Suite is unique in offering the ability to co-simulation both high and low-level micro-controller code in the context of a mixed-mode SPICE circuit simulation. PCB editing software that is included in the Proteus Design Suite. It is fully compatible with ISIS Schematic Capture.

3.1.2 Working Procedure of The ISIS 7 Proteus

STEP 1: Run the ISIS professional program by clicking the icon on the desktop, then this splash screen will appear.

STEP 2: Next, a work space with interface buttons for designing circuit will appear. Note that three is a blue rectangular line in the workspace; make sure that whole circuit designed inside the rectangular space.

STEP 3: Select the components from library. In menu bar library → pick device / symbol. Then one window will open that shown in below is another way to select the components. In work space left side there is a tool bar. In that tool bar click the component mode button or pick from library.

STEP 4: Select the all components from library, that components are added to devices list. Click on the device and change the angle of the device by using rotate button. Then click in the work space then the selected component is placed I work space.

STEP 5: Place all the devices in work space and put the curser at the component pin end then draw the connections with that pen symbol. Connect all the components according to circuit then that designed circuit is show in below image.

STEP 6: If any modifications want to do the component place the mouse point and click on right button then option window will open.

STEP 7: The components are connected with the wires or it can connect with the wire label by giving comm..on wire label.

3.2 Circuit Diagram of Smart Meter

The schematic representation is shown in following figures which shows the connection of current transformer (CT), LCD, switches, potential transformer (PT), load, with the microcontroller. The CT is used for measuring the current (A). The potential transformer is used to measure the voltage (V). It consists of two sections, one is EB section and another one is home section. Two types of loads are connected in the home section to analyze the consumed power. Figure 1 shows the simulation diagram of smart meter.

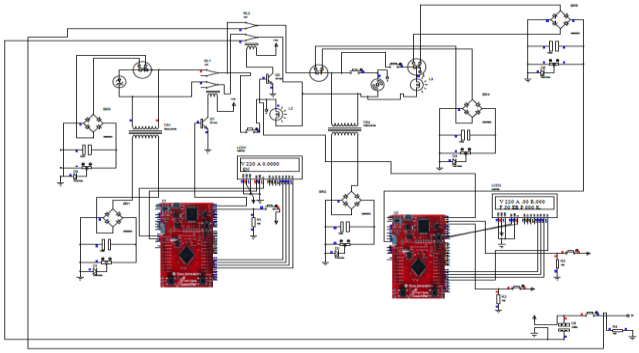

Figure-1 Simulation diagram of smart meter

3.3 Simulation of Measuring Voltage, Current And Consumed Power

Case 1: In Figure 2, when load L1 is ON, the voltage value (220 V), current value (0.4545 A), consumed power (kWh), frequency (50 Hz) and power factor (0.72) are displayed in both the sections. Based on the power consumption, the billing price is gradually increased.

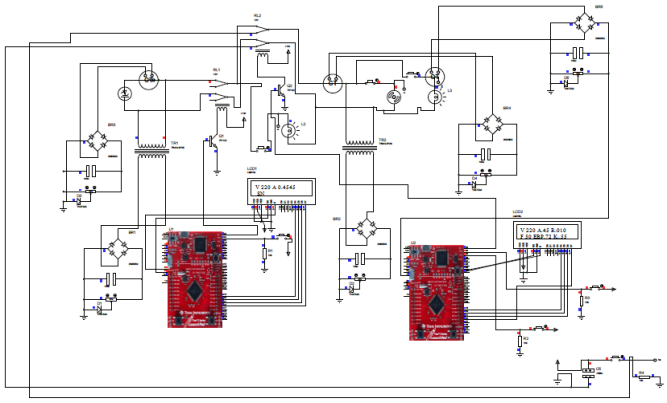

Figure-2 Simulation diagram of smart meter when load L1 is ON

Case 2: In Figure 3, when load L2 is ON, the voltage value (220 V), current value (0.3636 A), consumed power (kWh), frequency (50 Hz) and power factor (0.58) are displayed in transmitter and receiver sections. Based on the power consumption, the billing price is gradually increased.

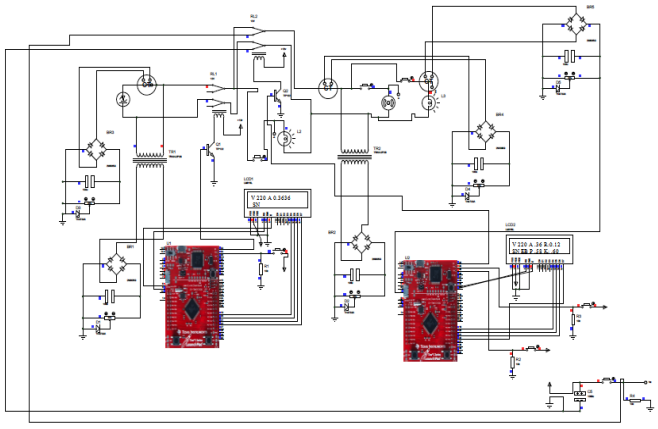

Figure-3 Simulation diagram of smart meter when load L2 is ON

Case 3: In Figure 4, when load L1 and L2 are ON, The voltage value (220 V), current value (0.8181 A), consumed power (kWh), frequency (50 Hz) and power factor (0.30) are displayed in both the sections. Based on the power consumption, the billing price is gradually increased.

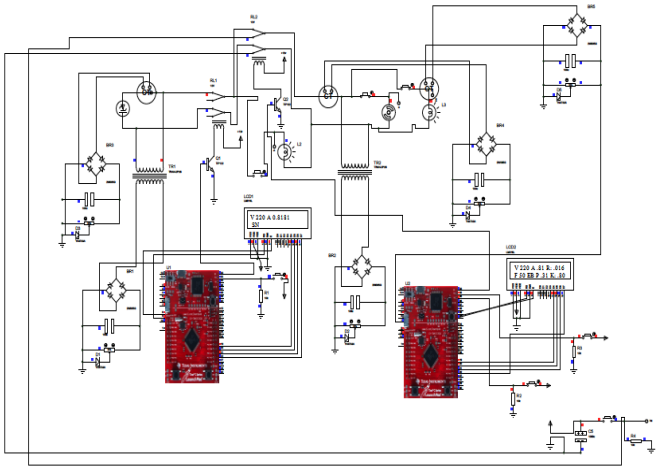

Figure-4 Simulation diagram of smart meter when L1&L2 are ON

3.4 Simulation of Smart Meter For Identifying Power Theft

In Figure 5, both the energy meter readings are monitored simultaneously. When the mismatch occurs, then it is the indication of the power theft. Extra load connected before the home unit helps to detect the theft occurrence in the transmission line. Once the power theft is identified in the EB section then the other loads are shut down in the home section automatically.

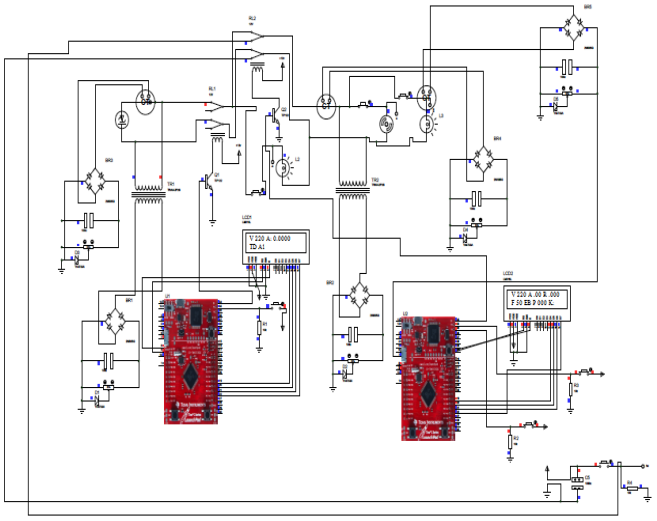

Figure-5 Simulation diagram of smart meter for detecting power theft

3.5 Simulation of Smart Meter When Renewable Resources Are On

In Figure 6, renewable energy is integrated with smart grid technology which operates in standalone or parallel with smart grid in case of peak demand and urgent cases. When a renewable resource switch is turned on, consumed power, power factor and billing amount in the home section drops to zero and the entire home section will be operated in renewable resources. RS represents the renewable resources which are displayed in LCD, intimating renewable resources switch is in active state.

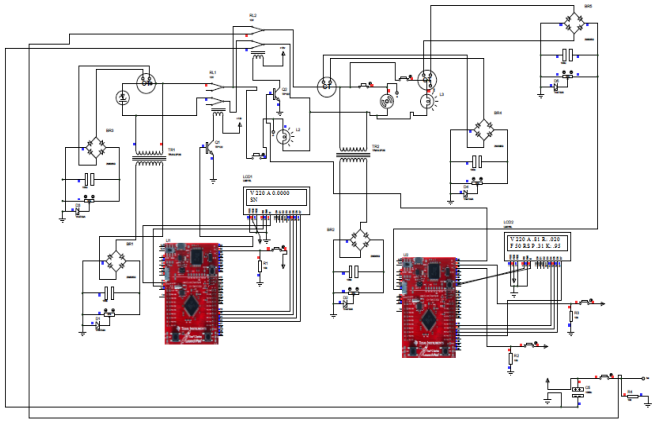

Figure-6 simulation of smart meter when renewable resources are on

4 CONCLUSIONS

In this project, the proposed smart meter system using proteus software has been proposed. This system which records the energy utilized by the consumers and transmits that information to the utilities for monitoring, controlling, billing and other purposes. The collected data's and parameters such as voltage, current, power factor, consumed power, frequency and billing amount are transmitted to the monitor section as well as the home section. Hence smart meter will reduce the man power and provides accuracy. Smart meter also reduces the difficulty faced by the people when readings are taken manually. The proposed smart meter provides better accuracy in meter reading, better control over distribution and management.

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