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An Improved AMR/AMI Approach for Metering & Energy Monitoring

Swapnil R. Katre
M.E. Student
Dept. Electronics and Telecommunication
Dhole Patil College of Engineering
Wagholi, Pune, India.
swapnilkatre@gmail.com

Prof. V. Nikam
Head of Department,
Dept. Electronics and Telecommunication
Dhole Patil College of Engineering
Wagholi, Pune, India.
nikamvb78@gmail.com

***Abstract*—**The growing demand of energy in day to life has also increase the demand of monitoring and managing it. So a connectivity solution for smart metering address the challenge of liable, secure and robust communications for remote metering and home energy management, Enabling remote metering with Web connectivity is needed.

In this paper an AMR solution with standalone transceivers to complete systems-on-chip with 32-bit ARM® core and embedded memory, supporting both sub-GHz frequencies (including 868/915MHz) and 2.4 GHz license-free frequency bands is discussed with other available solution.

***Index Terms* —** *Smart Grid, Smart Energy Monitoring Unit, Billing Service, AMR, AMI, ADE7880, MK60FN1M0VLQ12.*

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I. INTRODUCTION

Governments worldwide are mandating improved energy efficiency, requiring an investment in the new smart grid and smart energy management structure .The goal is to create a smart grid that will change the way power is deployed for sustainable energy around the world. This document will address design challenges within the smart grid.

- **Lower system cost**: Required to reduce time to market, R&D investment and BOM costs while adding features for smart grid requirements
- **Low (system) power**: Must have efficient metering code to enable energy calculations at low processing speeds for meters supported by capacitive supplies
- **Data preservation during fail or brownout events**: Low-power, real-time clock with the ability to switch to battery supply, on-chip clock compensation, calendaring or an internal clock if the external crystal fails
- **Meter tampering**: Requires the ability to time stamp even if supply is disconnected due to tampering
- **Increased meter complexity** for smart metering communication, which requires more GPIOs and serial communication modules (I2C, SCI and SPI)
- Aggregate information from individual meters and communicate usage to utility sub via power line communication in order to regulate energy usage.

II. METROLOGY

There are many Metrology available from different providers like Texas instrument, Freescale, NXP, Analog, etc. with some online survey; I could find some universal solutions which could be developed at comparatively cheaper cost and less time.

Survey for solutions:

Texas Instrument:

a. MSP430AFE2xx energy measurement IC solution more details can be referred in Whitepaper [1]
b. 1-phase and 3-phase metrology function with processor ranging from Cortex™-M to Cortex-A8 [2]

Freescale Semiconductors:

a. S08xx: ultra-low-power, Flexis 8-bit LCD microcontrollers based Smart Meters [3]
b. MK30: Kinetis microcontroller based on the Cortex-M4 core based Smart Meters [3]

NXP

a. Energy metering IC with ARM Cortex-M0 for non-billing applications like Wireless Plug Meter[4]

Analog Semiconductors:

a. Analog Front End Computing SoC ADE78xx [5]

After completing survey on basic of maximum features that can be available with respect to Figure 1, with lowest possible BOM cost, I decided to stick to the Freescale Kinetis Family as

it was easily available with support. In this family K60 series microcontroller has an inbuilt Ethernet, USB, SDIO, Meter tamper circuit and many more features[].

With use of Kinetic K60 controller I can run a data logger to save data in SDcard as well as display it through web interface. Thus meter will have a global connectivity.

For metering, and Analog Devices provided proven highly accurate, sturdy and robust AFE chip ADE78xx is used with SPI interface to microcontroller.

III. New Proposed Metering Method

This Meter will have the capability to Meter different Energy like Electricity, Heat, Gas and Water for Billing or analysis. Nowadays use of Electricity has increased in all fields, So according to the usage Meter's are now sub categorized as Industrial Meter, Residential Meter and Non-Billing Meters. The Residential Meters should be capable to measure all types of Energy.

The Generalized System with Generation, Distribution, Consumption, Smart Metering, Billing or Analysis

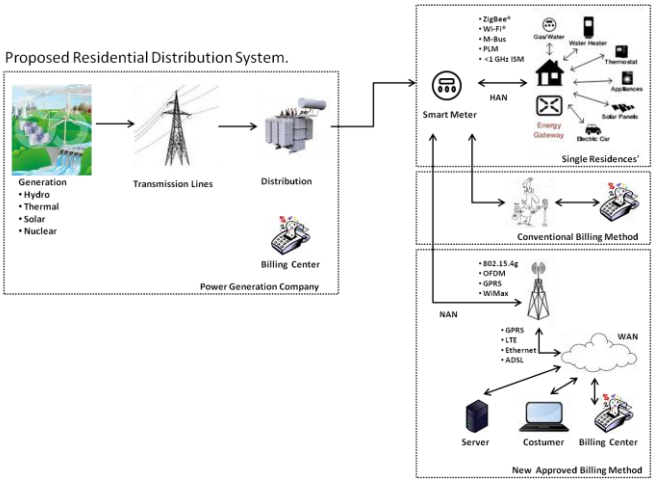

Figure 1 Electrical System Integration

IV. The Smart Energy Meter

In Figure 1 it is easily seen that the single residence can have many possible different type of the Energy consumption for which he/she has to pay either to Municipal Corporation or a provider company. In conventional method of billing, most of the time costumer is unaware of real time energy consumption. They have to wait till final bill arrives at the end of the month. The main drawback of this process is undisciplined use of Energy.

To save energy, we have to know in real time how much our consumption is; basically we have to get aware of our different energy consumption habits.

The Smart Energy Meter will give us one stop solution for this. This meter can measure all types of energy like water flow, heat, gas, electricity, wind flow and also will have arrangement to attach existing measuring devices which will work as sensor.

BLOCK DIAGRAM

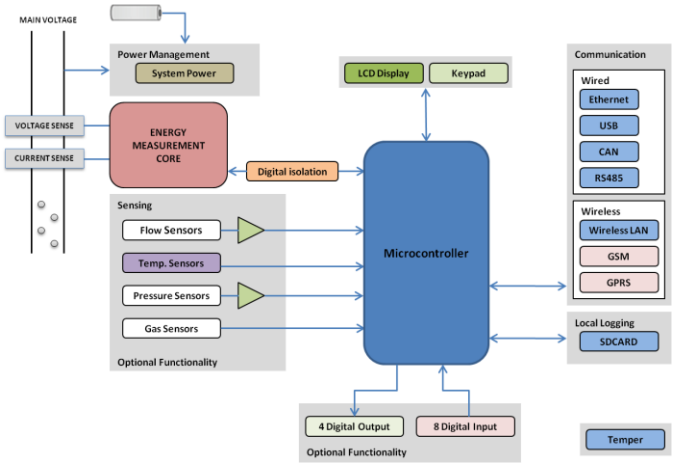

Figure 2 Block Diagram

The Block diagram in Figure 2 gives us the detailed block diagram of the Smart Meter. As in Figure 2, Meter will sample voltage and current; will do all DSP computing internally to provide all best possible electrical values related to analysis incoming and consumption of Electricity. AD7880 is the proven, accurate and sturdy AFE provided by Analog semiconductor used for this purpose. It supports EN 50470-1, EN 50470-3, IEC 62053-21, IEC 62053-22 and IEC 62053-23 certification. The sampled electrical data will then be pulled by Freescale MK60 controller which has Cortex M4 core with 1MB Flash and 128 KB RAM which is sufficient to run an Embedded Web server in it.

SENSORS:

The voltage sensor-resistance is shown in as following Figure 3 is always used for voltage because it is simple and extremely cheap. The values of resistor chose depending on Vmains and desired range for VIN to A/D. There is no level shifter necessary for differential inputs and gain amplifier stage not required.

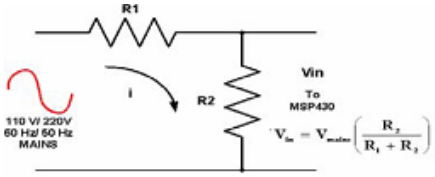

Figure 3 the voltage sensor-resistance

The Current-Sensor-Current-Transformer seen in the Figure 4 It provides electrical isolation protecting the measuring device, the current in secondary is proportional to in current in primary, with zero losses, the secondary current is the primary current divided by N (number of turns on the core).It provides a best accuracy, and subject to internal phase shift that needs to be compensated.

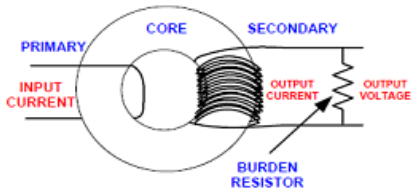

Figure 4 Current-Sensor-CT

ENERGY MANAGEMENT CORE:

The ADE7880 is high accuracy, 3-phase electrical energy measurement IC with serial interfaces and three flexible pulse outputs. The ADE7880 device incorporates second-order sigma-delta (Σ-Δ) analog-to-digital converters (ADCs), a digital integrator, reference circuitry, and all of the signal processing required to perform, the total (fundamental and harmonic) active, and apparent energy measurements, RMS calculations, as well as fundamental-only active and reactive energy measurements. In addition, the ADE7880computes the RMS of harmonics on the phase and neutral currents and on the phase voltages, together with the active, reactive and apparent powers, and the power factor and harmonic distortion on each harmonic for all phases. Total harmonic distortion (THD) is computed for all currents and voltages. A fixed function digital signal processor (DSP) executes this signal processing. The DSP program is stored in the internal ROM memory.

The Smart Meter is a three phase electrical meter, so all three phase computed data provided by AFE with meter configuration data together would be of 7 Kilo Bytes data. This much data should be Logged each time it is generated. So for local logging we have used SDCARD of maximum 32GB capacity.

DATA LOGGING:

The records will be written at interval, user defined from 1 minute to 60 minute. So, with one record of around 7000 bytes if written using the minimum and maximum values then with simple calculated records logged per day will be,

Table 1 Per day Record Calculation

	Number	Size	Units
Min record in a Day	24	164.0625	KB
Max records in a Day	1440	9843.75	KB

I have done calculation using values in TABLE 1 to find out how many years will it take to complete GB's of Space,

Table 2 Year's data per GB's

	Max	Min	Unit
1 GB	0.28	17.53	Years
2 GB	0.56	35.07	Years
4 GB	1.12	70.14	Years
8 GB	2.24	140.27	Years
16 GB	4.49	280.55	Years
32 GB	8.98	561.10	Years
64 GB	17.96	1122.19	Years

WEBSERVER:

The meter will run a web server with maximum 6 users and a dedicated client connection to Data collector Server. The WebPages would be Dynamic page which on clicking menu will run subroutines and display data in tabular and graphical w.r.t to time.

A sample website with Google app will looks like,

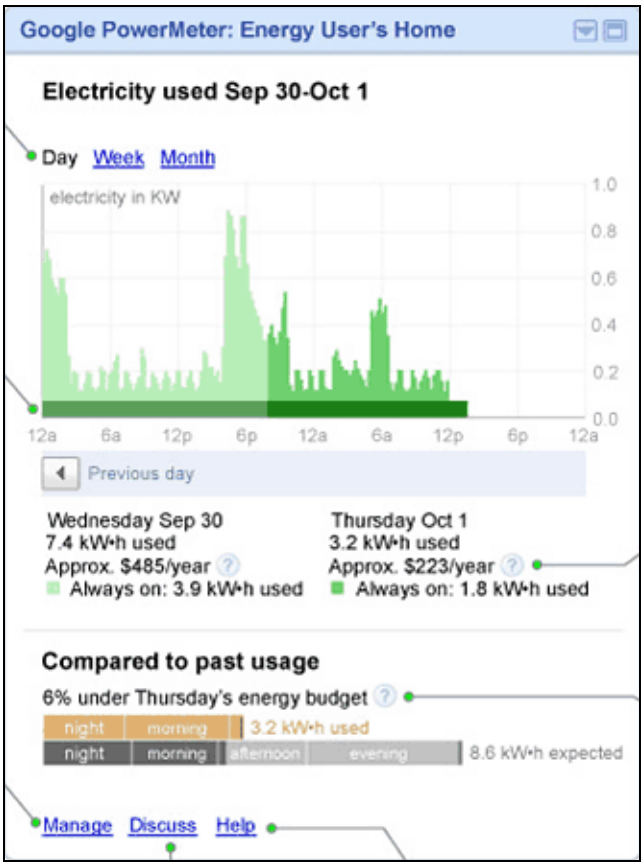

Figure 5 Web Application proposed

With this user can check consumption of the Electrical energy every one minute to max every hour. A recent study by CenterPoint Energy Inc. [6] and the Department of Energy found that 71% of customers reported changing their energy consumption as a result of accessing energy data through in-home displays. And preliminary results from a pilot

program between IBM and the City of Dubuque, Iowa, indicate strong engagement by residents and energy savings of up to 11%.

OPTIONAL FEATURES

DIGITAL OUTPUT

In Figure 2 we can see digital outputs and digital inputs. The Digital output can control appliances like turn ON or OFF on the basis of consumption over limited value or can work on Schedules which would be user define. The user can program Meter for entire year, like for 4 seasons, National Holidays, etc.

When the Scheduler triggers event or occurrences of events, Meter will check current condition of the appliances connected, turned it ON or OFF after comparing user parameter value with the current generated valve for a specific timeout, if the condition is fulfilled than appropriate action would be taken by Meter.

While taking action, Meter would also Log this information in the SDCARD for future analysis.

DIGITAL INPUT

The Digital input can be used to interface device like other vendor Water, Gas, Temperature, wind Meter as they have a pulsating output pins. With this pulse input we can calculate the consumption of these Energies.

This Feature will be very helpful while installation, as it can easily adjust with other installed Meter or other devices. With this reusability will increase and extra cost for purchasing other interfacing will reduce.

V. ADVANTAGE & DISADVANTAGE

ADVANTAGE:

- 71% of customers reported changing their energy consumption as a result of accessing energy data. [5]
- Without effecting existing Bill Method, this method with Smart Meter can be implemented.
- Energy Consumption audit can now be possible to every customer.
- Industries can save money by changing consumption plans by the Energy audit provided by using accurate data provided by this Meter.

DISADVANTAGE:

- Implementing all this features is really challenging.
- If any problem in the algorithm, we can face out of memory problem.
- Initial cost would be high. But in mass production the desired cost could be achieved.

A. Abbreviations and Acronyms

AFE – Analog Front End, AMI – Automated Meter Infrastructure, BOM – Bill of Material.

VI. CONCLUSION

After going through IEEE paper [7] [8] [9] and with some internet survey, I have find solution much better than proposed MSP430 solution [8]. The ADE7880 AFE is more rugged and accurate compare to MSP430FE423A AFE. With this we can calculate till 63rd Total Harmonic values, which is useful for industries in Energy audit. With implementing of this Smart Meter we can actually make a close loop between End to End users. This will create self awareness resulting in changing consumption habits to save valuable resources.

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