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SMART ENERGY METER – A SURVEY

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Abstract: - The developments in the day to day life have led to smartness in everything, including technology. Smart devices are those devices which are controlled by receiving the signals either directly by the user or by another device. One such smart device is the Smart Energy Meter which provides the electricity consumption measurements and time-of-use information to the utilities and consumers. Various implementations of the smart energy meter have been done previously using various smart components such as sensors, transformers, IC's, etc. Knowing their working, efficiency and output is the main aim of this paper. Also comparison of the methods, components and costs used in the implementation for optimization of future work is also being discussed.

Keywords:- *Smart Energy Meter, Smart Components, Sensors, Energy, Wireless Communication, Efficiency, Optimization.*

I. INTRODUCTION

The introduction of the smart devices in most of the fields has been a trend. Smartness of the device include the automation of every work to be done depending on the conditions occurring in day to day life. Smartness also includes sensing the changes occurring in the environment within the boundaries provided to it and taking the decisions appropriately and executing them. One such smart device is the Smart energy meter where in the power utilized by the customer at a domestic or industrial place is being measured, calculation of energy is done with respect to time the power is being utilized and the user is made known. These all measurements take place with the help of the sensors used. The old conventional meters such as analog meters, digital meters and other energy meters have been replaced by the smart meters since the conventional meters are less accurate and efficient. Also the reason for replacement of the conventional energy meters was there was no flexibility to add more features. Limited flexibility and intelligence, no decision making power, limited efficiency, bulkiness, etc. led to the use of the smart energy meters with the replacement of the old ones. With the new technology being utilized for metering purpose, various advantages have also risen. The next section deals with the various features being implemented as a part of the smart energy meter.

II. IMPLEMENTATIONS

Various methods have been implemented for the Energy Utilization and in most methods, there has been a way to eliminate the magnetic induced rotational motion and replace the same using various sensors and Developmental boards by caliberating it via some programming language used for coding purpose. Various papers propose the automatic billing as per the energy consumed according to the tariff plans of the particular circle.

Various papers have been published under the same subject but different methods of whom some of the papers along with their results are being considered here for surveying purpose.

2.1. Design of Embedded Based Automated Meter Reading System for Real Time Processing [1].

The meter readings are being fetched from the Energy meter directly and are sent to the ARM 7 (LPC2148) where the readings are being noted. To store the energy readings during a power cut, an EEPROM is in place such that the priorly measured readings are safely stored and are resumed for calculation purpose once the power is ON again. The meter readings are intimated to the central gateway via an RFID module every 3 minutes and then are communicated to the database via a GSM module. A provision has also been provided to recharge the energy meter remotely just by sending an SMS. A SMS sent is being sensed and the recharge for the specified amount is automatically processed. The bill generation, payment facilitation and the SMS intimation to the customer is done at the database end. A DBMS here is being created using MySQL and HTML/PHP is the language used for building the Webpages and for the communication with the database. Electricity tampering protection is also a feature included in the system where any energy theft done is being recorded. Automatic control of the power from the server via a Relay module upon payment of the bills on the web-portal is also being facilitated. The block diagram used for the home domestic purpose is as shown below:

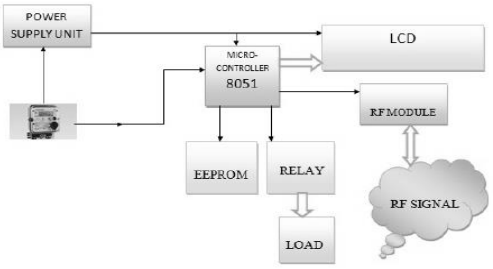

Fig 1: Home Communication Unit

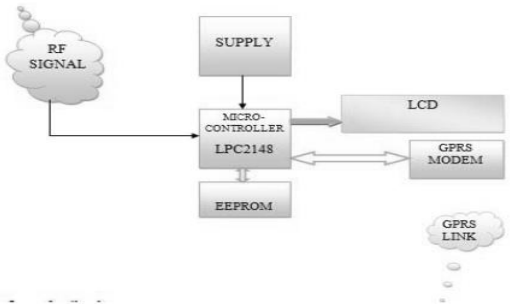

Fig 2: Central Controlling Survey

On the other side, there exists a metering ad the billing unit whose block diagram is as shown above. No voltage and sensors were used, during the implementation of the work. The circuit can still be optimized if the voltage and current sensors are used.

2.2. Smart Power Monitoring System Using Wireless Sensor Networks [2].

A Low cost, flexible, real time smart power management system and easily integratable power system is being discussed in this paper. This system has been designed in measuring the energy used by household appliances. A voltage sensing is being done via a voltage sensing circuit built with the help of the discrete components such as resistors, capacitors, etc. Voltage obtained is being reduced to below 3.3V via a Voltage divider circuit and to obtain a DC voltage, a rectifier is being used. For current sensing purpose, a ASM010 current transformer is being used which measures the primary current in the range of 1-100A. A proportional voltage to the current is being generated at the output of the current transformer. The current and voltage measured is being stepped down to below 3.3V and then is being given to the Zigbee module to transfer it to the system where the results are being observed based on the calculations being done. The results are being communicated via a hyperterminal and also the current equivalent voltage monitoring is being done on the CRO. An application is being developed for the monitoring purpose of the power consumed. Various Loads are tested and bill is being calculated as per the tariff. The functional diagram of the implemented work is as shown below:

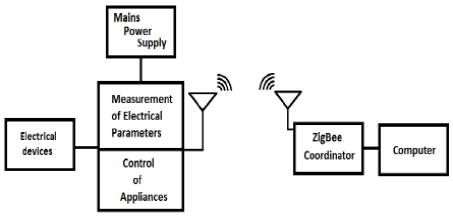

Fig 3: Functional Block diagram

The work uses a current transformer and the conventional discrete components for the measurement of the voltage and current. No Sensors are being used. Also using Zigbee provides a limited range of communication.

2.3.GSM Based Automatic Energy Meter Reading System with Instant Billing [3].

This paper discusses a low cost GSM Energy meter and the database which manages the information of the energy consumed from the energy meter. This method also replaces the method of a person visiting each house for the purpose of bill distribution purpose and also enables remote access of the energy meter. A 10A Class I single phase meter is being design with the help of a Current Sensor and a Voltage Divider designed using discrete components. The Energy calculation is being done with the help of the PIC16F877A microcontroller on the Evaluation board MCP3905A. The power is measured and then intimated as per the real time requirements of every 2 minutes via GSM SIM900 to the Database. The database is being managed using C# and .NET programming languages. The billing software is being designed using Microsoft Visual Studio .NET 2008 managed by the Microsoft SQL Server 2005 on PC. The billing is as per the tariff plan of the particular circle. With proper authentication, the users can access their account from anywhere in the world and view his complete details. Simultaneously the user is being notified with an SMS. The detailed design block diagram of the functional unit is as shown below.

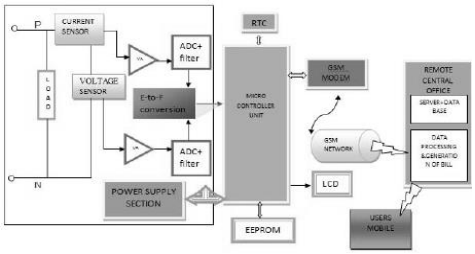

Fig 4. Functional Block diagram

The implemented work makes use of the voltage and the current sensors and thus this optimizes the circuit.

2.4.Smart Energy Meter using Android Application and GSM Network. [4].

This paper discusses a fully automatic energy billing system. This paper also discusses about the malpractices occurred in the locality and determination of it via Board. For the malpractice occurred an extra penalty is being added onto the billing. Online Payment is also being facilitated. The energy is being calculated via an Energy Meter and is then transmitted to the Database via GSM module. An application is being developed to fetch the details from the database, calculate the bill as per the tariff plans and then display it to the customer via the application. The user can access this application after authentication. Based on the bill payment, a notification is being sent to the Relay and a connection/disconnection takes place. The connection/disconnection is also being facilitated in case of malpractice. This method of implementation is mainly based on GSM and is very economical and time saving. The block diagram of the implemented work is as shown below.

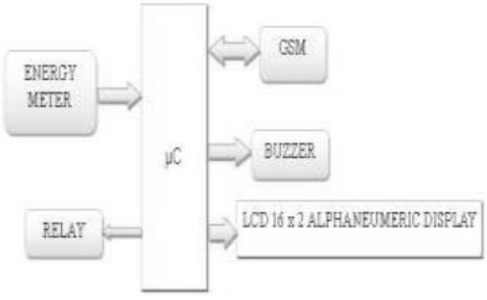

Fig 5: Basic Block Diagram of the System

Here the energy meter is being designed using sensors and the energy consumed is intimated to the customer via GSM.

2.5.IOT Based Electricity Energy Meter Reading, Theft Detection and Disconnection using PLC Modem and Power Optimization.[5]

This paper discusses the Energy Meter using IOT concept using a PIC184F6k22 Micro controller module. The design eliminates the complete human intervention and facilitates an automated system for the whole process of electricity maintainance. Automatic disconnection of the supply is being facilitated via a distant server on non-payment of the bills within a stipulated schedule. The user can also check his energy consumption via a Web Portal by providing his IP address. Theft detection is also being facilitated based on the temperature increase logic and intimation of the same is being done to the Electricity board via a PLC modem. Wi-Fi is being used for wireless transmission of information from the energy meter to the server and this information can be accessed via an IP address. A TRIAC switch circuit, DB18B20 temperature sensor, PLC Modem, ESP8266 Wi-Fi module are the hardware components used. The calculated energy is also being displayed on the LCD module. Here energy consumption calculation is based on counting the number of pulses that are calibrated using PIC18F46k22 Microcontroller System. The functional block diagram at the consumer end is as shown in the figure below.

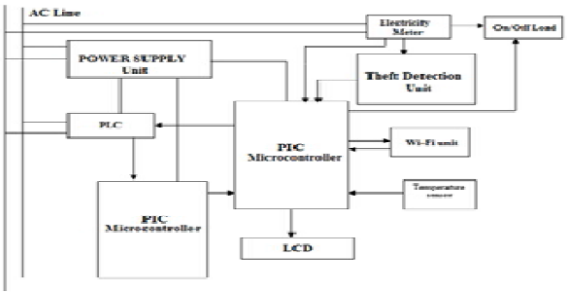

Fig 6: IoT Based Electricity Energy Meter

The implemented work indicates the theft occurred with the help of the PLC and the microcontroller. A temperature sensor is being interfaced for the detection of the theft. Also the units consumed by the customer is being displayed.

2.6.IOT Based Smart Energy Meter Monitoring and Theft Detection Using ATMEGA.[6]

This paper mainly discusses about the theft occurring at various places which lead the increase in the cost of electricity. Electricity theft detection is being checked using a physical check of tamper evident seals by field personal and by using the balance meters. The owner is being identified with an SMS of the occurred theft. Simultaneously the energy calculations are being sent to the owner along with the rates. Adding to this, the readings and the rates are being loaded on to the database using the IOT concept. Current Sensor and The Voltage Sensors are being used for the measurement of the electricity. The measured current and voltage are being stepped down and are given to the ATMEGA328P microcontroller. A TTL-USB is being used for the purpose of IOT connection, updating the database such that the user can access his account from anytime and anywhere. Based on the non-payment of bill within the scheduled date, the disconnection of the supply is being facilitated. The consumed energy and bill for the relevant energy consumed is also being displayed on the LCD.

The diagram below indicates the block diagram of the functional unit of the energy meter.

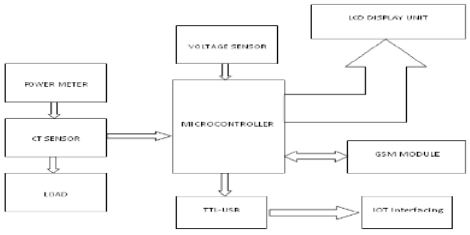

Fig 7: System Block Diagram

The system just measures the energy consumed and notifies the user of the units consumed. It also aims at the theft detection and communication based on IoT.

2.7.ARM based Smart Single Phase Energy Meter with Automatic Bill Generation and SMS Alert.[7]

This paper discusses about the development of the Single Phase Energy meter using an ARM based microcontroller LPC1768 board which has the capability of calculating the true values of the reactive, active, apparent power, power factor, total harmonic distortion (THD) and energy consumed. The voltage and the current utilized by the load are being fetched from the signals obtained by the voltage and the current sensor modules after conditioning the signals obtained by them. The paper also discusses of eliminating the manpower by wirelessly transmitting the energy consumed (in units) and bill generated to the customer using a GSM module. The energy consumed data is logged in and is used for the analysis purpose in order to improve the power quality and also understand the load and usage pattern. The bill generated is also mailed to the customer's mail ID. The functional block diagram of the implementable work is as shown below.

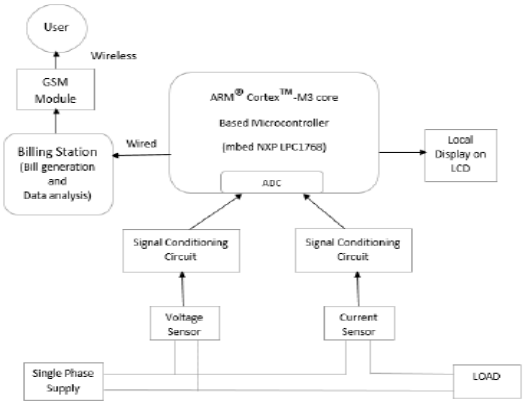

Fig 8: Block Diagram of the Energy Meter

The work uses the voltage and the current sensor due to which the circuit is optimized. Also since LPC1768 board is being used, the calculations and the computations made are very high.

2.8.GSM Based Automatic Energy Meter Reading System with Instant Billing [8].

The paper discusses about the elimination of the current energy metering system by proposing a new method of metering the energy consumed. It enables the remote accessing of the energy meter by the energy provider via a GSM module interfaced to each entity. The GSM modem at the Energy meter side transmits the energy consumed to the PC end where it gets updated to the database. Live meter reading is being sent to the database every 2 minutes for updation in the user's account in the centralized database. The users can access the webpages from anywhere in the world. The paper also proposes a prepaid energy recharge by logging into his portal. The consumed energy is being stored in the EEPROM such that the energy readings are being stored whenever there is a power cut. Also the bill generated by the centralized database is being sent to the user's mail ID. The architecture of the system implementation is as shown below.

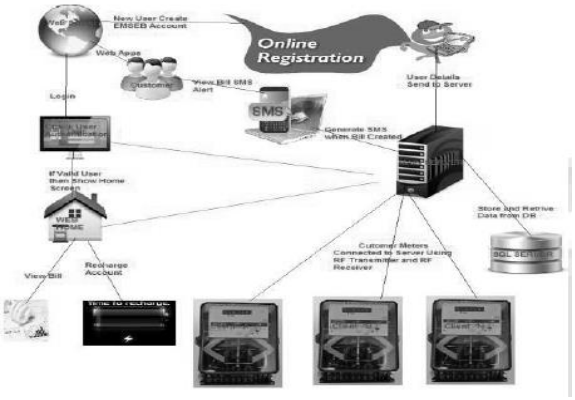

Fig 9: System Architecture

The implemented system makes use of the energy meters for the reading measurements, transmits them wirelessly via a GSM module. Billing calculations are being done on the portal and are notified to the user. The implemented work needs a separate circuit only for tapping readings, transmission and reception.

2.9.An Embedded Electric Meter Using ARM, ZigBee and GSM[9].

The paper discusses an embedded Energy Meter based on the Zigbee Data Acquisition. The Energy Meter is being programmed on the Cortex ARM M3 Processor. The Voltage and Current Sensors are being interfaced to the ARM board providing the Voltage and Current readings. Power consumed is being calculated and the Energy consumption with respect to time is also being calculated. The calculated Energy in Units is then transmitted to the database via a ZigBee module and is simultaneously transmitted to the customer via GSM after the calculation of the bill. This system has the important advantages of low power consumption, low cost and low data rate. Other advantages include the system is simple, anti-interference, integrated, stronger mobility and practicability. The Energy meter dedicates to the automatic meter data collection and energy auditing and management. Fig 10 below indicates the system overview.

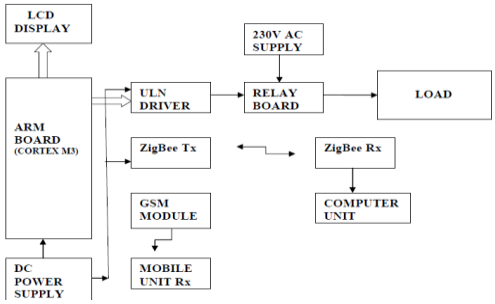

Fig 10. System Overview

The system provides a detailed reading of the current, voltage and power. Also the power leakage, power limit message and used power is being notified.

2.10. Design of Wireless ARM-Based Automatic Meter Reading and Control System[10].

This paper discusses about the implementation of the Wireless ARM based automated Energy Metering system and its Control System (WAMRCS) for distribution automation. This system is designed on a 32- bit ARM7TDMITM Processor

which deals with the relay control and the power-data processing. The Voltage Sensing circuit is being designed using the discrete components such as resistor and capacitor and the current sensing circuit is being designed with the help of the Current Transducer which produces equivalent voltage with respect to the current. The 2 way communication between the WAMRCS and the company is being facilitated via a GPRS modem. The WAMRCS sends the usage, power quality and the outage alarm to the utility company. The features of WAMRCS are its more accurate, cost- effective, reliable, quick and free from man made errors. It provides extra capabilities such as distribution automation, load management and time-of- use rate.

The system at the consumer end communicates with the system via GPRS, bill generation is being done at the utility board end. A print of the copy is also being generated using a printer.

2.11. Automatic Power Meter Reading System Using GSM Network[11].

The paper discusses about the intimation of the energy consumed to the customer via a GSM module. The load are being connected to the Energy Meter which inturn is being connected with the GSM module. Based on the time duration that is being set, at so specific time intervals, a message is being triggered to the user indicating the units used by him. The GSM Automatic Power Meter Reading (GAPMR) is a single phase IEC61036 standard compliance digital kilowatt hour power meter with the embedded GSM modem which sends the SMS from time to time. The GSM module simultaneously transmits the energy units to 2 places: to the user side and to the server side. The server side receives the meter reading, computes the billing costs, update the database and publish the billing notification to the respective consumer via SMS, Email, Printed Postage Mailing and Web Portal Payment. The system is highly effective and efficient.

2.12. Wireless ARM-Based Automatic Meter Reading and Control System (WAMRCS)[12].

This paper discusses about the implementation of the Wireless ARM based automated Energy Metering system and its Control System (WAMRCS) for distribution automation. This system is designed on a 32- bit ARM7TDMITM Processor which deals with the relay control and the power-data processing. The Voltage Sensing circuit is being designed using the discrete components such as resistor and capacitor and the current sensing circuit is being designed with the help of the Current Transducer which produces equivalent voltage with respect to the current. The 2 way communication between the WAMRCS and the company is being facilitated via a GPRS modem. This paper also deals with the disconnection of the supply which is based on the non-payment of the bills within a stipulated time. The WAMRCS sends the usage, power quality and the outage alarm to the utility company. The features of WAMRCS are its more accurate, cost- effective, reliable, quick and free from man made errors. It provides extra capabilities such as distribution automation, load management and time-of- use rate.

The system at the consumer end communicates with the system via GPRS, bill generation is being done at the utility board end. A print of the copy is also being generated using a printer.

2.13. ARM Based Automatic Energy Meter Reading System using GSM[13].

This paper discusses the Automatic Energy metering system using GSM. It uses ARM7 (LPC2148) for the purpose of the meter reading and thus this energy is being sent to the database and to the customer via a GSM module interfaced to it. The utility center does the work of power data processing. A current transformer is being used for the current equivalent voltage generation and the power transformer is being used for the voltage required. The voltage and the current are stepped down to below 3.3V for the power calculation purpose. The Relay or the Circuit breaker is also facilitated for the disconnection of the supply based on the non-payment of the bills by the customer in the utility center. The design is very simple, effective and economical. The functional block diagram of the system is as mentioned below.

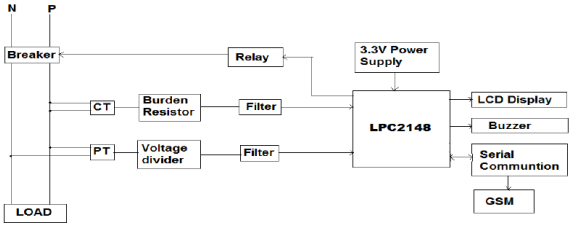

Fig 11: Block Diagram of the Meter Unit

Current Transducer and the conventional discrete components are being used for the measurement of the current and voltage. Being processed by the ARM board, they are communicated via GSM module and are being processed by PIC Microcontroller for Billing and intimation. The functional block for the receiving purpose is as shown below.

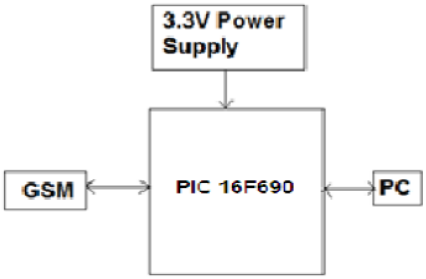

Fig 12: Receiving Unit

The circuit can be optimized using the voltage and current sensors.

2.14. Cortex M3 based Prepaid System with Electricity Theft Control. [14]

This paper discusses about a system with both the ends being equipped with a GSM module used for communication. This GSM module facilitates the bidirectional communication. This paper deals with designing of the a prepaid energy meter with theft control. The Instrument Transformers is being used for the measurement of current in the circuit and Power transformer is used for the measurement of voltage. The voltage obtained at the shunt resistance is proportional to the current in the circuit due to variable loads. The theft detection is being done by complete line bypassing and phase shorting wherein a SMS is being triggered indicating which type of theft is being occurred and resulting in the disconnection of the supply using a Relay. Consumers can easily recharge their energy meters by sending the hidden pin number via SMS through the GSM modem or their mobile. The bidirectional GSM communication using SMS ensures the effectiveness of the system. Below figure depicts a block diagram of the prepaid system.

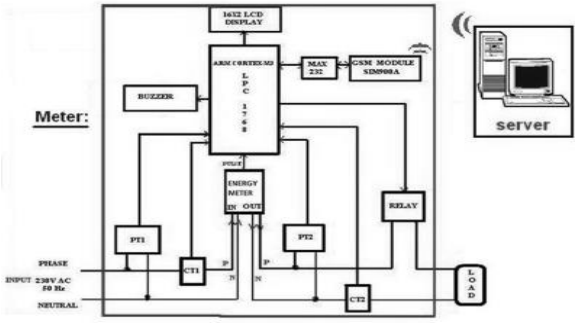

Fig 13: Block diagram of a prepaid system

The conventional components such as current transformer and voltage transformers are being used. This basically works as a prepaid meter comparing everytime with the currency present in the system. A wireless medium is being used to transmit the data everytime to the server and verify.

2.15. New Age Energy Meter Reading System [15]

This paper discusses the remote monitoring and control of the Domestic Phase Meter. This facilitates the Electrical board to read the readings of each meter without visiting each individual's place. An EEPROM is being programmed using Embedded C for the purpose of storing of the Energy meter readings and then send it whenever necessary. The voltage and current is being measured using the power and current transformers. The development board of ATMEGA32 microcontroller is being used. The energy calculated is transmitted to the database via a SMS through a GSM module. An android application is being designed for the user such that the user can not only view his e-bills but can also switch off the device if it exceeds certain limit. A bulky Digital energy meter is being used for tapping the readings via an ATMEGA microcontroller. Readings are being displayed on the LCD and are communicated wirelessly to a computer server and are managed by an Android Mobile Application.

2.16. Automatic Energy Calculation Through Wireless Smart Meter Using Zigbee [16].

This paper discusses about the energy calculation, data collection and giving intimations of the energy by displaying it on the LCD. The system uses multiple channels and frequency hopping is being used and also it co-exists even when there are interferers in the system. The power consumed by the user is being monitored via Electronic Billing (EB) wirelessly. Different hardware techniques for tripping, indicating and intimating the customer and power monitoring are being discussed. A ZigBee module is being interfaced with the PIC microcontroller for wirelessly transmitting the power information to the EB module. Zigbee is used since its very much efficient in communication and power utilization. ZigBee even works for data rates as low as 20Kbps and as high as 250Kbps with minimum power consumption. A block diagram of the Consumer Module is being shown below.

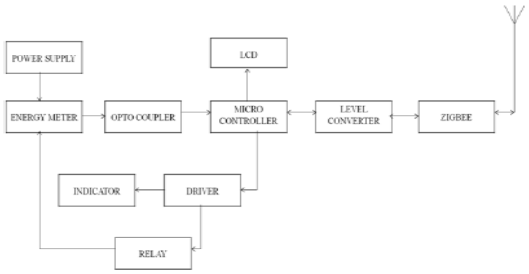

Fig 14: Block diagram of a consumer module

The smart component here is that it includes an optocoupler which isolates the main supply from the measurement circuit to avoid risks of current shock. Relay is being used for the connection/ disconnection purpose based on the bill payment. A level converter used in between the Zigbee and Microcontroller interfaces the both. Energy meter is being directly used which makes the system bulky.

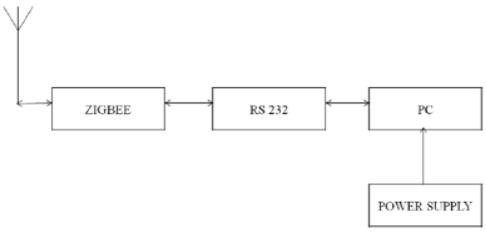

Fig 15: EB module at the Utility End.

The EB circuit receives the readings and generates the bill and intimates the user.

2.17. Design of GSM Based Smart Automatic Energy Metering System. [17]

The paper discusses about an ARM Based Energy System (AES) and 89C51 based system which is used for the Energy metering purpose. The voltage and the current are being sensed using a conventional hardware discrete components such as resistors, capacitors and the current transformer. The Power is being calculated and then the energy is calculated with respect to the time for what the power is being consumed. The load determination is being done, automatic bill invoice for the energy consumed is being generated by the Utility Control Center (UCC), Tampering in the connection, Payment facilitation at the remote end and the alarm warning in case of theft or overloading are the features.

The system allows a full dupleix connection in between a customer and the electricity board. The following features are achieved: Faster execution, load management, automatic billing, accurate energy metering, tamper detection, remote access and alarm warning. The current transformers and the voltage transformers are being used which makes the system bulky. Optimization here includes the sensor modules.

2.18. Smart Energy Meter. [18]

This paper discusses about the energy consumption using Arduino. This paper also discusses about the various methods to reduce tampering and thus reduce the power consumption and cost. The circuits here deal with the measurement of line voltage, phase current, neutral current, computation of active power and energy consumption. The paper also proposes a method for disconnection of the supply whenever the voltage and the current exceeds a certain specific limits such that no equipment fails. The computed energy is then transmitted to PC via a Xbee module where the billing of the energy is being performed at the Utility Control Center. Hardware implementations are being done and the results are being observed varying different loads. The design is capable of measuring upto 1000V and 35A. The device also enables the user to easily track the power consumption done with relative fast update rate and optimizing power. The functional block diagram is as shown below.

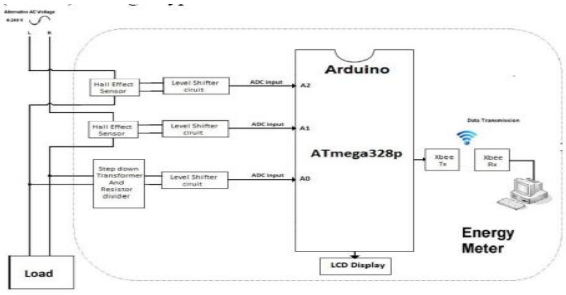

Fig 16: Block Diagram at the Customer End

Arduino Microcontroller is being used along with the sensors for the metering purpose. Using Zigbee makes the communication range small.

2.19. Smart Energy Meter Using Power Factor Meter and Instrument Transformer. [19]

The paper discusses about the energy meter which is smart enough for payment and billing system. The meter is designed in such a way that the supply is disconnected when there is an absence of any person within the room or place, thus very helpful in power saving. The proposed meter uses a pre-paid smart card for recharging purpose. First time, the customer has to pay the full amount in order to recharge to the maximum extent such that the meter gets the maximum usage of it. When the recharged value reaches a minimum low value, warning message is being generated for re-recharging the energy meter. Provision is being provided to recharge the card via Net-Banking, Debit Card or Credit Card. The voltage is directly

fetched from the main line and stepped down to below 3.3V. The current is obtained from the current transformer rated 400/5 ratio. The power factor meter indicates the current in the circuit is leading or lagging. A fixed coil with a coil indicates the power factor meter in the circuit. A Smart Card reading unit is being provided for reading the prepaid recharge card. The power transformer's transformation ration is 33KV/110V. EEPROM facilitates the backup of the readings whenever there is a power cutoff. The output is given via Relays which acts as a control switch for the appliances. The block diagram of the energy meter is as shown in the figure below.

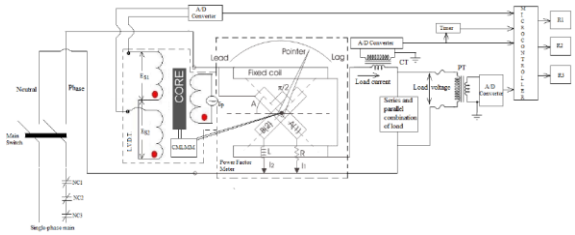

Fig 17:Block Diagram of the Energy Meter

The work intends to find out the power factor in the circuit whether lagging or leading. Also the current and the voltage sensors are being used making the circuit optimized.

2.20. IOT Based Energy Meter Monitoring using ARM Cortex M4 with Android Application.[20]

This paper discusses about the remote monitoring of energy meter which overcomes the disadvantages of Automatic Meter Reading System (AMR). The Energy meter is being wirelessly monitored using the Wi-Fi, IOT MQTT Protocol. CMSC 766 is a micro-controller based energy meter with serial communication link that is used for measuring the energy. This module/ microcontroller comes in with the inbuilt CT module and isolated MODBUS connection. The paper discusses about using the ARM Cortex M4 (TM4C1294NCPDT) for the purpose of Energy Monitoring. This controller is a 32-bit controller rom Texas Instruments. A thermal printer is being interfaced with the micro-controller for the purpose of printing the invoice. The Energy meter module measures the energy consumed and then wirelessly transmits it to the Server via IOT MQTT protocol. An android app is being developed which fetched the energy units and bill stored in the database, The bill computation is being done on the server. The Android app fetches all the user data from the database and displays it on the user mobile. Based on the stipulated duration provided for the bill payment, the relay operates. If no bill is being paid within the stipulated time, the connection is disconnected else it is continued. The overview of the implemented work is as shown below:

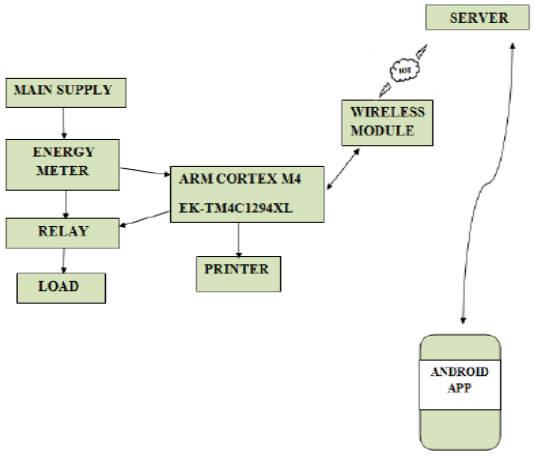

Fig 18: Overview of the proposed work.

The implemented work involves the energy meter which adds up as a bulk, instead sensors would be used. A high performance Cortex M4 is used for processing and execution. Also communication to the server is via MQTT IoT protocol which is a another plus point in the project.

III. CONCLUSION

Various systems and implementations were analyzed. Some of the implementations had an addon advantage of the current and voltage sensors being interfaced. Some implementation involved 2 processors which again makes the syatem bulky. Some implementations used IoT as a medium of communication but Energy meter's did not make use of the current and the voltage sensors. Some of the implementations made use of all the sensors for the metering purpose, but since the Xbee was used in communication, the range of communication was limited. All the implementations mainly aimed at the power saving purpose using a relay for disconnection and reconnection based on the payment of the bills. Current, Voltage, Power and Energy parameters were efficiently measured by the system in the works implemented. Some implementations involved the billing and payment via a SQL server on the utility end while some others involved another microcontroller for billing and intimation purpose.

Based on analysis made by reviewing all the papers, a more efficient could be designed using the voltage and current sensors, any powerful microcontroller for metering, transmission of the metered energy for a long distance remote access using IoT where bill generation and payment is being facilitated on a SQL server, intimation of the payment back to the energy meter module via IoT and connection/disconnection being facilitated by the relay module. Also load determination may be done based on the voltage sensed. The energy consumed by the user may be stored for the analysis purpose and diverting the unnecessary power to the other domestic homes wherever necessary. The only advantage of the SQL server on the Utility side is that the energy data of the consumer may be maintained and analysis may be done whenever necessary.

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