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Energy Understanding Device (EUD): An Innovative Energy Metering and Monitoring Solution: Perspective Bangladesh

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The present system of energy metering as well as billing in Bangladesh which uses electromechanical and digital energy meters are error prone and inefficient to some extent. Still, the Bangladeshi power sector faces a serious problem of revenue collection due to energy thefts and poor management of vital energy usage information. The aim of this project is to minimize the hassle related with electricity billing and energy wastage by taking enough data of usage amount of electricity and making it available to end users and suppliers using appropriate wireless technology. We are going to develop a low cost energy meter that records & displays the consumption of electrical energy real time in households, offices or industries provided with communication and information technology. The project also aims at proposing a system that will reduce the loss of power and revenue due to power thefts and other illegal activities. The implementation of this project will help in better energy management and in solving the unnecessary hassles for incorrect billing. The device is named as "Energy Understanding Device (EUD)" which will provide almost all necessary information about usage of electricity to the supplier and the customer as well.

Keywords: EUD, hassle free, efficient energy usage, online monitoring, GSM, Information technology

1. Introduction

"If you cannot measure it, you cannot improve it." - Derived from Lord Kelvin

Now-a-days, digital technologies have resulted to enormous developments in wireless communications which clearly shows that the place of Global System for Mobile (GSM) Communications technology cannot be over-emphasized. This paper therefore, explores its possibilities in the implementation of a GSM-Based Energy meter which will help general people to understand their energy consumption process with high reliability and accuracy. An electricity meter or energy meter in simple terms would be a device that measures the amount of electric energy consumed by a residence, business houses, or an electrically powered devices or appliances. Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. Periodic readings of electric meters establish billing cycles and energy used during a cycle, the cycle generally extending for a month. The kind of Energy Monitoring System which we are proposing is appropriate for Industries, manufacturing plants, commercial Buildings or any situation where an electrical system is used and needs to be monitored. The system provides the centralized Power Monitoring and Control for the electricity department and easy bill payment for the customers. The overall design of the Energy Understanding device (EUD) consists primarily of a Microcontroller and a GSM communication module along with a liquid crystal display (LCD). The existing energy

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meters which are placed in our home/office collect data of the energy consumed and display it on either a number dial or digital display. With the proposed system both consumer and service provider will easily understand the meter reading as well as can control the energy consumption. Also, the customer and the supplier can view current meter reading, bill for current cycle and all other related information from anywhere through internet connection.

2. Literature Review

The recent works on energy meter provides a pathway to implement this project. However every work has its own limitations which we will overcome in this project. Shwehdi and Jackson (1996), in their paper presented the Digital Tele-wattmeter System as an example of a microcontroller- based meter. The meter was implemented to transmit data on a monthly basis to a remote central office through dedicated telephone line and a pair of modems. It is only a stand- alone metering system. Zhang, Oghanna and Bai (1998) utilized a DSP-based meter to measure the electricity consumption of multiple users in a residential area. A Personal Computer (PC) at the control centre was used to send commands to a remote meter, which in turn transmits data back, using the power Line Communication (PLC) technique. The major problem with this system is that it cannot detect tampering by consumers.

Koay et al (2003) in their work, designed and implemented a Bluetooth energy meter where several meters are in close proximity, communicated wirelessly with a Master PC. Distance coverage is a major set-back for this kind of system because the Bluetooth technology works effectively at close range.

In their paper, Scaradozzi and Conte (2003) viewed home- automation systems as Multiple Agent Systems (MAS). Home automation system was proposed where home appliances and devices are controlled and maintained for home management. It is only a home management system and does not measure the amount of energy consumed by users. Hong and Ning (2005) in their paper, proposed the use of Automatic Meter Reading (AMR) using wireless networks. Some commercial AMR products use the internet for data transmission.

Stanescu et al (2006) present a design and implementation of SMS -based control for monitoring systems. The paper has three modules involving sensing unit for monitoring the complex applications. The SMS is used for status reporting such as power failure. Issues on billing system for electricity board usage were not considered. Prepaid meters can also make use of state of art technologies like Wi-MAX owing to the idea of centralized accounting, monitoring and charging. It brings telecommunication to the core of its activities to support more Smart Grid applications such as Demand Response and Plug-in electric vehicles (Khan et al, 2007). Prepayment poly phase electricity metering systems have also been developed consisting of local prepayment and a card reader based energy meter (Ling et al, 2010).

In their paper, Maheswari and Sivakumar (2009) aimed to develop an energy efficient and low cost solution for street lighting system using Global System for Mobile communication [GSM] and General Packet Radio Service [GPRS]. The whole set-up provides the remote operator to turn off the lights when not required, regulate the voltage supplied to the streetlights and prepare daily reports on glowing hours.

Malik, Aihab and Erum (2009) in their paper, mainly focused on the controlling of home appliances remotely and providing security when the user is away from the place using an SMS- based wireless Home Appliance Control. Sharma and Shoeb (2011), in their paper suggested a method where we utilize telecommunication systems for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS, Email.

Amit J and Mohnish (2011), suggested in their paper a prepaid energy meter behaving like a prepaid mobile phone. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests.

3. Present Scenario

In present days, old modeled analog meter or a new modeled meter with digital display are in use. The prepaid meters in the market today are coming up with smart cards to hold information on units consumed or equivalent money value. When the card is inserted, the energy meter reads it, connects the supply to the consumer loads, and debits the value. The meters are equipped with light emitting diodes (LED) to inform consumers when 75 percent of the credit energy has been consumed. The consumer then recharges the prepaid card from a sales terminal or distribution point, and during this process any changes in the tariff can also be loaded in the smart card. From these existing meters, only supplier can get data and create bill but the general consumers do not get any useful data from this meters. Even sometimes they face unnecessary hassles for incorrect billing. Now-a-days, our government is going to implement pre-payment metering system where if we can't afford to buy tokens or recharge our card or key, we won't have any energy! It is crucial to learn that energy, which is a right to every citizen, will soon become a privilege.

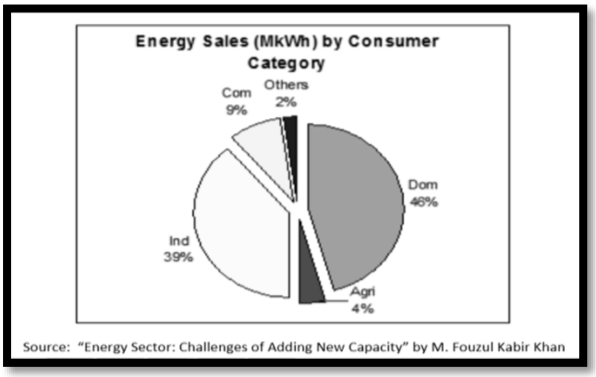
Figure 1: Present Energy Capacity of Bangladesh (September 2014)

Installed Capacity of BPDB Power Plants as on September 2014		
Unit Type	**Capacity(Unit)**	**Total(%)**
Coal	250.00 MW	2.39 %
FO	0.00 MW	0 %
Gas	6719.00 MW	64.33 %
HFO	1963.00 MW	18.79 %
HSD	783.00 MW	7.5 %
Hydro	230.00 MW	2.2 %
Imported	500.00 MW	4.79 %
Total	10445.00 MW	100 %
Derated Capacity of BPDB Power Plants as on September 2014		
Unit Type	**Capacity(Unit)**	**Total(%)**
Coal	200.00 MW	1.92 %
FO	52.00 MW	0.5 %
Gas	6731.00 MW	64.78 %
HFO	1926.00 MW	18.54 %
HSD	761.00 MW	7.32 %
Hydro	220.00 MW	2.12 %
Imported	500.00 MW	4.81 %
Total	10390.00 MW	100 %

The power infrastructure of Bangladesh is small and insufficient but the demand is rapidly increasing. The per capita power consumption in Bangladesh is about 136kwh. Although this is one of the lowest in the world, our power sector is in enormous pressure for higher population density. Figure 1 shows present energy capacity of Bangladesh released on September 2014 by Bangladesh Power Development Board (BPDB).

In Figure 2, we see that most of the energy was sold to the general house hold consumers. On the other hand, 46% of Bangladeshis don't have access to electricity from the national grid, according to the Bangladesh Power Development Board. So, from this discussion, it is clear that we need to use the available electrical energy carefully and the information of energy consumption by end users needs to be understandable to them for utilizing this minimal amount of energy efficiently.

Figure 2: Present Statistic of Energy Sales (M.kwh) By Consumer Category



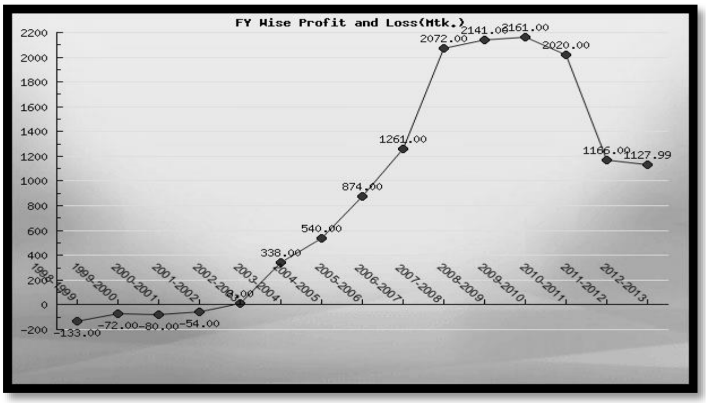
4. Problem of Existing Devices

There are some vital problems in existing metering devices and systems. Some of the problems of existing devices are given bellow:

-General consumers can't understand the function of analog or digital displayed meters and even they can't forecast their electricity bills.
- For some customers on low incomes, there may be some difficulty in paying in advance for electricity while using prepaid energy, seeing this as a benefit for the retailer rather than for customers.
- While using pre-paid energy, customers without access to the internet or a mobile phone may only have limited options for making top up payments.
- While using pre-paid energy meter, payment is done by using a recharge card. Access to a recharge point may not be convenient, they may not be open at all hours, and for remote and rural customers, there may be costs involved in getting there.
- Competitive tariffs may not be available upfront so customers on prepaid meters may end up paying more for consumed energy.
- Customers cannot access discounts for paying on time, or by direct debit, which are available to other customers, even though the retailer has the benefit of their paying in advance for the energy.
- While using prepaid energy meter, customers must keep checking the balance left on the meter, or risk running out of energy!

In the following Figure 3, we see that after starting implementation of prepaid meters, the profit of energy supplier has decreased with an alarming rate. So, new and innovative metering system may be a solution at this point.

Figure 3: Fiscal Year Wise Profit Loss –BPDC



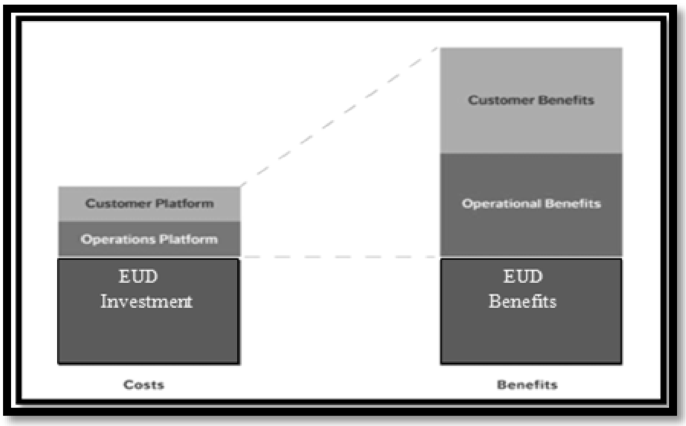
5. Benefits and Overall Cost Estimation

The EUD meters are likely to cut the cost of meter reading as no meter readers are required. In addition, they eliminate administrative hassles associated with disconnection and reconnection. Besides, going by Bangladesh's experience, EUD meters could help control billing of electricity in a better way than conventional meters by reducing financial risks of the distributor companies. Since the payment is up-front, it reduces the financial risk by improving the cash flows and necessitates an improved revenue management system. EUD will also ensure better energy management at customer ends. It is reliable in monitoring of energy consumption and it provides graphical display of energy consumption of various loads individually. It also has the property of detecting peak energy consumption period which is important information for Power Company.

Energy Understanding Device (EUD) will allow us to:

-Verify energy bills of any AC/DC electrical device and get informed about load shifting and shedding decisions with PIC & OF-PIC time information
-Fairly and accurately allocate energy costs to users. User can see the calculated bill in the meter display.
-Identify wasteful practices and decrease unnecessary usage of electricity.
-Produce an energy profile for every single user.
-Secure the optimum utility rate structure.
-Better energy management with easy implementation.
- A consumer will be able to connect AC/DC load along with IPS or other electricity sources in this device.
- Customers will control their own power consumption, budget and won't face any hassles of disputed bills.
- Mass using of EUD will reduce the "technical & energy losses" at national grid lines (an estimated 18% nationwide and nearly 25% in some areas – due to "non-technical losses" on customer level).
-Sometimes bad customers connive with the meter reader and illegally connect electricity line directly to the distribution line. In such cases, EUD can change the scenario and save the power company from losing a lot of money.
- The power companies will be benefited & thus they will be able to decrease non-technical losses, lower overheads, increase revenue, and will get a better load management and eventually customers will pay for their consumed energy only.

Figure 4: Benefit Chart of EUD



6. Special Features of "Energy Understanding Device"

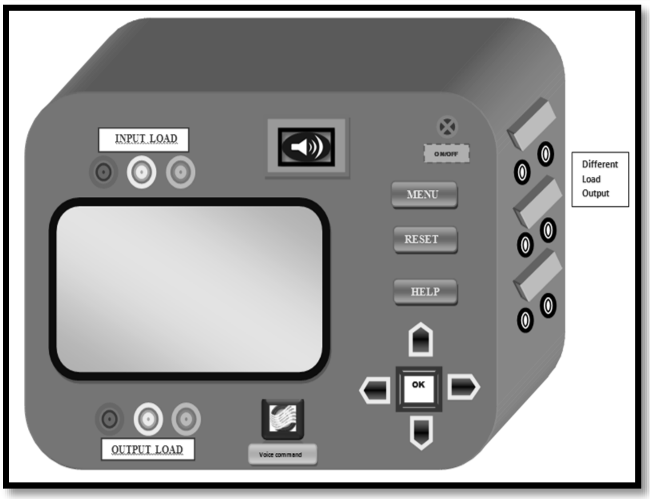
There are some special features in the proposed Energy Understanding Device (EUD). Some of the special features are given bellow:
- Intelligent switching operations.
- Improved system performance.
-Improved ability to supply information of price of electricity.
- Availability of data of already consumed energy.
- Cost containment, and end-to-end power delivery and Intelligent, works autonomously.
- Suppliers can upgrade the program with latest energy unit cost easily.
- Overvoltage protection, Overload protection.
- Two way communication via GSM/wireless network and real-time energy usage monitoring.
- Real-time power outage and restoration alarms and overall customer satisfaction
-Auto LED on/off by using IR sensor.
-To ensure security we can use password protection system or voice recognition system with smart alarm.
- Any customer will be able to know the reading through internet etc.

7. Methodology

To develop the EDU, we are using Microcontroller Atmega32. The Atmega32 is programmed such that power supply will be switched off by using relay when the recharged amount gets used up. Here, microcontroller based system is designed and the readings can be continuously recorded. This reduces human labor and at the same time increases the efficiency in calculation of bills for used electricity. The GSM communication module is used to send a message to the consumer about the units of power consumed and their balance. Energy Metering IC ADE7755 and LCD display is used to display the balance amount.

8. Proposed Design

Figure 5: 3D View of "Automated Hassle less Low Cost Energy Device"



(Front with Left side view) (Front with Right side view)

Each appliance belongs to one household from where it consumes energy. The rate at which the energy is consumed is different for each appliance. Each appliance can have different states that affect its energy consumption profile. An appliance also belongs to an appliance category that holds information for the load distribution, presence and schedule for all the appliances of that category. The load is represented by a probability distribution function and indicates how much energy the appliance consumes over time. Both the control is done by Logging processing control device and the communication is executed by modem. There are two measuring units by which Logging processing control unit will decide which load should be cut off or remain.

Our Proposed EUD metering system is similar to that of an EMS (Energy Management System)-type system. To popularize this EUD metering system, we tried to find a method to enable its installation in existing buildings without extra construction. To achieve this, we can consider GSM, PLC or any other wireless methods for system communication.

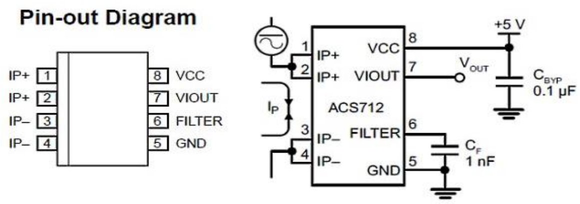
8.1 Voltage Sensor

Energy meter IC (AD7751) is biased around the neutral wire and a resistor divider is used to provide a voltage signal that is proportional to the line voltage. A voltage divider is made in combination of 1 MΩ resistor and 1 kΩ resistor. The output voltage across the 1 kΩ resistor is applied to the voltage channel of the energy meter IC.

8.2 Current Sensor

The voltage outputs from a calibrated resistor of 3.335 mΩ connected with the neutral wire is applied to the current channel of the energy meter IC. Current channel has a programmable gain amplifier with gains of 1, 2, 8, or 16. The maximum peak differential voltage is ±660 mV divided by the gain selection. We can use ACS712 as current sensor.

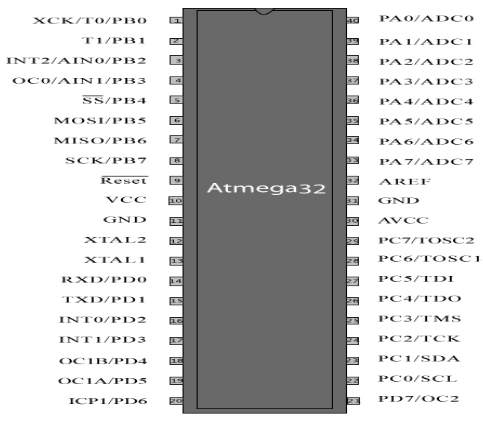
Figure 6: Pin Diagram of IC ACS712



8.3 Microcontroller

Microcontroller is a programmable device which contains a microprocessor, memory, input-output ports etc which can be compared with the microcomputer. Microcontroller is a single chip computer. As microcontroller is a low cost programmable device. It is used in the automatic control application. Now the pulses produced at the pin CF is directly applied to the counter pin of the microcontroller. The microcontroller counts the pulses that appear at pin 1 of Microcontroller (ATmega32) within every 20 seconds. The number of pulses per second appeared at pin 22 of Energy Meter IC is directly proportional to the instantaneous real power information for a particular load. Information such as power, energy, and maximum demand are stored at the EEPROM of the Microcontroller (ATmega32).

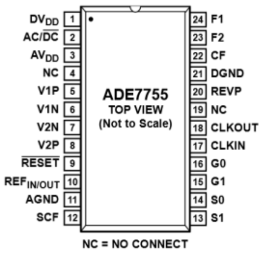
Figure 7: Pin Diagram of Atmega32



8.4 Energy Metering IC

The ADE7755 is a high accuracy electrical energy measurement IC. The part specifications surpass the accuracy requirements as quoted in the IEC 1036 standard. This analog circuitry used in the ADE7755 is in the ADCs and reference circuit. All other signal processing (for example, multiplication and filtering) is carried out in the digital domain. This approach provides superior stability and accuracy over extremes in environmental conditions and over time. The ADE7755 supplies average active power information on the low frequency outputs, F1 and F2. These logic outputs can be used to directly drive an electromechanical counter or interface to an MCU. The CF logic output gives instantaneous active power information. This output is intended to be used for calibration purposes or for interfacing to an MCU. The ADE7755 includes a power supply monitoring circuit on the AVDD supply pin. The ADE7755 remains in a reset condition until the supply voltage on AVDD reaches 4 V. If the supply falls below 4 V, the ADE7755 resets and no pulse is issued on F1, F2, and CF. Internal phase matching circuitry ensures that the voltage and current channels are phase matched whether the HPF in Channel 1 is on or off. An internal no load threshold ensures that the ADE7755 does not exhibit any creep when there is no load. The ADE7755 is available in a 24-lead SSOP package.

Figure 8: Pin Configuration of IC ADE7755



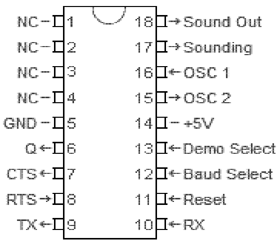
8.5 Integrated Linear Current Sensor IC

The Allegro ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and over current fault protection. The device is not intended for automotive applications. The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized Bi CMOS Hall IC, which is programmed for accuracy after packaging.

8.6 Speech Chip

The TTS256 is an 8-bit microprocessor programmed with letter-to-sound rules. This built-in algorithm allows for the automatic real-time translation of English ASCII characters into allophone addresses. The TTS256 is offered in a through-hole, 28-pin package. Supplied power should be +5V.The TTS256 contains over 600 rules for pronouncing English text. As the rule set is constrained by the amount of memory in the device, the TTS256 will be able to translate and pronounce correctly roughly 90% of text sent to it. The translation quality is adequate for many embedded applications but is guaranteed to mispronounce some common words from time to time. While it does a pretty good job of the task, with a less than 5% error rate in most sentences, it will mispronounce some words. Often times, some creative spelling will help.

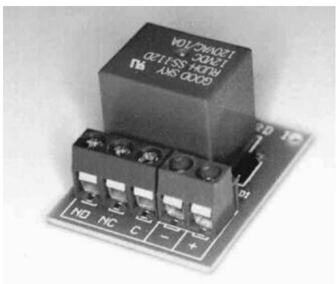
Figure 9: Pin Configuration of TTS256 Microprocessor.



8.7 Relay Control

Five relays each of rating 10A are used. One relay is only used to provide the coil current. When this relay will conduct then it energizes the rest of the relays and consequently the load current will flow through the four relays only which acts as one relay of rating 40A. When the number of units stored in the EEPROM reaches zero, the microcontroller (ATmegs32) initiates a pulse to the base of the transistor. Then the transistor will be switched on which initiates the operation of the relay and consequently the relay will be off. When the credit card is again recharged, the ATmega32 will send a pulse for which the relay establishes a connection between the load and the supply mains.

Figure10: 10A Relay



8.8 Display Unit

The liquid crystal display controller displays alphanumeric characters and symbols. It can be configured to drive a dot-matrix liquid crystal display under the control of microcontroller. In this paper, LCD is mainly used to display energy consumption by the load, the number of units recharged by the consumer, units left to consume maximum demand of consumer etc.

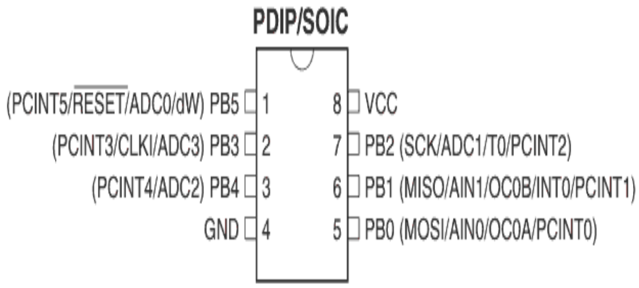
8.9 Power Supply Unit

Every electronic circuit needs proper power supply for its operation. Microcontrollers, Energy Meter ICs, Liquid crystal display and relays operate on ±5 volts supply. For this reason, we have used a ±5 volt power supply. We have taken into consideration the small energy consumed by the power supply itself that will be paid by the consumers.

8.10 Communication with Server

A microcontroller (ATtiny13) is used as the numbers of measuring units to be loaded by interfacing with the USB port and the user operated PC of server terminal. The Atmega32 will send the information contained on it to the microcontroller (ATtiny13), when the DIP switch connected with the two microcontrollers is switched on. Then the information of microcontroller (ATtiny13) will be transferred to the microcontroller (ATmega32) and stored in the EEPROM of the microcontroller (ATmega32) while erasing the content of the ATtiny13. The number of recharged units is contained in the EEPROM of the microcontroller (ATmega32) and will be gradually decreased with the increment of the energy consumption by the load. The updated value after the execution of the every step will be stored in the EEPROM of the microcontroller (ATmega32). Now the EDU will automatically upload all the data in online that consumer & distributor can use the data for further use.

Figure 11: Pin Diagram of Attiny13



8.11 Communication Network

8.11.1 GSM (Global System for Mobile Communications

GSM (Global System for Mobile Communications, originally Grouped Special Mobile), is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones. It is the default global standard for mobile communications with over 90% market share, and is available in over 219 countries and territories.

The GSM standard was developed as a replacement for first generation (1G) analog cellular networks, and originally described a digital, circuit-switched network optimized for full duplex voice telephony. This was expanded over time to include data communications, first by circuit-switched transport, then packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution or EGPRS).Subsequently, the 3GPP developed third generation (3G)

UMTS standards followed by fourth generation (4G) LTE Advanced standards, which are not part of the ETSI GSM standard.

GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G), with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead (for example in Canada and the United States). In rare cases the 400 and 450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems.

Most 3G networks in Europe operate in the 2100 MHz frequency band. For more information on worldwide GSM frequency usage, see GSM frequency bands. Regardless of the frequency selected by an operator, it is divided into timeslots for individual phones. This allows eight full-rate or sixteen half-rate speech channels per radio frequency. These eight radio timeslots (or burst periods) are grouped into a TDMA frame. Half-rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833 kbit/s, and the frame duration is 4.615 ms. The transmission power in the handset is limited to a maximum of 2 watts in GSM 850/900 and 1 watt in GSM 1800/1900.

Figure 12: Mini GSM module for EUD

Beside GSM system, we can use some other existing networking system. Some of them are given bellow.

8.11.2 Home Area Network (HAN):

The Home Area Network (HAN) provides utilities a powerful platform to establish two way communications with the consumer premise. HAN helps Consumer to Utility Communication having Actual energy usage information and response to device energy management control signals. It also helps Utility to Consumer communication having near-real time energy usage information, time of use pricing information appliance control/energy management signals.

8.11.3 Two Way Communication:

Other countries such as Australia and US use Zigbee wireless communication. But in the context of Bangladesh, both Wi-max and Zigbee communication are too much expensive and are not affordable to most of our customers. As we have discussed earlier that we don’t want to make extra construction for Communication, we will use the GSM network established by our mobile operators and the fiber optic communication chain which has been already set up by PDB (Power Development Board) among 132KV substations. We can also use the fiber optic communication set by Bangladesh Railway as well. PLC (Power Line Carrier) will be the most versatile medium for two way communication for Bangladesh. Various coding techniques may be used for wired PLC; however OFDM is rising in popularity due to its robustness against time-varying noise. This is the key to high throughput as many commercial products introduce a number of high frequency components onto the transmission line that is highly attenuated at the MV to LV transformer but present in adjoining properties next to the source.

8.11.4 W –LAN

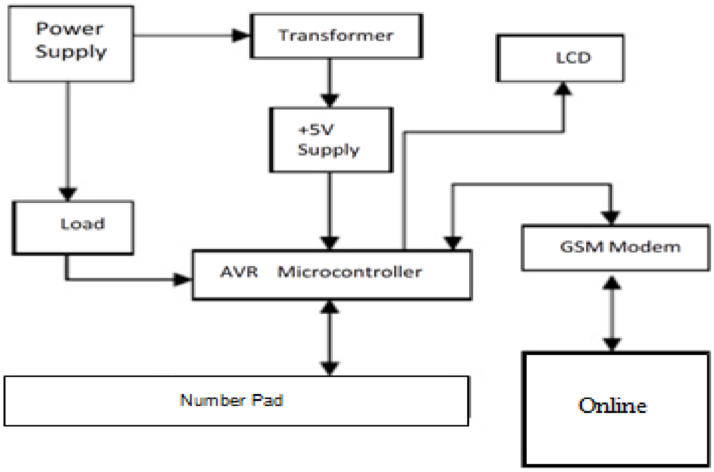
Wireless LAN uses the 2.4 GHz, 3.6 GHz and 5GHz frequency bands for signaling according to the IEEE 802.11 standards. In Europe, this frequency band is open to public use, and is divided into 13 channels. The W-LAN technology is used widely in computer networks. Current W-LAN systems can provide data rates of typically 11 Mbit/s for 2.4 GHz band, 54 Mbit/s for 5 GHz frequency band. But, the W-LAN rates might go even up to 600 Mbit/s with the latest IEEE802.11n specification. For use in home automation systems, other standards are more suitable, however. ZigBee uses the same frequency band as W-LAN, but in contrast also specifies auto-routing of information packages from one node to any other node allowing reaching devices within the entire building, as long as all nodes can contact any other node of the network. For using W-LAN, direct radio signal connectivity between all nodes (clients) and the central access point is required unless special repeaters are used. This would increase cost and power consumption of the system. For this reason, W‑LAN is not further considered for home automation in this project. W‑LAN can be very helpful for the connection between the customer interface and the display, however.

8.11.5 Power Line Carrier (PLC)

One of the most widely used technologies for advanced metering; power line communications makes use of the existing electricity wires to transfer data. Its spectral position is about 1.6MHZ-80MHZ and its estimated bandwidth is almost 256Kbps-2.7Mbps. Power-line communications systems operate by adding a modulated carrier signal to the wiring system. Different types of power-line communications use different frequency bands. Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power-line communications. The main issue determining the frequencies of power-line communication is laws to limit interference with radio services. Many nations regulate unshielded wired emissions as if they were radio transmitters. These jurisdictions usually require unlicensed uses to be below 500 kHz or in unlicensed radio bands. Some jurisdictions (such as the EU), regulate wire-line transmissions further. The U.S. is a notable exception, permitting limited-power wide-band signals to be injected into unshielded wiring, as long as the wiring is not designed to propagate radio waves in free space. Data rates and distance limits vary widely over many power-line communication standards. Low-frequency (about 100 200 kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second; however, these circuits may be many miles long. Higher data rates generally imply shorter ranges; a local area network operating at millions of bits per second may only cover one floor of an office building, but eliminates the need for installation of dedicated network cabling.

9. System Architecture

Figure 13: Block Diagram of EUD (For Prototype Model)



The energy metering system consists of Energy Meter chip, Microcontroller, Voltage and Current controlling unit, GSM module, Relay and Liquid Crystal Display (LCD).The system structure of EUD also contains:
• Energy Meter IC generally produces electrical pulses proportional to the power consumed by the consumer and the power supply of microcontroller.
• Microcontroller calculates the energy consumed by the consumer utilizing the output of Energy Meter Chip and programs loaded on the microcontroller.
• Voltage and Current controlling unit feeds the actual current and voltage of load connected to consumer side to the energy meter chip.
• Relay mainly performs the opening and closing of a connection between energy meter and load through supply mains depending upon the number of units present in the smart card at a moment.
•The GSM module sends the data to internet server.
• Liquid Crystal Display shows the energy consumption, number of unit recharged by the consumer, rest of the unit and maximum demand.

10. Ensuring Secured Operation

The incorporation of a communication capability within a meter creates some risks—most particularly, the risk of attacks by hackers. In the worst case, such an attack might cut the lifeline of a utility's metering system, crippling its power distribution infrastructure and thus causing a catastrophe. To reduce the huge potential danger entailed by this type of situation, communications must be encrypted. In particular, two types of data protection are probably required. First, high-level encryption should be implemented—at the router level, for example—to block remote hacking attempts. Second, anti-tampering features are necessary to ensure that any hackers who get direct access to the meter itself will not be able to steal confidential information from the smart meter's microcontroller section.

11. Results and Discussion

11.1 Power calculation

The active power calculation method also holds true for non-sinusoidal current and voltage waveforms. All voltage and current waveforms in practical applications have some harmonic content. Using the Fourier Transform operation, instantaneous voltage and current waveforms can be expressed in terms of their harmonic content.

$$v(t) = V_O + \sqrt{2} \times \sum_{h \neq 0}^{\infty} V_h \times \sin\left(h\omega t + a_h\right)$$

Where:
v(t) is the instantaneous voltage.
VO is the average voltage value.
Vh is the rms value of the voltage harmonic, h

ah is the phase angle of the voltage harmonic.

$$i(t) = I_O + \sqrt{2} \times \sum_{h \neq 0}^{\infty} I_h \times \sin(h\omega t + \beta_h)$$

Where:
i(t) is the instantaneous current.
IO is the current dc component.
Ih is the rms value of the current harmonic.
βh is the phase angle of the current harmonic.

Using Equation 1 and Equation 2, the active power (P) can be expressed in terms of its fundamental active power (P1) and harmonic active power (PH).

$$P = P_1 + P_H$$

Where:
P1 is the active power of the fundamental component:

$$P_1 = V_1 \times I_1 \cos\Phi_1$$
$$\Phi_1 = \alpha_1 - \beta_1$$

And PH is the active power of all harmonic components:

$$P_H = \sum_{h \neq 1}^{\infty} V_h \times I_h \cos\Phi_h$$

$$\Phi_h = \alpha_h - \beta_h$$

A harmonic active power component is generated for every harmonic, provided that the harmonic is present in both the voltage and current waveforms. The power factor calculation previously shown is accurate in the case of a pure sinusoid; therefore, the harmonic active power must also correctly account for the power factor because it is made up of a series of pure sinusoids.

11.2 Measurement Error

The error associated with the energy measurement made by the ADE7755 is defined by the following formula:

$$\text{Percentage Error} = \frac{\text{Energy Registered by the ADE7755} - \text{True Energy}}{\text{True Energy}} \times 100\%$$

12. Conclusion

We believe this project will be an efficient addition to Bangladesh's energy sector. This technology is very much useful for all electricity distribution companies, private communities, IT parks and home accessories. The general customers can use this device for different purposes in deferent sectors to understand their energy consumption profile. The voice command recognition system, use of GSM networks and internet will allow greater security and real time analysis of energy consumption. This Smart "Energy Understanding Device (EUD)" will create awareness on unnecessary wastage of power and will eventually reduce wastage of power. This module will reduce the burden of energy providing by establishing the connection easily and no theft of power will take place. We believe that, customers want processed data and they want the usage of energy data to be easy and user friendly whereas this project aims at a low cost and trouble free system with numerous economical advantages. We believe the proposed EUD will easily fulfill that demand and revolutionize our energy infrastructure.

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