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IoT based Smart Energy Meter

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Abstract - *One avenue through which today's energy problems can be addressed is through the reduction of the energy usage in households. The existing system provides the feedback at the end of the month in the form of bill and consumed kilowatt hours (kWh). The Arduino based wireless power meter is a noninvasive power meter. Current is measured using split core current transformer. This data is then transmitted over a Wi-Fi connection to the base station. The project aims to provide a clear picture of a home's current usage, and through this data provide an estimate to power consumption. The goal of provided such a data to a user is that they will optimize and reduce their power usage.*

Key Words*: *Smart Energy Meter, Non-Invasive, Current transformer, Arduino, Wi-Fi.

1. INTRODUCTION

In the existing power utility set up, consumers are presented with usage information only once a month with their bill. The length of time between updates about power usage is far too long for a consumer to observe a changed behavior's effect on power usage. In addition utility bills can be convoluted in how they present usage information, and a consumer may not be able to decipher changes in their power usage from the last bill. An opportunity to educate customers on power usage is lost because of these realities. If a person can instantaneously see how much power leaving a device on by accident consumes per minute, they may be more careful in the future about letting devices run when not needed. The goal of creating more awareness about energy consumption would be optimization and reduction in energy usage by the user. This would reduce their energy costs, as well as conserve energy.

In most households, power comes into the house through a three wire, single phase connection. One "hot" wire carry current into the circuit breaker. A neutral wire also provides a connection for ground for the house circuit. A hot wire has an RMS voltage of 240V +/- 5%. The apparent power consumed by a household can be found by taking the product of the RMS voltage and total RMS current. The real power can be calculated from discrete samples by taking the average of the product of the voltage and current samples over a specified window. The power factor can be calculated by dividing the real power by apparent power. This project only included current measurements, and thus both power measurements are estimates, as opposed to measurements.

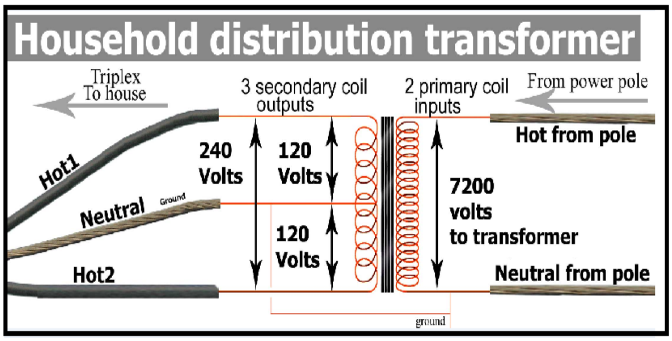

Fig -1: Household Power Connection

2. WORKING OF SMART ENERGY METER

The hardware of the system consists of three parts: sensor capture, the MCU board, and the wireless board. The sensor capture hardware consists of the current transducers and rectifier circuit, connected to the analog to digital converter (ADC) of the MCU. The MCU board is a standalone Arduino Uno development board. The wireless board is a shield designed to pair with the Uno.

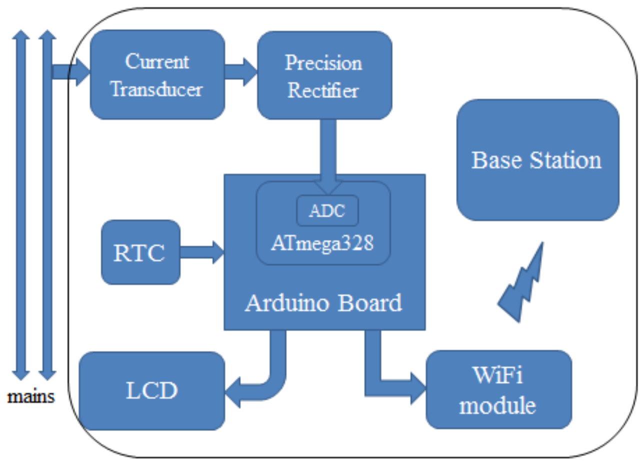

Fig -2: Block Diagram

The Arduino based wireless power meter centered on the design and development of a current measurement device with an ESP8266 Wi-Fi module to a base station running a graphical user interface (GUI). The software portion of the project resided on the Arduino board and on the base station computer. Current was measured from the two current carrying wires into the main power panel, sampled by the Arduino board, and then sent as a UDP packet over the Wi-Fi network to the base station computer. The base station's software then parsed the packet, and converted the raw analog to digital conversion into current data, where it could be used to either display current usage to the user, or estimate power or estimate power for display to the user. The current measurement circuit connects to the Arduino board through analog pins 0 and 1.This allows the Arduino to sample the output voltage from the current measurement circuit with the ATMega328's 10-bit ADC. A voltage of 3.3V was applied from the USB to serial converter chip to the voltage reference pin, AREF, in order to provide the ADC with the required reference voltage. Connections to the ground and VCC pins were also provided for the op amp in the precision rectifier.

A split core current transducer is non-invasive in nature. The sensor can be clamped onto the mains lines without interrupting power into the circuit breaker. Avoiding interrupting the lines into the circuit breaker makes the installation of the sensors both safer and easier. Current transducer is clamped onto "hot" wire going into the circuit breaker. The total current being drawn by the household is the sum of the measured current in both wires. The output of the current transducer is an AC voltage proportional to the AC current enclosed by the sensor's ring. The required output voltage is determined by this equation:

$$V = I*R /3100$$

Where V is RMS AC voltage across the burden resistor, I is the RMS AC current enclosed by the transducer, and R is the resistance of the burden resistor. This equation means that the output range of the sensor is determined by the selection of the burden resistance R.

The output of the sensor could not directly interface with the Arduino board because of the maximum limits of reverse voltage on the MCU pins. A rectifier was therefore required to ensure that a negative voltage would not be applied to the pins of the MCU. Two rectifier circuits were considered for this role: a full wave rectifier using a diode bridge, and a half wave precision rectifier an op amp. Diode Bridge was also paired with a smoothing capacitor and discharging resistor in hopes of reducing the voltage ripple. This design proved inadequate due to the forward voltage drop of the bridge rectifier and response to rapid changes in current. A precision rectifier is built around an op amp, two diodes, and two resistors. Using this circuit instead of the diode bridge solved the forward voltage drop problem, because the op amp corrects the output for any voltage loss over the two diodes. AC ripple was allowed to reach the analog pin and dealt with in software. The transceiver module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to Wi-Fi network.

The transceiver is capable of either hosting an application or offal doing all WiFi networking functions from another application processor. Each transceiver module comes pre-programmed with an AT command set firmware, meaning, we can simply hook this up to microcontroller device and get about as much Wi-Fi ability as a Wi-Fi Shield offers. The transceiver module is an extremely cost effective board. Transceiver is an impressive, low cost Wi-Fi module suitable for adding Wi-Fi functionality to a microcontroller via a UART serial connection. The module can even be reprogrammed to act as a standalone Wi-Fi connected device.

3. CIRCUIT DIAGRAM AND SIMULATION RESULT

As discussed in the block diagram of the system, the system consists of mainly three major sections i.e. Input Section, Processing Section, Output Section.

3.1. Input Section

Input section consists of the non-invasive current transformer or also known as current transducer, rectifying circuitry and filters. The function of the current transducer is to accept the generated voltage across it and pass on to the rectifying circuit. The burden resistor connected across the current transducer converts the produced current into the required voltage. Hence the value of burden resistor is chosen in such a way that the produced voltage is compatible with the voltage required by the processing section to process. Hence in short the current transducer along with the burden resistor produces the proportional AC current according to the current applied to it.

In this case the value of voltage at input does not matter at it remains constant and has a standard value of 230V/50Hz. The load connected to the power supplies in the residencies, industries etc. are connected in parallel to the supply. Hence the voltage remains constant in parallel connection but the current varies as per the load vary.

The output of the current transducer is given to the rectifying circuitry. The type of rectifying circuit used is precision rectifier. The task of precision rectifier is to convert the AC voltage into the pulsating DC voltage. It does not give the pure DC voltage. The purpose of using precision rectifier and not the usual bridge rectifier is because of the forward drop by the bridge diode and response to rapid changes in the circuit. The forward voltage drop of the device was around 1.1V and depended on the current flowing through the device. A voltage drop this large essentially meant that the currents below 1/3 of the maximum voltage would not be detected at all.

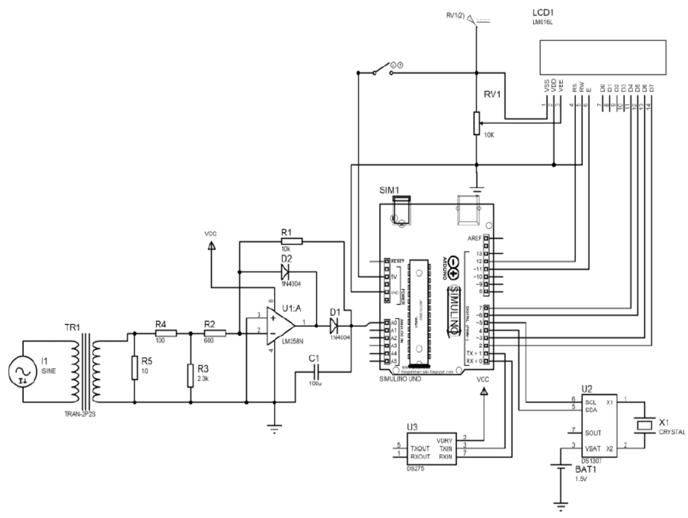

Fig -3: Circuit Diagram

Hence these causes hampered the accuracy and real-time response of the system. The above figure shows the output waveform of the precision rectifier. The output of precision rectifier is in the range of 0V-5V as it is compatible to the ADC of the Arduino board for the reference voltage i.e. 0V as minimum level and 5V as maximum level.

The output of the precision rectifier is given to the smoothing filters to remove the AC ripples and convert the pulsating DC voltage into the accurate and ideal DC voltage. The smoothing capacitors can be used as the filters as they are very easily available and also do not effect on the performance of the system. They also don't make the circuit very bulky. For the protection of the circuit from back current or the sudden high spike of voltage zener diode can be used after the filter.

3.2. Processing Section

Processing section consists of the Arduino development board. The purpose of using Arduino board is because of its compactness and simplicity in programming and interfacing the required components. Arduino board can be considered as the brain of the system. The accepting input from input module, calculation of consumed power, transmission of data, displaying the data on LCD display all the functions are controlled by the Arduino board. Now the calculation of power and its conversion into the units is done by the following formulae.

$$\boldsymbol{Voltage}\ (\mathrm{V}) = \frac{I * R}{1800}$$

Where,

I = Current from the input section

R = Burden resistor

$$\boldsymbol{Current}\ (I) = \frac{ADC\ value * 1800 * V_{ref}}{1023 * 1.414 * R}$$

Where,

V_{ref} = Reference voltage given to arduino board.

R = Burden resistor

$$\boldsymbol{Power}\ (P) = V * I$$

3.3. Output Section

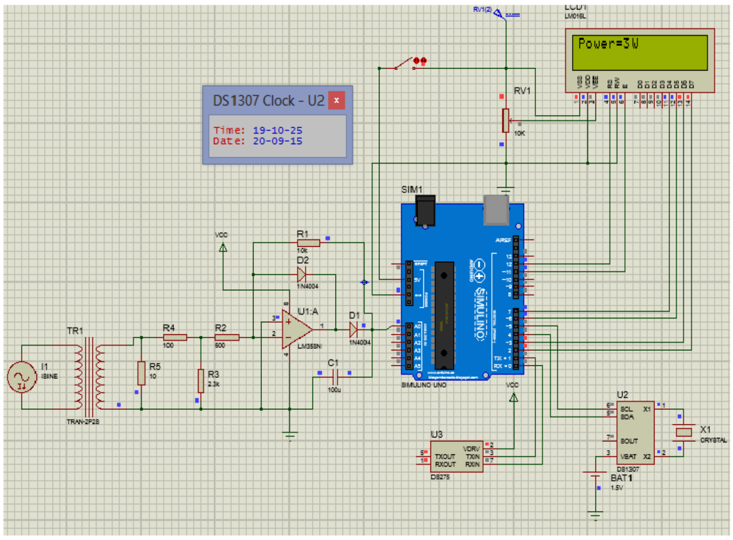

Fig -4: Simulation of Circuit Diagram

Output section consists of the LCD display and the transceiver module. The output generated by the Arduino board is displayed on the LCD display and transceiver module is used to transmit the data over the Ethernet and store the data in the database of the user created by the provider. RTC is used to provide interrupt to the Arduino and enable the transceiver pin.

Simulation of the designed circuit diagram was done using the Proteus 8.0 software and the required results were checked and verified according to the specifications. Proteus provides the real time simulation of the designed circuitry to the user for testing purposes. The above diagram also shows interfacing of the input module, LCD display, transceiver module and RTC module with the Arduino Development board.

The input given to the current transformer is the 230V/50Hz and the current is the variable parameter which varies from 0A-32A as per the change in the load. The load and the current are directly proportional to each other. There is increase in value of current are directly proportional to each other. There is increase in value of current as load is increased. The output produced at the current transformer secondary is the proportional current according to the current at its primary. This produced proportional current is transformed into AC voltage by using burden resistor.

A database would be created for storing the data of the user's name, address, data of consumption of power, calculation of cost. At the transmitting end the RTC would interrupt the Arduino and data in packet form would be generated at the transceiver module and the data would be transmitted to the created database. The data would be stored in particular user's profile. For transmission of data the particular suitable protocol would be used which would efficiently transfer the data. Designing of websites and creating the database would be done by using Java Applets, Servlets, and Swings etc. The software environment to be used will be Eclipse IDE.

4. IMPLEMENTATION AND RESULTS

Fig -5: Smart Energy Meter

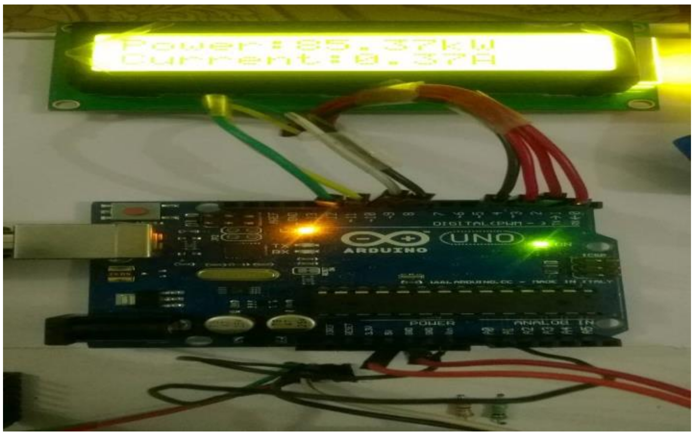

Fig -6: Smart Energy Meter Measuring Consumed Energy

The figure 5 and 6 shows the transmitter side of the system. The calculation of the consumption of electricity is done in the Arduino uno and transmitted using ESP8266. LCD display is used to display to the user.

The transmitted data send on the IoT based website ThingSpeak.com and the data can be represented in many forms like tables, pie-charts, graphs etc. Also the data can be stored in the database like Oracle, MS-Access etc.

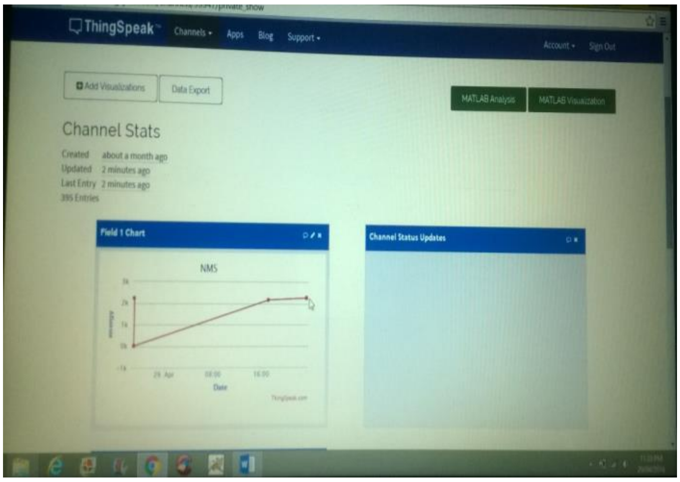

Fig -7: Transmitted Data displayed on ThingSpeak

5. CONCLUSIONS

The project describes the design and working of Smart Energy Meter and represents how Smart Energy Meter can be used for Automatic Meter Reading. It is the most economical implementation to develop mankind in this era of technology. With the present enhancement in the use of technology to facilitate mankind, it is an efficient and practical utilization of present networks. System is providing real time data and convenient billing system. It provides more accurate energy statistics and good governance in billing system.

6. FUTURE SCOPE

Smart Metering has very wide scope in future for research and development. A complete home automated system can be generated including additional features like over voltage protection, over current protection, calculation of consumed energy by specific applications etc. Also the system can be built for industrial applications including features like calculation of power factor, phase etc. For future research, it is suggested that image processing be done in the mobile device as the image gets captured. The send the numeric value can be sent to the server through Web service. However the use of GSM in this particular system provides numerous advantages over methods that have been previously used. Data transmission is charged at standard SMS rates, thus the charges are not based on the duration of data transmission. The cost efficient transmission of readings ensures that power consumption values can be transmitted more frequently to a remote station.

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