Intelligent HEMS using IOT Enabled Smart Energy Meter with Renewable Energy Source

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Abstract: With increasing population, the demand for power is increasing at an exponential rate. Power theft, unpaid bills, poor usage of energy leave the energy market crippled. Hence to increase energy consumption efficiency, monitor power quality, closely monitor the energy usage pattern of customers many utilities have employed smart energy meters. The primary goal is to provide a bi - directional communication between customer and the utility. The main aim is to reduce the energy consumption and also reduce the electricity bill. This Home Energy Management system (HEMS) provides the detailed information about their energy consumption. The Time of Use price (TOU) is notified to the customers, so the customers can manage the usage of loads. In this modern energy meter are used to measure the accurate power consumption and intelligent load schedule given to our home. During the peak load time if the demand is exceed the power supply will cut off and the load will be operated by using renewable solar energy source. Users are known the electricity usages at easily and save the unwanted power consumption and money by using the IOT Module.

IndexTerms **- HEMs,TOU,IOT.**

I. INTRODUCTION

Smart Energy Meter is a device which monitors the consumption of electrical energy by the customers and communicates the information to the utility for the customer at set intervals. Customers are more aware of their energy consumption and utility can curtail manual reading of energy meters hence improving accuracy and saving time. The system that utilizes simplex communication to read the energy meter data is called Automated Meter Reading (AMR), and which facilitates bi-directional communication between the customer and utility is called Advanced Metering Infrastructure (AMI). The basic aim behind employing AMR is for taking automatic reading of energy meter data. Hence it increases efficiency and helps utility to closely monitor energy meter data. AMI is a step ahead of AMR which incorporates into itself a special infrastructure for duplex communication architecture. The communication medium ensures data transfer between the customer and utility server. Various communication options are available example wired- Power Line Communication (PLC), Local Area Network (LAN), Wireless- Global System for Mobile (GSM), Wireless Local Area Network (WLAN), General Packet Radio Service (GPRS) and Internet of things (IOT).

India Smart Grid Forum (ISGF) was established in 2010 with the primary goal to employ smart meter technology and stimulate the roll out of smart meters in India. Smart metering systems of different countries have been reviewed and smart meter systems for Korean residential have been developed. It also demonstrates the effectives of In Home Display (IHD), Design of simple prototype of smart energy meter using IOT, Design of an economic model of smart energy meter for Ontario residential have been presented. The present scenarios of Smart grid pilots and key performance indicators have been investigated. The feasible communication technology for deployment in Advanced Metering Architecture (AMI) has been discussed and a cost effective smart energy meter have been proposed. Their work is limited to just design of smart energy meter. Also, their model incorporates use of dedicated equipment's such Liquid crystal display (LCD) only. Also, no work has been reported on design on smart energy meter practicing Time of Use (TOU) pricing. Also, no methodology for intelligent scheduling of load appliances in correspondence with TOU is proposed.

The main objectives of the work are

a) Design of a Smart energy meter.
b) Design of an IHD.
C) Design of TOU pricing and analysis of results.
d) Design of methodology for intelligent scheduling of Appliance.

II.EXISTING SYSTEM

In traditional days rotating wheels are used to measure the total energy consumption of home appliances. And also nowadays we are using the digital meter. This meter have sensor to show only voltage, current, power factor, frequency readings. But it does not monitor and control the any loads.so this does not give any rectification about the energy wastage and it also can't reduce the electricity bill. There is no bi-directional communication between the customer and utility.

III.PROPOSED SYSTEM

Smart energy meter which have the sensors to measure the current, voltage and power quality parameters. The data from these smart energy meters are collected by data concentrator of level-0.The data are communicated by IOT MODULE. The data are processed and analyzed in the utility. The brain of a smart energy meter is an Arduino UNO microcontroller which reads voltage, current and the squared pulse wave generated by XOR gate of current and voltage waveform. It calculates the energy utilization data using RF transceiver and the calculated data is sent to the Arduino UNO connected to the system with LABVIEW. Real power, instantaneous voltage, instantaneous current, Harmonic analysis of voltage waveform, percentage total harmonic distortion (THD), detected fundamental frequency, magnitude spectrum of the voltage waveform, frequency spectrum of the voltage waveform, indication for automatic tripping of load appliances are displayed in the IHD. The energy data is communicated to the utility server using GPRS and customers mobile phone using GSM. Thereby establishing a bidirectional communication between the customer and utility.

The main functional features of the smart energy meter are

a) Read and process voltage, current.
b) Measure the time difference between the current and voltage waveform.
c) Transmit the information to the utility web hosting server using WLAN and customers mobile phone using GSM.
d) Transmit data to IHD using RF transceiver.

IV. ARCHITECHURAL MODEL

The explanation of the architectural model is as follows

- When the various appliances of the household consume energy the energy meter reads the reading continuously and this consumed load can be seen on meter.

Figure1: Architectural Model of HEMS using IOT Enabled Smart Energy Meter with Renewable Energy Source

- We can see that the LED on meter continuously blinks which counts the meter reading. Based on the blinking, the units are counted. Normally, 3200 blinks is one unit.
- In this paper we are trying to develop, a system in which Arduino Uno act as main controller, which continuously monitor energy meter.
- As per the blinking of LED on energy meter the Arduino will measure the unit consumption.
- The measured reading with the calculation of the cost will be continuously displayed on web page that we have designed.
- Threshold value can be set on webpage with the help of Wi-Fi, as per the consumer's requirement. When the consumers reading will be near about to the set threshold value it will send a notification value to the consumer.
- This threshold value notification will increase the awareness amongst the consumer about the energy.
- When the consumer gets the notification he can visit the webpage and change the threshold value.
- If the consumer is not aware with the threshold notification, then the meter will automatically get off. Then the consumer has to visit the webpage again and increment the threshold value. By the incrementation, the meter will automatically get ON.
- Finally the overall monthly bill with cost will be sent to customer as well as service provider in the form of text at first day of every month.

V. Block Diagram

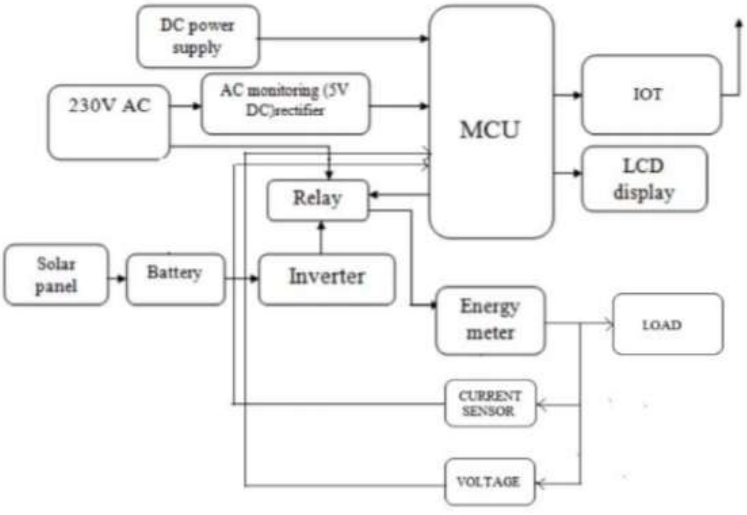

Figure 2: Block Diagram of Home Energy Management System

5.1 POWER SUPPLY

A power supply is an electronic device that supplies electric energy to the Arduino Micro controller. The primary function of power supply is to covert one form of electrical energy in to another and as a result, power supplies are sometimes referred as electric power converters. Some power supplies are discrete, stand-alone devices, whereas others are built into larger devices along with their loads.

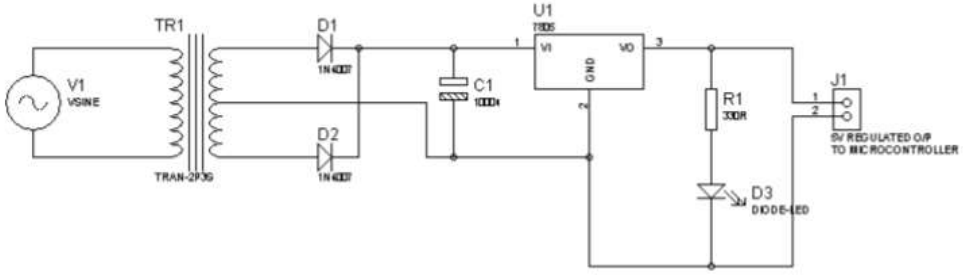

Figure 3: Power Supply Unit with Regulator

5.2 ARDUINO (ATMEGA 328)

The Arduino is a Micro controller board based on the ATmega328 (data sheet).It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs ,16 MHz crystal oscillator, a USB connection , an ICSP header, and a reset button.

Figure 4: ARDUINO (ATMEGA 328)

Arduino board is the heart of our system. Entire functioning of system depends on this board. Arduino reacts to the 5V supply given by opto-coupler and keeps on counting the supply and then calculates the power consumed and also the cost. This data, it continuously stores on webpage, so that users can visit any time and check their consumption. It even reacts accordingly as per programed, to the situations like message sending during threshold value etc.

5.2.1 Features

• High-performance, Low-power AVR® 8-bit Microcontroller
• Advanced RISC Architecture
- ✓ 130 Powerful Instructions – Most Single-clock Cycle Execution
- ✓ 32 x 8 General Purpose Working Registers
- ✓ Fully Static Operation
- ✓ Up to 16 MIPS Throughput at 16 MHz
- ✓ On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory segments
- ✓ 8K Bytes of In-System Self-programmable Flash program memory
- ✓ 512 Bytes EEPROM
- ✓ 1K Byte Internal SRAM
- ✓ Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- ✓ Data retention: 20 years at 85°C/100 years at 25°C(1)
- ✓ Optional Boot Code Section with Independent Lock Bits
- ✓ In-System Programming by On- chip Boot Program
- ✓ True Read-While-Write Operation
- ✓ Programming Lock for Software Security

• Special Microcontroller Features
- ✓ Power-on Reset and Programmable Brown-out Detection
- ✓ Internal Calibrated RC Oscillator
- ✓ External and Internal Interrupt Sources
- ✓ Five Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, and Standby

• I/O and Packages
- ✓ 23 Programmable I/O Lines
- ✓ 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF

• Operating Voltages
- ✓ 2.7 - 5.5V (ATmega8L)
- ✓ 4.5 - 5.5V (ATmega8)

• Speed Grades
- ✓ 0 - 8 MHz (ATmega8L)
- ✓ 0 - 16 MHz (ATmega8)

• Power Consumption at 4 Mhz, 3V, 25°C
- ✓ Active: 3.6 mA
- ✓ Idle Mode: 1.0 mA

5.3 IOT

IOT is the Internet of Things refers to the concept of extending internet connectivity beyond conventional computing platforms such as personal computers and mobile devices. It gives the bidirectional communication between the customer and utility.

Figure 5:IOT Representation

The IoT allows objects to be sensed or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical system, which also encompasses technologies such as smart grids, virtual power plants, smart homes and smart cities. Each thing is uniquely identified through its embedded computing system but is able to interoperate within the existing internet infrastructure People also want to communicate with all non-living things through internet such as home appliances, furniture's, stationeries, cloths etc. The people already have a lot of technologies to interact with living things but IoT enables to communicate with non-living things with comfort manner. IoT is a convergence of several technologies like ubiquitous, pervasive computing, Ambient Intelligence, Sensors, Actuators, Communications technologies, Internet Technologies, Embedded systems etc.

5.4 LCD DISPLAY

LCD is a display which is used in the In-Home Display (IHD).It shows the values of energy consumption readings, voltage , current, power factor readings. And also it indicates the peak time period to consumers. So this will provide the detailed information about their energy consumption.

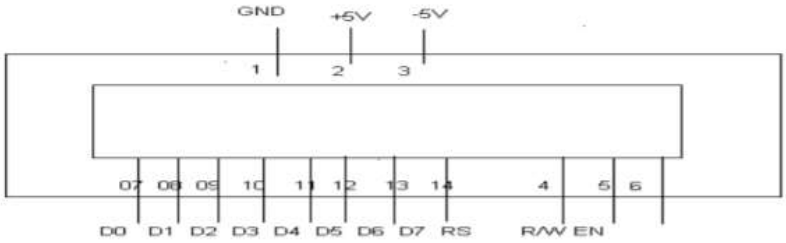

Figure 6 : LCD Display

5.5 RECTIFIER

Rectifier is an electrical device that converts alternating current into direct current (AC to DC) which flows in only one direction. This process is called rectification process.

5.6 RELAY DRIVER

A relay driver circuit is a circuit which can drive, or operate, a relay so that it can function appropriately in a circuit. The driven relay can then operate as a switch in the circuit which can open or close, according to the needs of the circuit and its operation.

Figure 7 :Relay Driver

This is a relay driver circuit which can be driven by either AC or DC input voltage. And unlike the other circuits, a specific voltage, such as the rated voltage values we used to drive the others, does not need to be used. Because this circuit contains a transistor, much less power needs to used on the input side to drive it

5.7 SOLAR PANEL

Photovoltaic solar energy comes from the conversion of sunlight into electricity using semiconducting materials, like silicon or covered with a thin metallic layer, that exhibit the photovoltaic effect. These photosensitive materials have the property of releasing their electrons under the influence of external energy. This is the photovoltaic effect. Energy is supplied by the photons (light components) which face the electrons and release them, inducing an electric current.

The electricity produced is available either as direct electricity or stored in batteries (decentralized electricity) or electricity fed into the grid. A photovoltaic generator is composed of photovoltaic modules themselves compounds of photovoltaic cells connected together.

5.7.1 PHOTOVOLTAIC TECHNOLOGIES

Different technologies are used to produce solar panels;the most common are those that use the following photovoltaic materials or technologies

- The crystalline silicon
- The amorphous Thin film Cells silicon

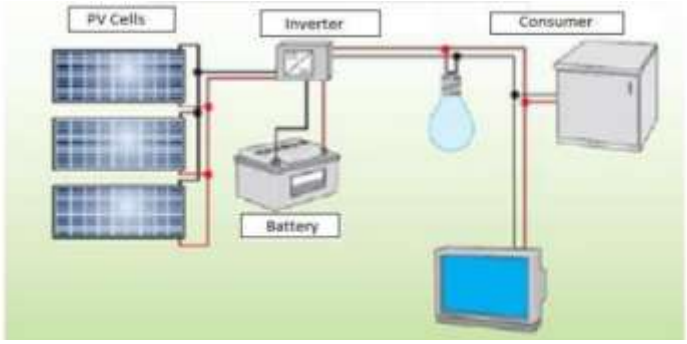

Figure 8 :Off Grid Solar System

5.7.2 COMPONENTS OF PHOTOVOLTAIC

The main components of a photovoltaic system:

- The photovoltaic solar panel: it produces the required amount of electricity.
- Solar charge controller and solar load limiter: protects the battery against overload and deep discharge.
- Solar Battery: It stocks the energy produced by the photovoltaic solar panel.
- Accessories:
  - ✓ Cables: They ensure the connection of components.
  - ✓ Converter: it adjusts the DC voltage from the solar battery to the receiver supply voltage if it is high or low.
  - ✓ Inverter: converts the direct current (DC) to alternating current (AC).

5.8 CURRENT TRANSFORMER

A CT is used for measurement of electric current .current transformer together with voltage transformer are also known as instrument transformer. A current transformer produces a reduced current accurately proportional to the current in the circuit which can be conveniently connected to the measuring and recording instrument.

5.9 BATTERY & INVERTER

Battery is used to store excess electrical energy produced by the one or more solar panels. This energy is stored in chemical form. At night it is the battery that provides energy. The storage is sized for a period of several days without sun, allowing for a wide range of emergency and taking into account the battery lifetime phenomena and loss of cycling-related capacity (charge and discharge).

The inverter is a DC-AC converter. For the Off grid system, the inverter provides power receivers operating on alternating current. We currently use inverters with an alternative quasi-sinusoidal output signal. For systems connected to the grid, you can use an inverter to transmit energy to the network. In this case, use a sine wave inverter, which costs 4 to 5 times more expensive than a quasi-sine wave inverter. The difference is that the signal is pure (sinusoidal) and that to reach this level, filters had to be used.

VI. CIRCUIT DIAGRAM

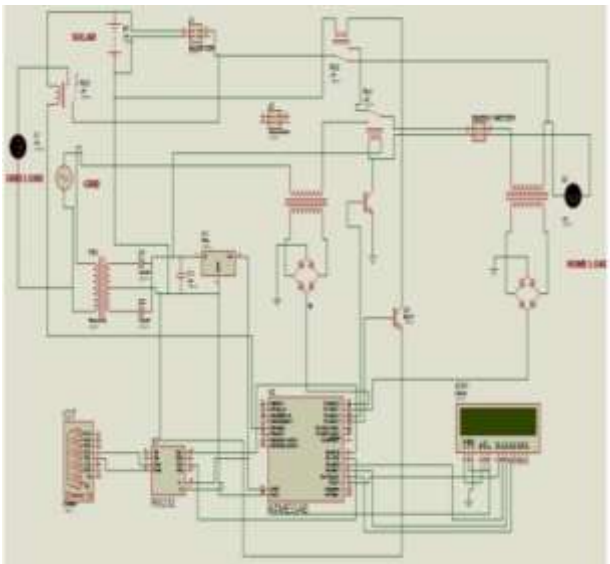

Figure 9: Circuit Diagram of HEMS using IOT Enabled Smart Energy Meter with Renewable Energy Source

6.1 WORKING PRINCIPLE

This System consists of Microcontroller unit, LCD Display, Sensors like Voltage and Current Sensor. The PCF8574 has a low current consumption and includes latched outputs with high current drive capability for directly driving LEDs or LCD Display. The I2C-bus is for 2-way, 2-line communication between different ICs or modules. The two lines are a serial data line (SDA) and a serial clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor when connected to the output stages of a device. Data transfer may be initiated only when the bus is not busy. One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as control signals.

The device consists of an 8-bit quasi bidirectional port and an I2C-bus interface. CT (Current Transformer) Sensor is used to measure the incoming current from the Power meter and shown in LCD Display. If you add load to the Power Meter it consume some power this value is shown in LCD as well as computer via serial communication. Voltage Sensor is used to find the voltage level from main supply and shown in LCD. This voltage value is sent to computer using TTL-USB convertor. The data in each register is transferred to the storage register on a positive-going transition of the storage register clock input (STCP). Shift Register which controls the 4 digit 7 Segment Led Display. GSM Module is used to send SMS to the Owner about billing Details and usage of Units. This alert message is received by owner instantly .The message contain Recent Current, Voltage and Usage values. Units are displaying in the 4 digit 7 segment LED Display. Along with this we use IOT service to make the global system connectivity to portrait the electricity oriented records to all its respective users via online.

VII. Hardware Implementation

Figure10: Hardware of HEMS using IOT Enabled Smart Energy Meter with Renewable Energy Source

VIII. CONCLUSION

This paper explained about the practical model of 'IOT Based Smart Energy Meter.' The proposed model is used to calculate the energy consumption of the household, and even make the energy unit reading to be handy. Hence it reduces the wastage of energy and brings awareness among all. Even it will deduct the manual intervention. The main concept of the project is monitoring and controlling the appliances in a home energy management system and we are using the solar PV panel to maximize the renewable energy source usages. The first phase is the collection of data from sensors. Then using the IOT based communication protocol module, the two way communication will be possible. In the second phase, data must be transmitted to the database through Ethernet or WI-FI module. At the last phase, the peak load time is indicated to the customers through the mobile applications, alarms, and LCD displays. During that peak load time some particular loads are connected to the renewable energy source. By this way, the consumers being aware of their energy consumption behavior and having close interaction with the electricity utilities can adjust and optimize their power and reduce their electricity bills.

IX.FUTURE WORK

In the context of the HEMS, a number of future projects could be undertaken to complete and enhance this capstone project:

- To enhancing privacy and security of the data communicated within the system.
- To enhancing the system's intelligence by using optimization algorithms
- Another one is a new invoice should be prepared to estimate the cost of the photovoltaic system.

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