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Application of Smart Energy Meter in Indian Energy Context

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Abstract: *In the Energy Management system, the main constraints are accurate metering, energy theft and implementation of proper tariff as well as billing system. This can be achieved by using Smart Meters. An energy calculation through smart meter is proposed for automatic meter data collection, give intimation through messages displayed on LED and energy auditing. This paper makes the consumer an active part of Energy Management duly monitoring the various parameters like voltage, current, power factor etc., directly in the Smart meter, (or) in the PC through RS 485 and necessary precautionary measures can be taken to improve power factor, and to minimize energy loss.*

Key Terms: *Energy Management, Energy Conservation, Demand Side Management, Smart Meters, Time Of Day Tariff.*

I. Introduction

Due to rapid increase in human population and the human's dependency towards electrical energy, the demand of electricity has increased, causing deficit of electrical energy during peak hours. As per the report of CEA, India [1], the gap between the electrical energy supply and the energy demand in July-2014 is -3.9% (MW). Accurate metering, detection of illegal activities and implementation of proper tariff and billing system would manage the consumption of electrical energy. Collecting meter reading is one of the most difficult procedures in billing [2]. The traditional electrical energy meter data collection is such that a person from the utility provider visits the consumer sites periodically to note the meter reading. This procedure has lot of drawbacks such as, it is time consuming, tiresome and requires more human resource, human error and even corruption is probable [2-16]. The process may be interrupted due to bad weather conditions, also if the consumer is not available, the billing will be pending and human operator needs to revisit. India is facing energy deficit during peak hours. Low voltage during peak hours has been reported as a major power quality issue. Load shedding is a common power management practice followed by the utility providers [17]. Energy conservation has great significance in this scenario of increasing electrical energy demand.

An Automatic Meter Reading (AMR) system equipped with advanced features like two-way communication, Time-Of-Day (TOD) tariff, etc. will address the problems of manual collection of meter data, energy deficit during peak hours and opens a channel for the consumers to participate in energy conservation. With development in technologies in the fields of communication and information technology, a wide variety of AMR and smart meters has been developed. A smart meter is an AMR with two-way communication infrastructure. Smart meters has been designed for various features like remote monitoring of energy consumptions, remote turn ON/OFF power supply, remote detection of energy theft, with time varying pricing system, remote fault detection, capable of monitoring power quality etc. [17-23]. Developments in information management and remote monitoring technology can play a vital role in energy management [18-19]. Smart meter reading cooperate both utilities and consumers in power management, giving them detailed information about power consumption [7].

This article proposes the advance features & application method of a smart metering system compared over traditional Energy meters which can address issues in the power distribution. This paper also makes the consumer an active part of Energy Management duly monitoring the various parameters like voltage, current, power factor etc., directly in the Smart meter, (or) in the PC through RS 485 and necessary precautionary measures can be taken to improve power factor, and to minimize energy loss.

II. Smart Meter Technology Evaluation

Smart Meters are an electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems. The combination of an electronic meter with two-way communications technology for information, monitor, and control is commonly referred to as Advanced Metering infrastructure (AMI). Previous systems, which utilized one-way communications to collect meter data were referred to as AMR (Automated Meter Reading) Systems. AMI has developed over time, from its roots as a metering reading substitute (AMR) to today's two-way communication and data system. The evolution from

AMR to AMI is shown in Table:1 with lists of stakeholders and benefactors for each step in Smart Meter evolution.

Table 1: Smart Meter Technology Evaluation

Smart System Capability ↑

Smart Meter system	Functionality	Stakeholders or Benefactors
AMI (Full two way)	• Integrated service switch • Time based rates • Remote meter programming • HAN interface	• Marketing & DSM • Load Forecasting • Power procurement • Unregulated services
	+	+
AMR Plus	• Daily or on demand reads • Hourly interval data • Outage notification • Other commodity reads	• T&D operations • T&D Engineering • Information Technology • Metering Services
	+	+
AMR one way	• Automated monthly reads • One way outage detection • Tamper detection • Load profiling	• Customers & external stakeholders • Meter reading • Customer service & field service • Billing, accounting, collections

Smart metering essentially involves an electronic power meter supplemented by full remote control, diagnostics, power peak and consumption analysis, anti-tampering mechanisms, fault alert, time-variable tariffs, and many more possibilities. Using power-line communication (PLC) or other wired and wireless technologies to connect the meter to the service provider enables all of the above features to be feasible and compatible with future smart-grid protocols. The typical block diagram of smart metering system is shown in fig 1.

2.1 Smart Metering System

The three main internal areas of a smart meter design include the (i) Power system (ii) Microcontroller and (iii) Communication interface. A power system has a switched mode power supply and battery backup to ensure that the metering electronics remain powered even when the main line is disabled. A Micro Controller Unit (MCU) typically includes an Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) to provide intelligence. A wired or wireless communication interface allows the meter to interact with the rest of the grid, and in some cases the end user's network

Every Smart Meter installed at the consumer end has a unique meter ID. In India, developing a low cost basic Smart Meters by upgrading the existing one is more acceptable. That is the system has to be cost-effective such that reduced implementation cost, maintenance free while providing robust and reliable performance. The main components of the smart Meter are AT89S52 microcontroller, DS1307 Real Time Clock (RTC), a single pole double through relay, LED Screen, RS 485 communication port.

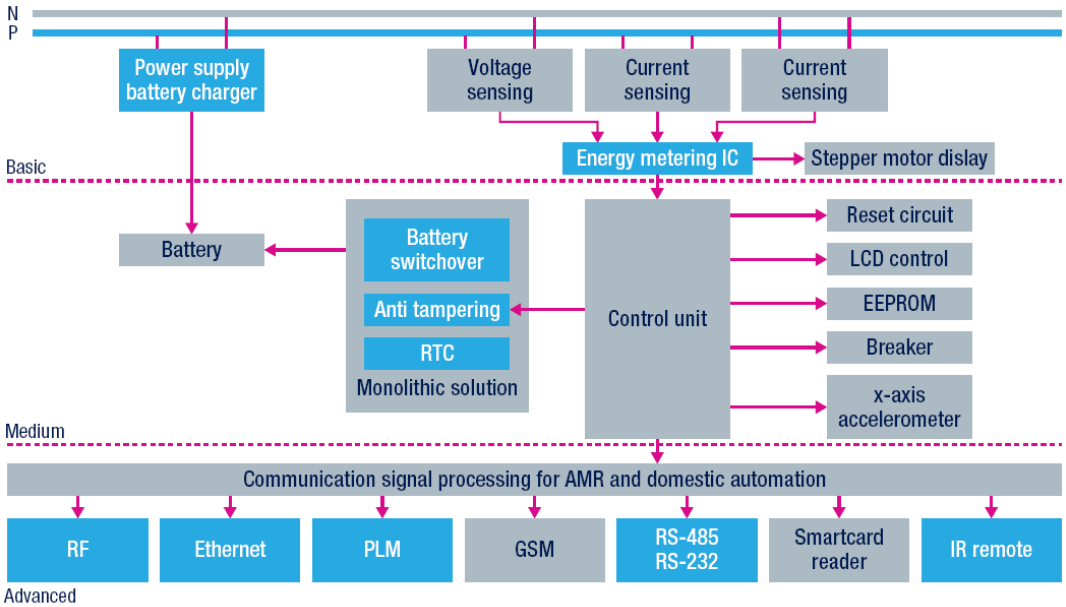

Fig.1: An Overview of Smart Metering System

III. Software Utilization

The designed software incorporates the functionalities necessary in the smart meter end and at the PC end. In the Smart meter microcontroller program is embedded in the flash memory of AT89S52 microcontroller and at the PC, a GUI is designed with LabVIEW.

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non volatile memory technology and is compatible with the industry- standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non volatile memory programmer.

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.

3.1 Program Embedded in Micro Controller

The functioning of the smart meter is based on the program embedded in the microcontroller and is written on „Keil µvision" platform. The program is designed in accordance with the hardware connections of the Smart Meter. The Keil µVision is an embedded development tool for Integrated Development Environment, Simulator, and Debugger for micro controller.

The energy consumption data is communicated to the server by the Smart Meter through communication port. Communication port has serial communication interface with the server. The server comprises GUI and software for billing, both designed with LabVIEW.

IV. Communication Schemes

The AMR system requires means of communication for transmitting and receiving their data. The information collected from each meter, must arrive reliably and securely to the utility provider, for billing and analyzing. In another way any command from provider office that addresses each node and each meter must arrive reliably and securely to its destination. In the network of node meter search node and meter are identified by their unique id (Node-Id and Meter-Id). A Group of smart meters interconnected to a control room with various communication technologies is shown in fig 2.

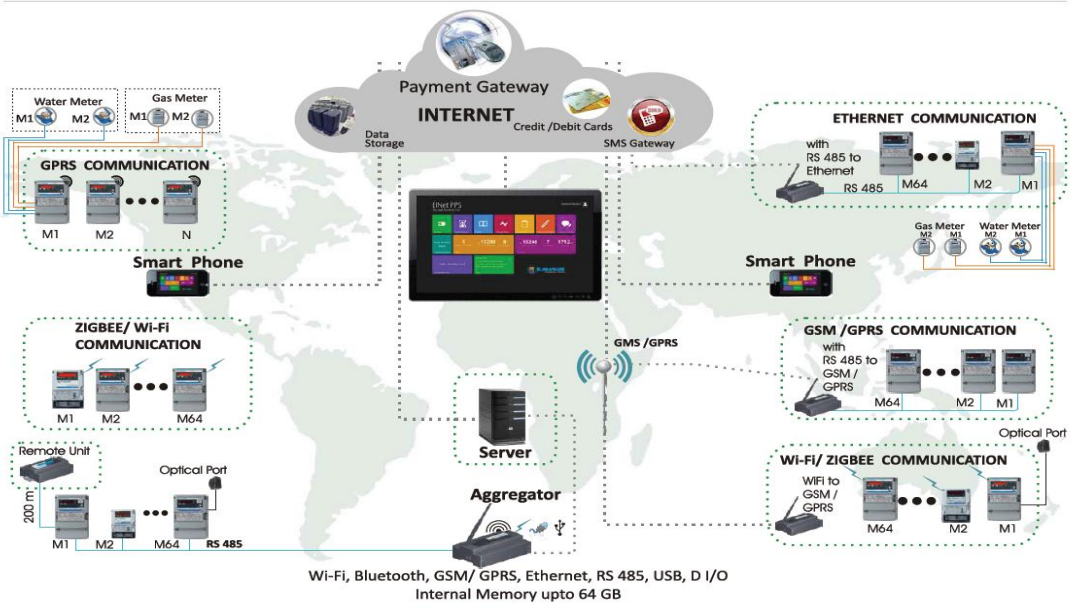

Fig. 2: Smart Meter with Various Communication Technologies

In the smart Meter the available communication Technology's are (i) RS485 with Isolated wired (ii) Ethernet wired (iii) Wi-Fi wireless (iv) Bluetooth Wireless (v) Zigbee Wireless and (vi) GPRS (2G & 3G) wireless. Among in all the communication Technology's available in the market, the Smart meter selected for this research utilizes the RS 485 communication Interface.

4.1 RS 485 Serial Interface

The RS-485 is for higher speeds over longer ranges or if duplex networking capability is required. Again, many standard parts are available to create the interface. ICs have drivers and receivers that can permit

more than 32 drops, and data rates can be as high as 40 Mbits/s. Some ICs also include dc-dc converters to furnish dual supply voltages.

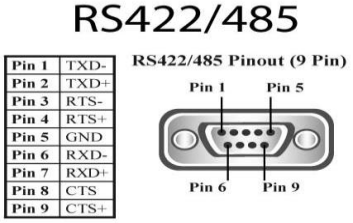

Fig 3. RS 485 Serial Interface

RS485 serial interface shown in Fig.3 is an improved version of RS422, it expands on the capabilities, the major change is to have multi-drop Limitation of RS422, it allowing up to 32 devices to communicate through the same data line. Any of the slave devices on an RS-485 bus can communicate with all the slave within the data line without going through master device.

V. Residential Application of Smart Meters

A residential Building is considered for conducting this analysis in which billing is made by an Electronic Energy meter. A smart meter is connected in parallel to the existing electronic meter and readings are noted in both the maters for comparison.

5.1 Wiring the Smart Meter

Connect the Voltage inputs for single phase AC : For LT Models (230 AC, L-Nominal), connect the phase voltage input directly to the terminals 1 and phase voltage output to the terminal 2. Neutral input to the terminal 3 & neutral output to the terminal 4. RS 485 communication port to the terminals 7 &8 as shown in fig. 4.

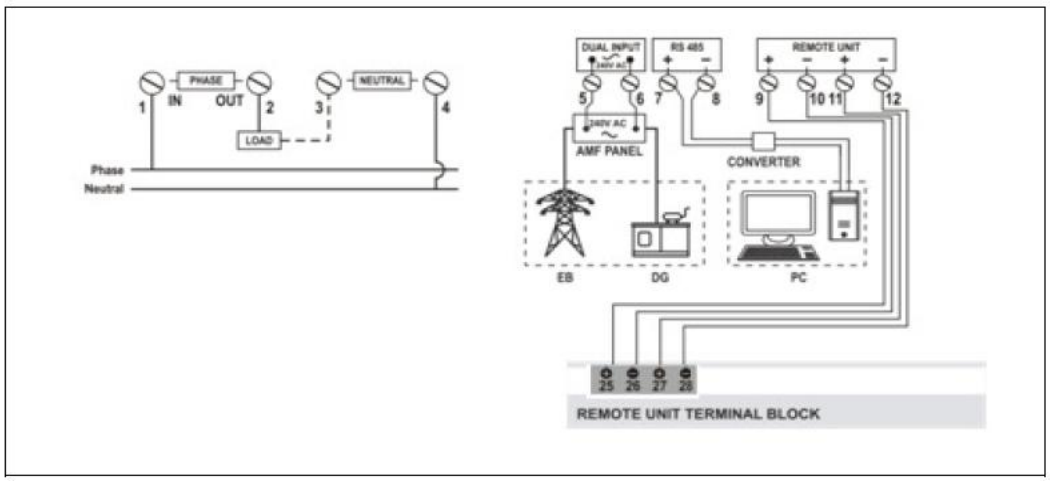

Fig. 4 Wiring the Smart Meter

5.2 Practical Application of Smart Meter used in this project

The smart meter is connected in parallel to the existing Electronic Meter in a residential building and measured the following parameters in both the existing electronic meter and smart meter. The energy Meter readings for a period of three months are noted in both the meters for comparing the parameters shown in Table 2.

Table.2 Comparison of parameters noted in existing electronic meter and smart meter

Electronic Meters	Smart Meter Parameters
The following Parameters can be noted in the Electronic meters ➢ Meter reading in KWh	The following Parameters can be record in the Smart meters ➢ Volts L-N ➢ Average Current - Amp ➢ Frequency - HZ ➢ KVA Total ➢ Power factor ➢ KW total ➢ Meter reading in KWh

The Experiment is conducted in a residential building for a period of three months and the experiment readings for one week are furnished in Table:3. The consumer can monitor various parameters of electrical supply in smart meter and can take necessary precautions to improve power quality.

Table.3 Practical readings noted in both the meters

		smart meter parameters							existing Elec. Meter reading kWh Rec
Date	Time	Volts L-N	Amps Ave.	Frequency	kVA Total	P.F	kW Total	kWh Rec.	kWh
01-02-2015	6.00 AM	249.5	0.486	48.96	0.124	0.653	0.078	19.323	602
	9:00 AM	241.2	0.445	50.03	0.104	0.61	0.065	20.251	604
	6:00 PM	258.0	1.398	50.06	0.362	0.481	0.174	22.118	605
	9:00 PM	256.4	1.52	50.23	0.393	0.652	0.261	23.215	606
02-02-2015	6:00 AM	238.0	10.44	50.8	0.2	0.573	1.423	24.590	608
	9:00 AM	256.3	0.532	50.0	0.8	0.907	0.416	26.451	609
	6:00 PM	249.1	1.764	49.93	0.439	0.502	0.22	27.076	610
	9:00 PM	257.6	1.692	50.07	0.66	0.643	0.428	27.490	611
03-02-2015	6:00 AM	245.4	0.882	50.01	0.21	0.466	0.1	28.206	612
	9:00 AM	248.1	0.452	49.75	0.113	0.485	0.053	30.147	613
	6:00 PM	254.6	0.793	51.07	0.2	0.836	0.15	31.322	614
	9:00 PM	257.3	1.565	50.12	0.4	0.599	0.24	31.952	615
04-02-2015	6:00 AM	244.1	1.372	49.42	0.336	0.602	0.201	32.713	616
	9:00 AM	254.8	1.234	50.06	0.315	0.62	0.195	33.862	617
	6:00 PM	250.2	1.491	50.97	0.37	0.629	0.23	34.760	618
	9:00 PM	256.0	1.129	50.12	0.28	0.775	0.225	35.430	619
05-02-2015	6:00 AM	239.0	9.68	50.01	2.331	0.997	0.23	36.257	620
	9:00 AM	251.6	0.94	50.01	0.236	0.605	0.142	37.298	621
	6:00 PM	256.8	0.793	50.21	0.2	0.805	0.15	38.874	622
	9:00 PM	256.1	1.617	50.06	0.41	0.65	0.266	39.370	623
06-02-2015	6:00 AM	250.5	0.933	49.93	0.23	0.63	0.143	41.016	624
	9:00 AM	251.5	0.94	50.05	0.236	0.605	0.142	41.523	625
	6:00 PM	254.6	1.346	51.07	0.342	0.457	0.158	42.061	626
	9:00 PM	258.9	1.178	50.06	0.3	0.798	0.22	43.276	627
07-02-2015	6:00 AM	253.7	0.924	49.9	0.23	0.536	0.126	44.722	628
	9:00 AM	248.9	2.287	49.77	0.568	0.685	0.41	45.369	629
	6:00 PM	248.5	10.06	50.09	2.51	0.999	2.5	46.659	630
	9:00 PM	247.1	1.163	50.97	0.25	0.844	0.23	48.342	631

Power consumption noted in the Smart Meter for one week (i.e) from 1-Feb-2015 to 7-Feb-2015 is 29.019 kWh (i.e meter closing reading on 7-Feb-15 - meter opening reading on 1-Feb-15) and Power consumption noted in Electronic Meter is noted as 29 kWh (i.e 631-602 = 29 kWh)

The Power Factor Monitoring curve is shown in Fig:5 and Load monitoring curve is shown in Fig :6

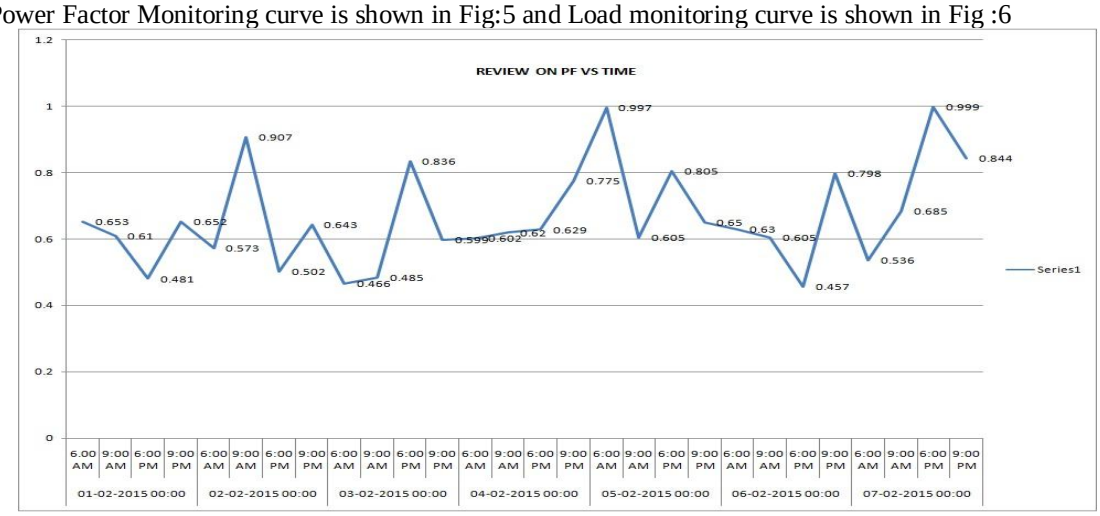

Fig. 5 A Plot for review of Power Factor Versus Time

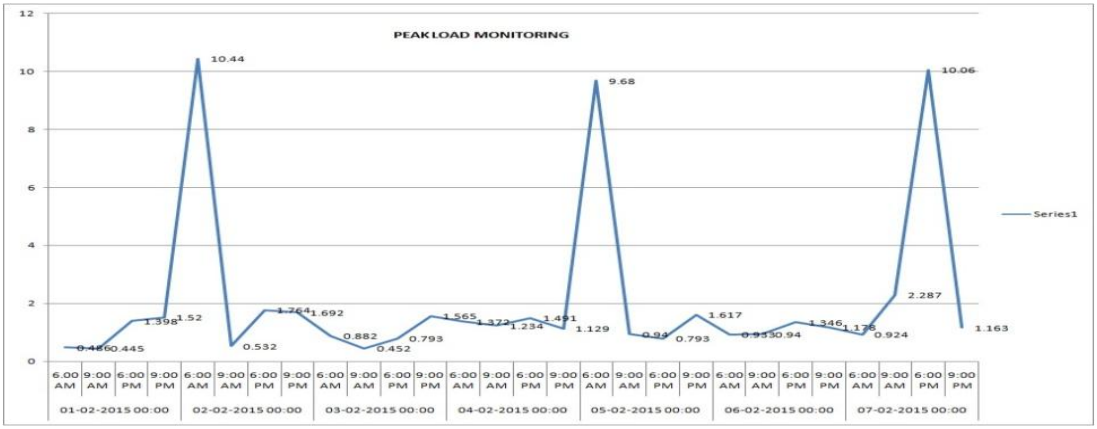

Fig. 6 A sample line graph showing Peak Load monitoring

5.3 Observations on the experiment Results

By observing the experiment results it is observed that, only energy Meter reading in kWh can be noted in the ordinary Electronic Meter, where as in Smart meter seven basic parameters (V, A, KVA, PF, KW and total kWh) can be recorded including the total kWh. The consumer can also monitor the load during peak hours. If the amount of load shifted to normal hours there by the peak demand will go down and hence power generation during peak hour can be reduced, this brings the production cost down. Since, the consumers get benefited for limiting the consumption during peak hours, they become vigilant in managing electricity consumption. Hence, the designed Smart metering system is useful to both utility Provider and consumers.

In this project, by observing the one month energy readings it is observed that, the supply voltage is high and the power Factor is Low. Due to the high supply voltage the life and performance of electrical appliances will decrease day by day. This high voltage problem can be eliminated by using the automatic voltage Stabilizers. The PF can be improved by connecting suitable capacitor banks.

VI. Conclusion

The proposed Smart Metering System is capable of monitoring various parameters of electrical energy like Voltage, Power Factor, Current, energy consumption in kWh etc., and the consumer can take suitable precautions to safe guard the electrical appliances. This makes the consumer an active part of Energy Management. The consumer can also monitor the load during peak hours. If the amount of load shifted to normal hours there by the peak demand will go down and hence power generation during peak hour can be reduced, this brings the production cost down. Since, the consumers get benefited for limiting the consumption during peak hours, they become vigilant in managing electricity consumption. Hence, the designed Smart metering system is useful to both utility Provider and consumers. An intelligent circuit which detects theft and generate a switching pulse on detection of theft can be designed and integrated with the system. An apt tariff system and theft detection circuitry can be integrated with the proposed smart meter design.

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