TOWARDS SMART HOME APPLICATIONS: DESIGN AND IMPLEMENT A SMART ELECTRICAL ENERGY MONITORING DEVICE FOR DOMESTIC USAGE

D. D. V. P. Gunawardana[1], M. W. P. Maduranga[2]

[1] Department of Electrical and Electronics Technology, Faculty of Industrial and Vocational Technology, University of Vocational Technology, Ratmalana, Sri Lanka. Email: ddvp.gunawardana@gmail.com
[2] Department of Electrical and Electronics Technology, Faculty of Industrial and Vocational Technology, University of Vocational Technology, Ratmalana, Sri Lanka. Email: pasan@univotec.ac.lk

ABSTRACT

Smart Home technology is a concept of networking devices and equipment in the house to provide convenience, comfort, energy efficiency and security. Progress and expansion in this field are highly influenced by social trends as well as emerging technologies. We have design and implement a smart electrical energy monitoring device to improve energy efficiency in homes through DSM (Demand Side Management). According to the DSM, changing the behaviors of electricity consumers for better energy management is essential aspect. To do so the initial requirement is provide direct feedback of day to day sense of energy usage of the consumer. Therefore our main objective was to develop a monitoring device to facilitate users to get the sense about their usage just glancing at monitor. This system consists of sensor unit which measures the real power and energy to be installed in the main distribution panel of domestic electrical installation. The other is monitoring device which can be used to see Energy units (kWh), consumed, Number of remaining days for read the bill, Column graph representing energy usage in last seven days and the effect of back colour change according to the usage level of energy as well. The sensor module has wireless data link to send energy related data to the monitor. This system provides facilities to have number of monitoring screens anywhere around home according to the requirement. We could successfully design and implemented low cost, easy to install energy monitoring system it may help the consumer to get alerts of energy usage frequently.

***Key words*:** energy management, Demand Side Management (DSM), energy monitor, Consumption feedback

1. INTRODUCTION

Today, the entire world is reaching towards a serious energy crisis due the inadequacy of energy sources, especially the electric energy. It is nowadays a big problem in Sri Lanka too with the increase of industrial and domestic power demand.

We can contribute to reduce the energy consumption by changing our energy usage. In order to do so, as a first step, it is essential to have a good sense of daily energy usage. But there is no such method to know the daily energy usage in individual appliances and the monthly electric bill is the only reference. But it is not displaying daily energy consumption. Hence it does not encourage consumers to examine how their electricity use may have changed over the month [8].

The main objective of this design is to assist the consumer lead to the proper management of energy through facilitating feedback of his energy consumption. It is one aspect of Manage Demand Side Management (DSM), which involves actions that influence the quantity or patterns of use of energy consumed by consumers. It ranges from improving energy efficiency by using better materials, over smart energy tariffs with incentives for certain consumption patterns, up to sophisticated real-time control of distributed energy resources. This paper mainly focuses on developing a unit which helps the user to achieve DSM in following way.

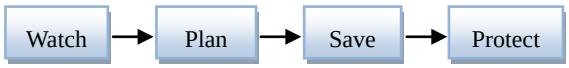

Figure 1: Energy saving from direct feedback

Energy savings from direct feedback - displaying information of daily energy consumption as meaningful figures can lead to energy savings as flowchart shown in Figure 1. Though vital to modern life, electricity is invisible and intangible. Most people aren't even sure how they use it, aside from turning on a light switch. Say

"kilowatt" and eyes glaze over instantly. A widely-cited study by Oxford University Environmental Change Institute's Sarah Darby shows that simply displaying information (providing direct feedback to the consumer) only reduces power consumption by five to 15 percent [1-3]. Furthermore it has been found obliviously that graphical representation is much better than numerical representation by a research done by Daisy Allen and Kathryn Janda, Oberlin College [7]. If home energy management is to be successful, electricity needs to be made obvious, tangible, and meaningful. Then the family members can effortlessly see the Daily Electrical Energy Consumption graph and other meaningful data which motivates them to manage their energy consumption. Developing an electrical energy meter coupled with an in-house display(s), households can view their electricity usage in real-time, and track their energy and cost movements with each and every turn of the switch. Such information can help households to understand what activities consume the most, and then to amend their consumption patterns, behaviours and appliance composition to reduce their electricity bill and carbon footprint.

2. METHODOLOGY

This section conveys design and development process of a smart electrical energy monitoring device for domestic application. Mainly it consists of two distinct units which have wires connection with each other. Electrical energy measuring unit and energy monitor (this unit can be one or multiple parallel units as shown in Figure 2).

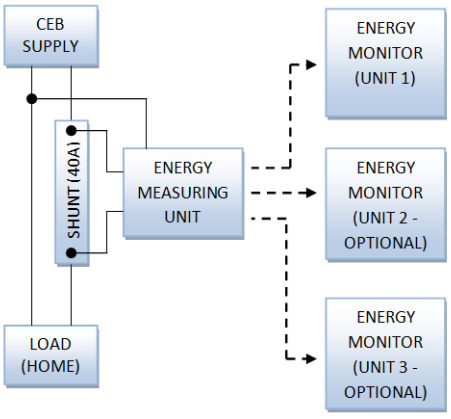

Figure 2: Smart electrical energy monitoring system

The energy measuring unit is installed in domestic electrical distribution panel. It senses the phase voltage, phase current drawn from the total domestic load and phase angle between these two parameters. Phase voltage (230V) is attenuated by resistor network and current is sensed using shunt resister rated for 40A. Then the real energy (kWh) is calculated, processed and transmitted via radio frequency (433MHz) to Energy monitors by energy measuring unit. Any number of energy monitoring units can be used by the consumer in different places around the home for convenience. The energy measuring unit can be represented as a collection of several functional units as shown in Figure 3.

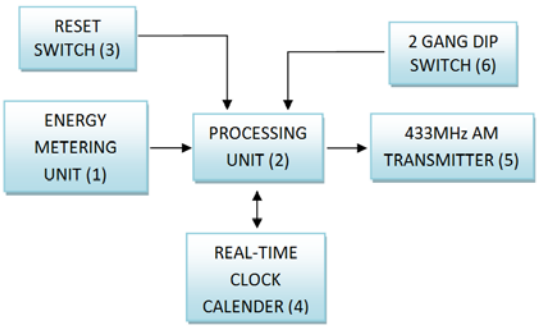

Figure 3: Energy measuring unit

ENERGY METERING UNIT (1)

This is the most crucial section of the system, because all the system processes and calculations depend on the accuracy of measurements acquired by this section. AD7755 energy measurement IC manufactured by Analog Devices Inc [4,5] was selected for this purpose. It is an accurate electrical energy measurement IC intended for use in two-wire distribution systems. It provides instantaneous and average real power based on line current and voltage.

PROCESSING UNIT (2)

This unit serves as the 'Brain' of the system, performing all required tasks and interacting with other units. It gets energy information from ENERGY METERING UNIT (1) and processes data according to the time period information supplied by REAL-TIME CLOCK CALENDAR (3). After that it saves processed data in its internal E2PROM and sends processed information to the 433MHz AM TRANSMITTER (5).Actually this unit is a Microcontroller which has sufficient resources to perform all the tasks described above. PIC 18F452 Microcontroller was selected for this function.

RESET SWITCH (3)

Pressing this push button switch user can reset the system and prepare it for next billing month

REAL-TIME CLOCK CALENDAR (4)

This is a semiconductor chip and keeps the time and sends time information into the Microcontroller when required to do so. It provides seconds, minutes, hours, dates, and months and year information in BCD format. It also has a built in power sense circuit that detects power failures and automatically switches to the battery backup supply provided by CR2032 type Lithium coin cell.

433MHz AM TRANSMITTER (5)

This unit provides simple radio frequency link between energy measuring unit and energy monitor.

The energy measuring unit can be represented as a collection of several functional units as shown in figure 4.

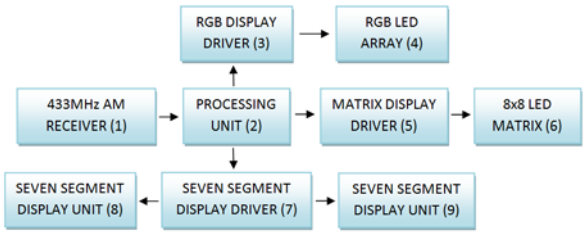

Figure 4: Energy monitor

433MHz AM RECEIVER (1)

This unit receives 433MHz radio frequency which is transmitted from the energy measuring unit and feed it to the PROCESSING UNIT (2).

PROCESSING UNIT (2)

This unit decodes received data packet into separate information to display and feet them into display drivers. Two seven segment display drivers, 8x8 LED matrix display driver and RGB colour display driver. PIC 18F452 Microcontroller manufactured by Microchip Inc was selected as processor.

2. RESULTS

To obtain the results of energy savings from direct feedback a simple and straightforward user interface was developed for this unit as shown in the figure 5. With the help of it consumer not only can easily interpret the meaning convey by figures and colours.

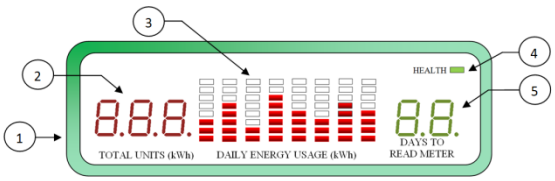

Figure 5: Front panel of Energy Monitor

According to the Figure 5;

a. Total energy consumption for previous days of month is shown by arrow head (2).

b. Numbers of remaining days for calculate next bill is shown by (5).

c. Daily Electrical Energy Consumption as bar-graph is shown by arrow head (3). - present day energy consumption is represented by far left side bar and the next nearby bar to far end bar represent energy consumption for last seven days respectively.

d. Outer colour band (1) changes its colour according to the energy usage of present day in five stages (light blue, green, yellow, orange, red). Conditions for change the colour are depend on the amount of energy consumption within 24 hours. There are four user selectable energy usage ranges as <60, 60-90, 90-120,120-180. Consumer can select appropriate range according to his energy consume per month. It appears light blue colour at beginning of each day. When exceeds the usage than 20% of daily average for the maximum of month range colour change into green, 40% - yellow, 60% - orange, 80% - red

e. System health indicating LED (4) blinks per second to indicate proper communication with energy measuring unit.

The accuracy of Energy measuring unit is very important to the overall effectiveness of the entire system. Energy meter circuit design is based on the manufacturer reference circuit of AD7755 energy measurement IC with following Design Parameters:

Line voltage:	230V
Maximum current (I max):	40A
Basic current (I basic):	5A

This reference circuit has been tested and confirmed for IEC 62053 - 21 [6] standard by the manufacturer [4, 5].

3. CONCLUSION

The main merit of the project is Economic feasibility. This system can be affordable to consumers at economical rates. Cost of the project to about 2000 LKR, which is fairly economical, compared to the long-term savings achieved by this system. It will be much beneficial for the country if this system is used as nationally - initially as a regional experimental project or directly installed by individual consumers. For future enhancements it can be facilitate energy related data acquisition by doing minor firmware modifications to the system.

4. REFERENCES

[1] S. Darby, *"Making it obvious: designing feedback into energy consumption."* In Proceedings of the 2nd International Conference on Energy Efficiency in Household Appliances and Lighting, Italian Association of Energy Economists/ EC-SAVE programme, 2000.

[2] S. Darby, *"Making sense of energy advice,"* Proceedings of the ECEEE Summer Study, 1217-1226, 2003.

[3] S. Darby, *"The effectiveness of feedback on energy consumption,"* a review for defray of the literature on metering, billing and Direct displays, Environmental Change Institute, Oxford University, 2006.

[4] A. Collins, *"AN-559 Application Note: A Low Cost Watt-Hour Energy Meter Based on the AD7755,"* Analog Devices, Inc., USA, REV A.

[5] *"Evaluation Board Documentation AD7751/AD7755 Energy Metering IC,"* Analog Devices, Inc., USA, REV 0, 1999

[6] IEC 62053 – 21:2003, *"Electricity metering equipment (AC) – particular requirements – part 21: static meters for active energy (classes 1 and 2),"*

[7] D. Allen, & K. Janda, *"The effects of household characteristics and energy use consciousness on the effectiveness of real time energy use feedback,"* A pilot study. Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings 7.1-7.12., 2006.

[8] W. Gansa, A. Alberini, & A. Longo, *"Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland,"* Energy Economics 36, 729–743, 2013.