Smart Energy Meter Using ADE 7758

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Abstract- *This study focuses on customer demand management and energy conservation through smart metering. The discussion here is based study on smart metering and implementation of new methodologies to promote energy conservation via two way interaction. Smart metering, a key element of the so-called smart grid. Electricity is one of the vital requirement for sustainment of comforts of life. IT should be used very judiciously for its proper utilization. But in our country we have lot of localities where we have surplus supply for the electricity while many areas do not even have access to it. Our policies of its distribution are also partially responsible for this because we are still not able to correctly estimate our exact requirements and still power theft is prevailing. On the other hand consumers are also not satised with the services of power companies. Most of the time they have complaints regarding statistical errors in their monthly bills. Smart meters are still evolving and many developers try to add new features to provide more interaction between the consumer and the supply authority. Improved measurement technology by displaying all per phase information and three phase information on LCD at the meter side, automatic meter reading, power quality and exported energy measuring capability are the main features of the implementation. The digital meter was developed using ADE7758 energy measuring chip and microcontroller. The data are sent to a remote server via SMS using SIM900 GSM module. PCF 8583 real time clock IC was used to read the time and generate alarm signals. The phase information, frequency, active energy, exported energy, power quality measurements, electrical demand, date and time are sent to the server. The server handles the incoming SMS, processes the data, displays and stores the required information. Energy consumption and its cost, average daily energy consumption and cost prediction for the month are calculated in the server side.*

Keywords- automatic meter reading, demand management, energy conservation, smart Grid

I. INTRODUCTION

This study focuses on customer demand management and energy conservation through smart metering. The discussion here is based study on smart metering and implementation of new methodologies to promote energy conservation via two way interaction. Smart metering, a key element of the so-called smart grid. Electricity is one of the vital requirement for sustainment of comforts of life. IT should be used very judiciously for its proper utilization. But in our country we have lot of localities where we have surplus supply for the electricity while many areas do not even have access to it. Our policies of its distribution are also partially responsible for this because we are still not able to correctly estimate our exact requirements and still power theft is prevailing. On the other hand consumers are also not satisfied with the services of power companies. Most of the time they have complaints regarding statistical errors in their monthly bills. Smart meters are still evolving and many developers try to add new features to provide more interaction between the consumer and the supply authority. Improved measurement technology by displaying all per phase information and three phase information on LCD at the meter side, automatic meter reading, power quality and exported energy measuring capability are the main features of the implementation. The digital meter was developed using ADE7758 energy measuring chip and microcontroller. We never think the life without the electrical power because human survival and progress totally depends over it. The onset of electrification provides opportunities for new and more efficient metering technologies to be implemented and the future residential development needs. Previously used Power Line Communication [PLC] for data communication has many limitations like complexity of network, cost of installation and maintenance. For different type of services we require different frequency bands and power line uses 50 Hz also unable to support higher frequency bands. The power line is uncovered since losses also increases on the other hand interference between different channels is also big problem. There are some general problems like highly person dependent, human errors can't be avoided, accessibility in rural zone, billing on monthly basis and its processing takes excess time. The Digital Tele wattmeter System is an example of microprocessor based meter. The meter was designed to transmit data on monthly basis to a remote central office through a dedicated telephone line and a pair of modems. Next was to use a DSP based meter to measure the electricity consumption of the customers in the residential area. So there is increased demand for Wireless Automatic Meter Reading (WAMR) systems which automatically collecting consumption, diagnostic, and status data from metering devices and transferring that data to a central database for billing, troubleshooting, and processing. It mainly reduces the human efforts as well as manual errors, provides real time correct consumption, Remote power switches on/off, which reduces required time and increases throughput.

II. RELATED WORKS AND METHODOLOGIES USED

Over the past years electric energy meters have undergone phenomenal changes and are expected to become even more sophisticated, offering more and more services. The electromechanical based energy meters are rapidly being replaced by digital energy meters which over high accuracy and precision. Now the generation of electric energy meters is that of AMRs. Various features offered by AMR are given below:

1. Higher speed
2. Improved load profile.
3. Automatic billing invoice
4. Real time energy cost
5. Alarm warning

History Of Meters

With improvement of national power and country's economy, demands and requirements also increases of various entities like power and proper management is also necessary for that the conventional energy metering systems are available. In last few years, metering devices have gone through much improvement, and are expected to become even more sophisticated, offering more and more services. Past year meters, like electromechanical devices with poor accuracy and lack of configurability with some challenges of theft detection, providing limited amount of energy consumption on site.

1. 1851 1st Gas Meter
2. 1872 Electric Meter Invented
3. 1889 1st Spinning Disk Power Meter
4. 1980s Solid State/Digital Meters
5. 1990s 1st AMR
6. 2009 Smart Meters w/ 2-way Communications

Figure 1: Mechanical & Smart Meter

Methodologies

The method used to carry out this project is the principle of serial communication in collaboration with embedded system. This meter is designed for a three phase system while it can measure the per phase parameters also. It has LCD to display all the parameters like phase voltage, phase current, active power, reactive power, apparent power, power factor, active energy, reactive energy , apparent energy, frequency and power quality measurements at the meter side. The user can switch in to any phase using the push button available at the meter. The energy chip (ADE 7758) used here provides accuracy of 0.1% in active energy measurement and 0.5% accuracy in phase voltage and phase current. The main server stores these data and calculates the total cost of energy. We have used time of day tariff scheme to calculate the cost of energy. Total energy consumption, cost of energy, and tariff for next hour, indication of power outages, average power consumption and estimated bill for the month are transferred to the consumer via SMS.

DIGITAL METER SUB SYSTEM

To measure the power, voltage and other electric parameters the energy measurement chip ADE 7758 is used. This chip is high accurate (0.1% error in active energy) over the selected current and voltage range and support IEC 60687 and other IEC standards. Even though this meter is specially designed for domestic three phase applications, it can be modified even for an industrial application. The chip is connected to a 8 Bit micro controller to communicate and calibrate purposes .The micro controller receives the data via the SPI bus from the energy chip and displays at the demand side using a LCD. The user has the freedom to monitor the phase parameters as well as the energy usage with the push button located at the bottom of the meter. The reset button is used to reset the energy information of the EEPROM. This system provides the basic functionality of a smart meter according to references .

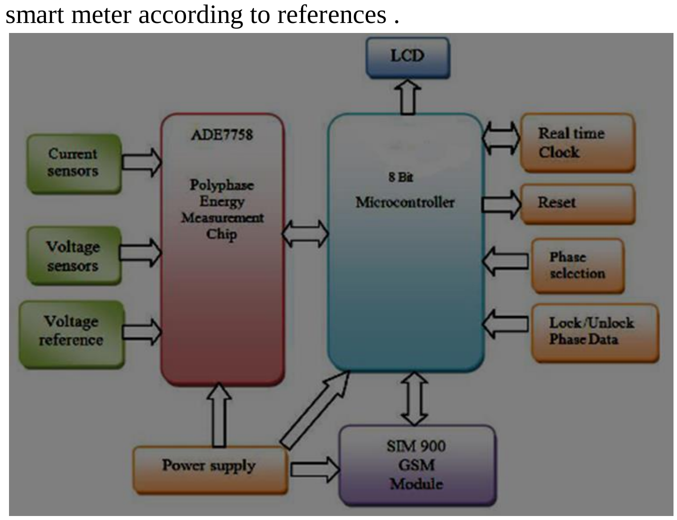


Figure 2 : Block diagram of the digital meter

Analog Inputs to ADE7758 Ic

The back end of the meter is made up of three pairs of voltage and current input networks Each of the three line voltages is attenuated by a resistor divider and filtered through identical antialiasing filters as shown in fig.2.The current channels signals are converted from current to a voltage through current transformers and burden resistors as shown in fig 3.The signals are then filtered by the antialiasing filter on each of the three phases, and the result is applied to the current inputs of the ADE7758.

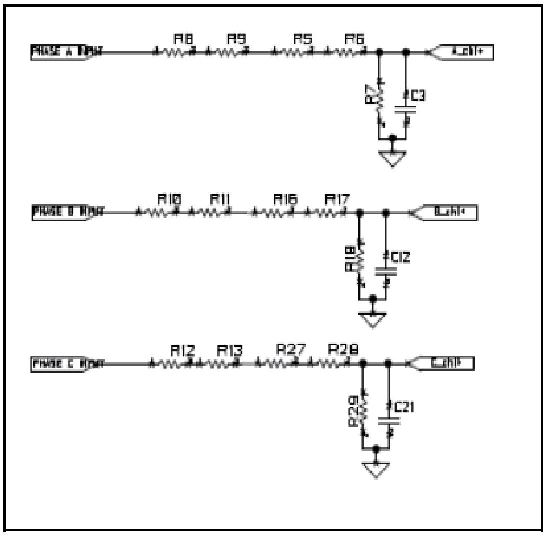


Fig.2: voltage divider network

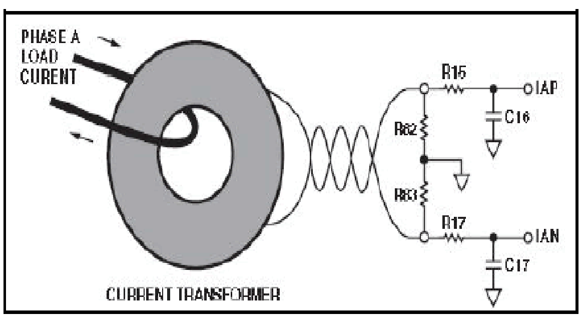


Fig.3: Current transformer wiring diagram

CURRENT CHANNEL ADC

Figure 4 shows the ADC and signal processing path for the input IA of the current channels (same for IB and IC). In waveform sampling mode, the ADC outputs are signed twos complement 24-bit data-words at a maximum of 26.0 kSPS (thousand samples per second). With the specified full-scale analog input signal of ±0.5 V, the ADC produces its maximum output code value (see Figure 41). This diagram shows a full-scale voltage signal being applied to the differential inputs IAP and IAN. The ADC output swings between 0xD7AE14 (−2,642,412) and 0x2851EC (+2,642,412).

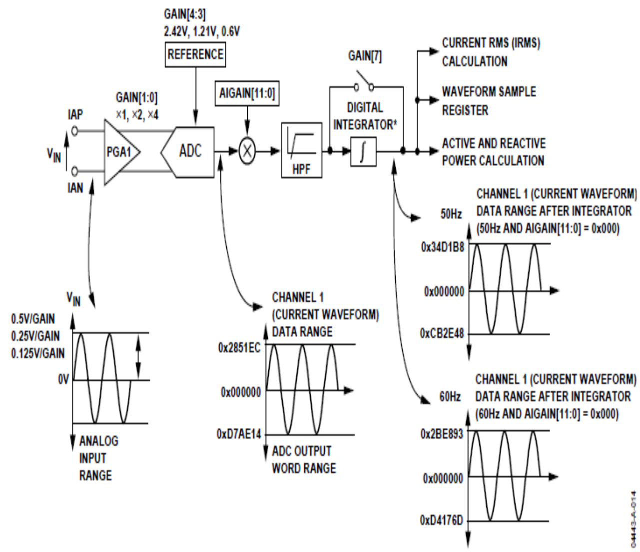


Figure 4: Current Channel Signal Path

III. SOFTWARE IMPLEMENTATION

A. Calibration Using Pulse Output

The ADE7758 provides a pulsed output proportional to the active power accumulated by all three phases, called APCF. Additionally, the VARCF output is proportional to either the reactive energy or apparent energy accumulated by all three phases. The following section describes how to calibrate the gain, offset, and phase angle using the pulsed output information. The equations are based on the pulse output from the ADE7758 (APCF or VARCF) and the pulse output of the reference meter or CFEXPECTED. Figure 5 shows a flow chart of how to calibrate the ADE7758 using the pulse output. Since the pulse outputs are proportional to the total energy in all three phases, each phase must be calibrated individually. Writing to the registers is fast in order to reconfigure the part for calibrating a different phase, therefore Figure 5 shows a method that calibrates all phases at a given test condition before changing the test condition.

B. Phase Calibration Using Pulse Output

The ADE7758 includes a phase calibration register on each phase to compensate for small phase errors. Large phase errors should be compensated by adjusting the antialiasing filters. The ADE7758's phase calibration is a time delay with different weights in the positive and negative direction (see the Phase Compensation section). Because a current transformer is a source of phase error, a fixed nominal value may be decided on to load into the xPHCAL registers at power-up. During calibration, this value can be adjusted for CT-to-CT error. Figure 6 shows the steps involved in calibrating the phase using the pulse output.

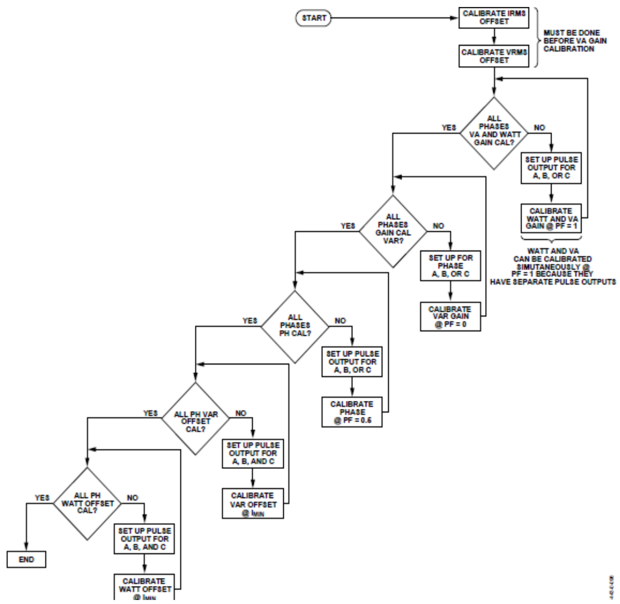


Figure 5: Calibration Using Pulse Output

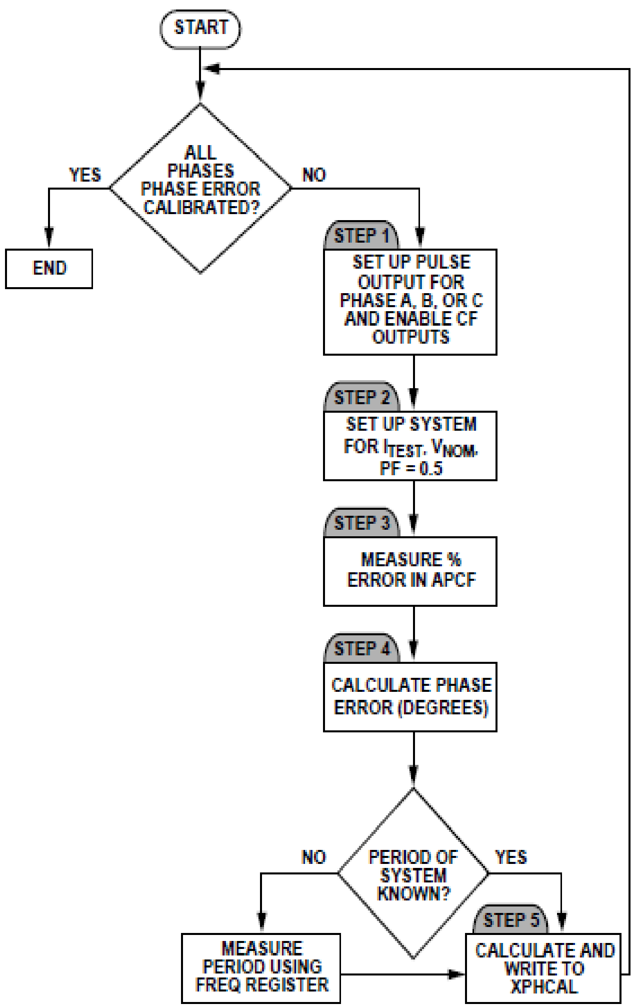


Figure 6. Phase Calibration Using Pulse Output

Algorithm Of The Main Program

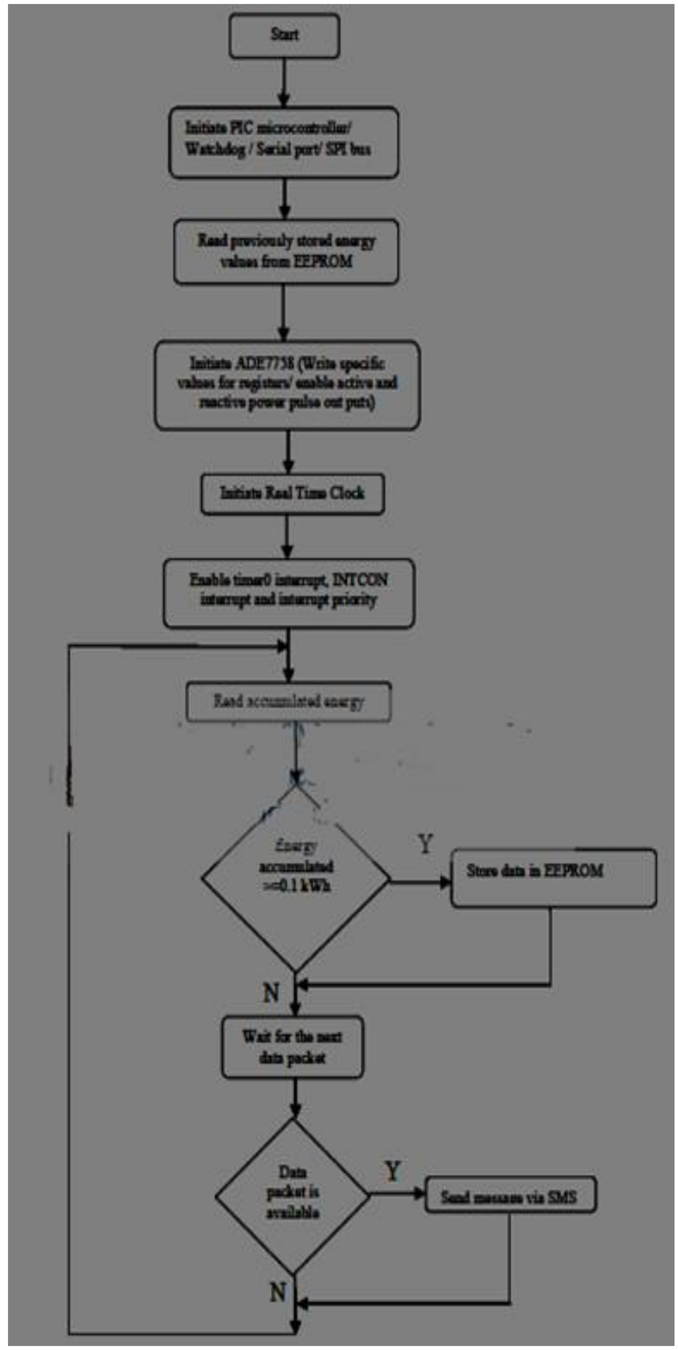


Figure 7

ADE7758 INTERRUPTS WITH AN MCU

Figure 8 shows a timing diagram that illustrates a suggested implementation of ADE7758 interrupt management using an MCU. At time t1, the IRQ line goes active low indicating that one or more interrupt events have occurred in the ADE7758. The IRQ logic output should be tied to a negative edge triggered external interrupt on the MCU. On detection of the negative edge, the MCU should be configured to start executing its interrupt service routine (ISR). On entering the ISR, all interrupts should be disabled using the global interrupt mask bit. At this point, the MCU external interrupt flag can be cleared in order to capture interrupt events that occur during the current ISR. When the MCU interrupt flag is cleared, a read from the reset interrupt status register with reset is carried out. (This causes the IRQ line to be reset logic high (t2)—see the Interrupt Timing section.) The reset interrupt status register contents are used to determine the source of the interrupt(s) and hence the appropriate action to be taken. If a subsequent interrupt event occurs during the ISR (t3) that event is recorded by the MCU external interrupt flag being set again. On returning from the ISR, the global interrupt mask bit is cleared (same instruction cycle) and the external interrupt flag uses the MCU to jump to its ISR once again. This ensures that the MCU does not miss any external interrupts. The reset bit in the status register is an exception to this, and is only high for one clock.

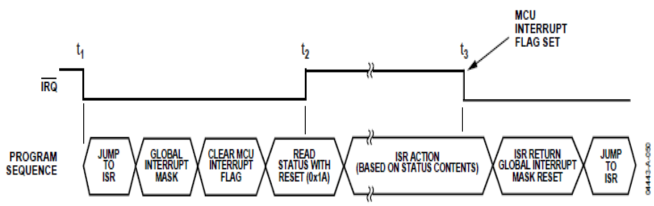


Figure 8 . ADE7758 Interrupt Management

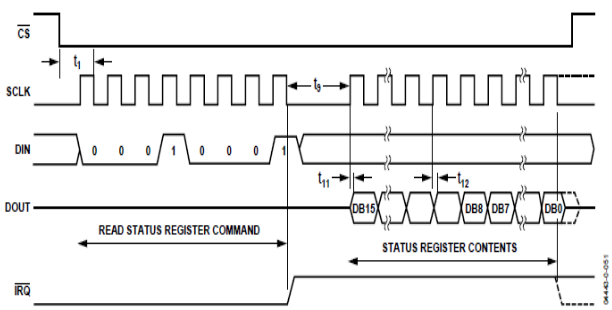


Figure 9 : ADE7758 Interrupt Timing

E. INTERRUPT TIMING

The ADE7758 Serial Interface section should be reviewed first before reviewing this interrupt timing section. As previously described, when the IRQ output goes low, the MCU ISR must read the interrupt status register in order to determine the source of the interrupt. When reading the interrupt status register contents, the IRQ output is set high on the last falling edge of SCLK of the first byte transfer (read interrupt status register command). The IRQ output is held high until the last bit of the next 8-bit transfer is shifted out (interrupt status register contents)—see Figure 9. If an interrupt is pending at this time, the IRQ output goes low again. If no interrupt is pending, the IRQ output remains high.

IV. MATHEMATICAL MODEL

1. Real Power: (P)

Alternative words used for Real Power (Actual Power, True Power, Watt-full Power, Useful Power, Real Power, and Active Power) In a DC Circuit, power supply to the DC load is simply the product of Voltage across the load and Current flowing through it i.e., P = V I. because in DC Circuits, there is no concept of phase angle between current and voltage. In other words, there is no power factor in DC Circuits.

Real Power formulas:

Real or True power = $\sqrt{}$ (Apparent Power^2– Reactive Power^2)

2. Reactive Power: (Q)

Also known as (Use-less Power, Watt less Power) .The powers that continuously bounce back and forth / onwards between source and load is known as reactive Power (Q).

Reactive power formulas:

$Q = V I \sin\theta$

Reactive Power=$\sqrt{}$ (Apparent Power^2– True power^2)

$$VAR = \sqrt{(VA^2 - P^2)}$$

$$kVAR = \sqrt{(kVA^2 - kW^2)}$$

3. Apparent Power: (S)

The product of voltage and current if and only if the phase angle differences between current and voltage are ignored. Total power in an AC circuit, both dissipated and absorbed/returned is referred to as apparent power The combination of reactive power and true power is called apparent power.

In an AC circuit, the product of the r.m.s voltage and the r.m.s current is called apparent power.

Apparent power formulas:

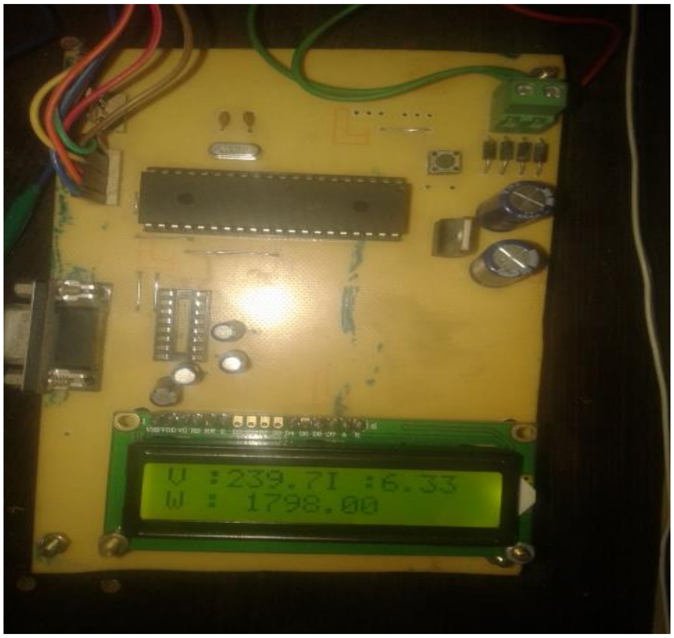
$$S = V I$$

Apparent Power = $\sqrt{}$ (True power^2 + Reactive Power^2)

$$kVA = \sqrt{kW^2 + kVAR^2}$$

V. EXPERIMENTAL SETUP

This section is used to represent the effectiveness of the designed system. It describes the experiments done to evaluate and quantize the performance of the system.When dealing with a system such as this where the outcome specifies target accuracy, many of the experiments might seem irrational and irrelevant. A system such as this, containing many subsystems, might introduce (or eliminate) some of the error percentage from the original test variable (being the energy measurement). It is imperative then, to test (at least to some extent) all the subsystems handling the test variable for accuracy.This section is used to represent the effectiveness of the designed system. It des cribes the experiments done to evaluate and quantize the performance of the syste



VI. CONCLUSION

With the latest advancements in integrated circuit development, implementing an electronic energy meter with a PIC microcontroller is a straight forward exercise. The design and implementation of a fully functional energy meter with added functionalities of PIC18F4550 microcontroller is presented. The energy meter is interfaced with the ADE7758 chip which has simple voltage and current sampling techniques in order to measure active power, reactive power, apparent power and total energy which satisfies emerging requirements of energy providers.

Compared to electromechanical electric meter, the power requirement of the designed energy meter is less. An experiment is conducted to verify the values, obtained from the designed prototype of energy meter, using the watt meters by taking induction motor as load. The percentage variation in the watt meter readings and the energy meter readings is discussed in results chapter. The energy meter designed is free from tampering hence, energy theft is prevented

SCOPE OF FUTURE WORK

1. Remote recharging can be implemented through telephone line or wireless network.
2. The protection against the power theft and energy meter tampering can incorporate in this project.
3. A mini printer can be interfaced to get a printed bill or details of billing.
4. Software can be modified to view the balance on request.

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