DESIGN & IMPLEMENTATION OF AN INTELLIGENT ELECTRICITY METER WITH COMPARATIVE ANALYSIS OF COMMUNICATION TECHNOLOGIES

KHUSHBU V. MEHTA1, BHAVIKA PRAJAPATI2 & UMANG SHARAD WANI3

1Electronics & Communication, MEFGI, Rajkot, Gujarat, India
2VLSI & ESD, GTU PG School, Gandhi Nagar, Gujarat, India
3Electrical Power System, BVM Engineering College, Vallabh Vidyanagar, Gujarat, India

ABSTRACT

Technology aims at making a huge modification in existing machines or appliances in order to solve problem at higher level and make life comfortable. In recent years, the need for electricity in many developed and developing countries have raised concern over and so there should be more focus on understanding power consumption patterns. The technology of employing intelligent electricity meters is still unaware to many common people and electricity utilities. The main discrepancy of preceding used traditional meters is that they do not provide information to the consumers, which is accomplished with the help of this research. This paper focuses on distributing the electricity smartly and efficiently to the consumers. Advent of potent cost effective digital components (ARM Cortex) and dexterous software tools (LPCXpresso) has made it possible for today’s applications. The paper also narrates the comparative analysis of communication standards, introducing intelligent monitoring and control of system.

KEYWORDS: Component; AMI; AMR; ARM Cortex; DCU Intelligent Meter; PLCC; M Bus

INTRODUCTION

Motivation

The efficient and prudent use of energy is now a global pre-occupation, the over-riding motivation being environmental damage-limitation to offset climate change. Energy expenditures will be decreased by increasing the possibility of reduced consumption using the Smart Electricity Meter. Further, high energy prices and widespread ‘fuel poverty’ have heightened the need to reevaluate our energy consumption. This has led to the concept of ‘Smart Energy’ (SE). The abundant developed, both traditional and elective ways, of electricity generation and transmission are available now-a-days then also there are a lot of problems with the distribution, metering and billing of electrical energy and its consumption measurement. With the use of traditional meters, there is inclusion of wastage of energy to man power.

Figure 1: Comparisons of Different Energy Meters
Today, consumers are demanding for better customer service, higher power quality, higher energy measurement accuracy and more timely data. Utility companies are being forced to fulfill all customer demand. The possible solutions are smart grid systems and Advanced Metering Infrastructure (AMI)/Automated Meter Reading (AMR). The innovation can only be carried out with the development of new technologies. The new intelligent energy meters are equipped with some additional functions, beside the measurement of consumed energy. AMI involves two-way communications with smart meters and other energy management devices. AMR is the technology of automatically collecting consumption, diagnostic and status data from energy metering devices and transferring that data to a central database for billing, troubleshooting, and analyzing. This advancement mainly saves utility providers the expense of periodic trips to each physical location to read a meter. In figure 1 comparison of different energy meters are included.

One of the benefits of a smart metering system with communication capabilities is the ability to use real time metering data to generate and analyze energy consumption patterns and peak energy demands of each individual consumer. This information can be used by the utility as well as the consumer. The utilities can offer dynamically varying peak and off peak tariffs depending on the overall load condition of the grid. On their part, consumers can schedule their consumption of energy to run heavier loads at off peak periods to benefit from reduced tariffs during those times. The utilities benefit from not having to operate power plants that produce power only during peak hours and lie idle during the off speak hours. This improves the efficiency of the system from the economic and reliability points of view.

A quick feedback analyze work explains a gap between the consumers and energy utilities so that they can communicate more efficiently through the implementation of conservation strategies [4]. The consumers need to be educated with broader knowledge regarding the meter so that wrong perceptions can be altered. Through load variable tariff customers can profit as well, since they can optimize their electricity consumption against the given prices. The identified reduction of operating costs for the utilities can be in the range of 30-50%. The objective has in this meter been enlarged to reduce and keep down carbon emissions and improve energy efficiency.

**METHODOLOGY**

The different sections are explained below:

**Power Supply Section:** The first and foremost requirement of any electronic circuit board is power supply. While designing a power supply, a designer can choose between a Switch mode power supplies (SMPS) and a capacitor-based power supply.
The power line voltage is the one which is going to be sensed. As this line voltage is high, cannot be directly supply to the individual blocks. Thus there is a need to down the voltage in required range and this purpose is served by this block.

**Analog Section:** The controller needs to be fed with voltage and current values, in order that it performs the energy (kWh/kVArh) computations. Hence we need to bring down the 230V ac voltage to an acceptable value (here 0.3 Vrms) by the controller.

The analog inputs to the chip carry the ac signal to be measured and further processed. The RC combinations form a low pass and filter out the high frequency signals. There are two current channels as shown in figure 4. The CT (Current Transformer) has a burden resistor of 50 ohms connected across it. Op-amp reference voltage is set at 0.33V for sensing current and 1.93V for sensing voltage for better output.

The output of CT is given to the Analog to Digital Convertor (ADC) of LPC 1114. The LPC 1114 includes inbuilt 10 bit ADC which perform the conversion. The ADC should not receive a noise corrupted signal or else it would result in erroneous calculations.
Microcontroller Unit: This section is the heart of an intelligent energy meter. The calculations of factors like Peak and RMS value of voltage and current, Active, Reactive and Apparent Power, Active, Reactive and Apparent Energy, Power factor (cos φ), Frequency and Tamper detection are done within this. Measurement accuracy is determined by resolution, precision, and dynamic range. The micro-controller unit is the first and foremost requirement to build up a meter. Here LPC1114 ARM CORTEX M0 microcontroller is used for developing this application. Simulation is shown in figure 6.

Real Time Clock: In this world of digitization we are working with real time systems. This clock function operates even when the power is turned off. In portable devices, it is important to reduce the current consumption RTC IC to extend the battery life.

Digital Display Section: The display module comprises of a driver IC and a screen to display power consumed by the users thus users are aware with the used energy. This driver drives various segments of LCD. A number of LCD drivers are available that are compatible with different MCUs. For example PCF8576D is a universal LCD driver by NXP which can drive up to 160 segments of LCD. I2C protocol is used to communicate LCD with MCU which reduced the number of pins used.

A Real Time Operating System (RTOS) is also used here to provide the task scheduling within a smart energy meter [8].
COMMUNICATION TECHNOLOGY

Different kinds of network topology and connectivity are possible between smart meters and energy providers; for example, smart meters can exchange data, using Radio Frequency (RF) or Power Line Communication (PLC), to and from a local data concentrator, which can communicate in real time with the utility using GPRS connectivity. Moreover, the smart meter should be able to synchronize and exchange information with other meters such as water, gas and heat meter, using proprietary or standard protocol. Various standards are available for the implementation of AMR.

- **Wireless M-Bus**

  The M-Bus (Meter Bus) is a common standard used for AMR implementation, for remote energy meter reading. The wireless M-Bus (Meter Bus) was developed to fill the need for a system for the networking and remote reading of utility meters. It defines wireless communication between electricity meter and the data concentrator. European smart meter communication standard EN13757-4.M-Bus specifies three modes of operation: R, S and T, differ by data rate, channel frequency and data encoding used [10]. The three layers supported here are physical layer; data link layer and application layer of an OSI network model as shown in Figure 6. The M-Bus is not a network, and therefore does not among other things need a transport or session layer, the levels four to six of the OSI model are empty.

  The M-Bus favors asymmetric network topologies with low-cost or low-power metering devices on the one side and data collectors or gateways with higher performance on the other side. Only point-to-point or star network topologies can be applied. It is open standard for Automatic Meter Reading and basis for new Advanced Metering Infrastructure (AMI) installations.

![Figure 8: The M-Bus Layers in the OSI-Model](image-url)
The Wireless M-Bus standard is defined by the European standards EN 13757-4 for Physical and Data link layers. The application layer is defined by EN 13757-3 standard. The standard defines the communication between remote meters and mobile readout devices, stationary receivers, and data collectors. The w M-BUS standard is designed to give a long battery life for battery operated meters, so that there won’t be any need for battery replacement over the normal life span of the meter.

- **PLCC**

PLCC, Power Line Carrier Communication, is an approach to utilize the existing power lines for the transmission of information. In today’s world every house and building has properly installed electricity lines. It is widely used to provide real-time communications for protection of high voltage transmission lines [12]. PLCC is often the most economical and reliable high-speed dedicated channel available for protective relaying as well as for data transfer. By using the existing AC power lines as a medium to transfer the information, it becomes easy to connect the houses with a high speed network access point without installing new wirings.

In this type system a Radio Frequency signal (RF) is sent over the normal building power wiring. There would be a transmitter to send the signal and a receiver to receive the signal. This signal may contain data to report or instruct.

The carrier can communicate voice and data by superimposing an analog signal over the standard 50 or 60 Hz alternating current (AC). It includes Broadband over Power Lines (BPL) with data rates sometimes above 1 Mbps and Narrowband over Power Lines with much lower data rates. Traditionally electrical utilities used low-speed power-line carrier circuits for control of substations, voice communication, and protection of high-voltage transmission lines. A short-range form of power-line carrier is used for home automation and intercoms.

**Operating Principle**

TDA 5051, an IC for the PLC communication system can be used to transmit and receive data over the power line. Both the MIU and the DCU should contain this IC. The binary data stream is keyed onto a carrier signal by means of the FSK, ASK or OFDM technique. The central frequency is shifted +0.3 KHz to represent 1 or 0 of the binary data stream [13]. This signal is then coupled onto the power line by the PLM. At the receiving end, an identical PLM will detect the signal and convert it back to a binary data stream.

![Figure 9: Working Principle of PLCC System](image)

There are three main components of PLCC system: Line Matching Unit (LMU), Wave Trap and Coupling Capacitor (CC). LMU fulfills the purpose of impedance matching between power line and coaxial cable. The factor behind using coaxial cable is for sending the high frequency signal from source to LMU.
Wave trap is used to block the transmitted HF carrier to enter inside the sub-station. The range of inductor used here is in between 0.5mH to 2mH. Coupling capacitor is used to couple the HF carrier with Power Line. The range of capacitor should be arranged between 4000pF to 10000pF. The coupling techniques used for PLCC system are: Phase to ground coupling, Phase to phase coupling and Inter circuit coupling.

Suppose a fault is detected in a protected area within transmission line AB. The relay situated at one end say B, will sense the fault and trip the circuit breaker at the end B. Simultaneously another relay will cause the carrier signal to flow towards A. To provide protection transmitter at B cuts off speech and unimportant tones momentarily. When this carrier signal will be received at A, Circuit breaker at A will be operated and the faulty part of system will be isolated. This process is shown in figure below:

![Figure 10: Fault Detection with PLCC System](image)

In smart energy meters, transmission speed is not a great concern but reliability is important. The data rate of the PLC channel is set at 600 bps, to ensure communication over a longer distance and reduced transmission error. With the sensitive signal detection and sophisticated digital filtering technique, this PLC communication is highly immune to electrical noise and interference.

### Table 1: Comparisons of Two Different Communication Technologies

<table>
<thead>
<tr>
<th>Parameters</th>
<th>wM-BUS</th>
<th>PLCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity</td>
<td>Wired or Wireless</td>
<td>Wired</td>
</tr>
<tr>
<td>Range</td>
<td>1000m</td>
<td>Multi-kilometre</td>
</tr>
<tr>
<td>Frequency</td>
<td>868MHz, 169 MHz, 433MHz</td>
<td>10-490 KHz</td>
</tr>
<tr>
<td>Standard</td>
<td>EN13757</td>
<td>IEEE 1901.2</td>
</tr>
<tr>
<td>Data Rate(kbps)</td>
<td>100(868 MHz), 4.8(169 MHz), 2.4(433 MHz)</td>
<td>&lt;500</td>
</tr>
<tr>
<td>Applications</td>
<td>Wireless meter reading, Building Automation/control, Wireless sensor network</td>
<td>AMR Home automation, Home security, Video conferencing</td>
</tr>
<tr>
<td>Modulation type</td>
<td>FSK, G-FSK</td>
<td>ASK, FSK, OFDM</td>
</tr>
<tr>
<td>Data protection</td>
<td>CRC</td>
<td>CSMA/CA</td>
</tr>
</tbody>
</table>
FLOWCHART FOR PROGRAMMING METER

CONCLUSIONS

The Smart Energy Meter presented in this paper absorbed many advanced study results communication technology. The meter-reading task can be completed at the Data Concentrator Unit by using this system. The energy production unit can monitor the real time power consumption in order to improve the utility of power. The use of embedded system improves the stability of data transmission. It is a win-win solution where consumers can avail tariff discounts by becoming more efficient while electric utilities can increase its revenue both through loss reduction and through the collection of penal charges.

ACKNOWLEDGEMENTS

It is a privilege for us to have been associated with Dr. Vithal N.Kamat, Managing Director of Centre for Apparent Energy Research(CAER), Baroda Electric Meters Ltd(BEM). Vithal Udyognagar. During this work we have been greatly benefited by his valuable suggestions and ideas. Without his experience and insights, it would have been very difficult to do quality work. We also take the opportunity to thank all the team members of Baroda Electric Meters to help us within this work and providing the facilities for the same.
REFERENCES


5. Botswana Power Corporation – A SAP IS-U and Smart Meter implementation project experience in Botswana, Africa.


8. Using the FreeRTOS real time kernel, Rechard Barry


10. KR HARIHARASUDHAN, Filippo COLAIANNI, Michele SARDO, Ramkumar S, Neha KOCHHAR : wireless m-bus in smart grid scenario


12. Jovita Serrao, Awab Fakih, Ramzan Khatik, Shaikh Afzal, Chaya Ravindra —transmission of data using power line carrier communicationl, November-201