Emerging Trends in Electrical, Electronics & Instrumentation Engineering: An international Journal (EEIEJ), Vol. 1, No. 2, May 2014

Home Energy Management System for High Power –intensive Loads

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Abstract

A home energy management (HEM) system is mainly used to improve the performance of the smart grid with the help of demand response enabled application for residential customer preference. Various developing countries continuous power supply is one of the problems which prevent the growth rate. So different methods can be proposed to increase the power generation and reducing the power demand by increasing the energy efficiency .One of the innovative technique is demand shifting. This paper aims at developing a demand shifting algorithm. The HEM system is developed in order to monitor the power consumption and time requirement for operation of various equipment & tries to shift the operation of certain non-essential and monitor the power consumption of individual equipment .It act as a modern home energy meter. The main aim of the system is reduce the peak power demand and tries to keep the load curve smooth without effecting customers comfort level. The HEM is developed using MATLAB and various scenarios are inputted into it and its output and its impact on the consumer is analyzed.

Keywords

HEM System, MATLAB, Load priority, Customer choice.

I. INTRODUCTION

Today 'Energy' has become the essential and basic need of human being. With the latest development of technology, the consumption of energy is increasing day by day. The demand of energy is far greater than the supply in almost all the countries. Energy is one of the back bone infrastructure for the growth of any economy and an important factor for assessing the progress of any state or country. Energy consumption is defined as the consumption of power or energy. The various power consumption sectors in India are Agricultural sector, service sector, industry sector Residential sector etc..Residential sector power consumption is increasing in our day to day life, so with the help of the home energy management system the consumer can able to reduce the power consumption during the peak hours.

This paper presents the design of smart home energy management system for domestic load shifting in response to peak demand. It is associated with Utility signals, HEM system, Communication unit, and Load controller for controlling and monitoring the Domestic load. It makes the changes of traditional meter reading methods and enables remote access of existing energy meter by the energy consumer. Also they can monitor the readings of meter regularly without the person visiting each house.

I. PROPOSED SYSTEM

Fig.1 shows the entire structure of the proposed home energy management system. It mainly consists of following features and sections of the architecture.

A. Demand Response

Demand response is one of the important parameter to determine the energy audit and energy management .It is generally used to encourage the consumers to reduce demand, thereby reducing the peak demand for electricity. Depending on the generation capacity from the utility center, however, demand response may also be used to increase demand (load) at times of low demand and high production. The Demand Response (DR) activities are defined as "actions voluntarily taken by a consumer to adjust the amount or timing of his energy consumption". There are three main types of demand response which includes emergency demand response, economic demand response, and ancillary services demand response. The type of demand response addresses critical system needs. The main advantages of the demand response program promises to greatly improve the efficacy of the system in a number of ways such as Accurate and Easy Verification, Automation Systems, Improved Communication, Early detection.

B. Home Energy Management (HEM) Unit

The HEM is the heart of the entire system it receives the external signal from the utility signal, which includes demand response request and duration, the algorithm is designed to maintain the total household power consumption below the specified demand limit level (kW) during the specified duration (hours).High power intensive appliances such as Air conditioner, clothes dryers, water heaters, and UPS charger can be controlled. Critical loads such as bulb, fan, Television etc.. are to be served at all time. The developed HEM demand response algorithm allows the consumer to operate their home appliances when needed as long. The home energy management system receives the external control signal from the utility center with the help of distribution board and meter (gateway).Then it will send the signal to the load controller, the load controller act as a automated switch, and also the load controller will take the power consumption data of high power intensive loads, with the help of communication unit and control signal the status of loads will be send to the HEM unit. Communication system module provides communication paths between the HEM unit and its load controllers.HEM unit makes a decision to switch ON/OFF selected end-use appliances based on the utility signal received, as well as the consumer load priority and their preference settings.

C. Load controller

Load controller is an automated switch which works according to the command from the HEM unit. HEM unit pass signals to the load controller in order to control the operation of load. It provides the basic power management functions (i.e., monitor, control, communicate) via a standard electrical outlet.

D. Communication Unit

Communication unit establishes the connection between the HEM unit and the Load controller and helps HEM unit to send command signals according to DR and load priority. It also helps on giving vital live parameters of the load, such as current consumption, voltage across load, temperature, water level human detector (PIR) etc., as these signals from sensor will helps in automation of the load. The type of communication modules selected will impact the overall

system's data communication rate, range, cost, and its residual power consumption. The various combinations of communication units such as Wi-Fi, Bluetooth, ZigBee and Power Line Carrier (PLC) etc...can be deployed in home area networks.

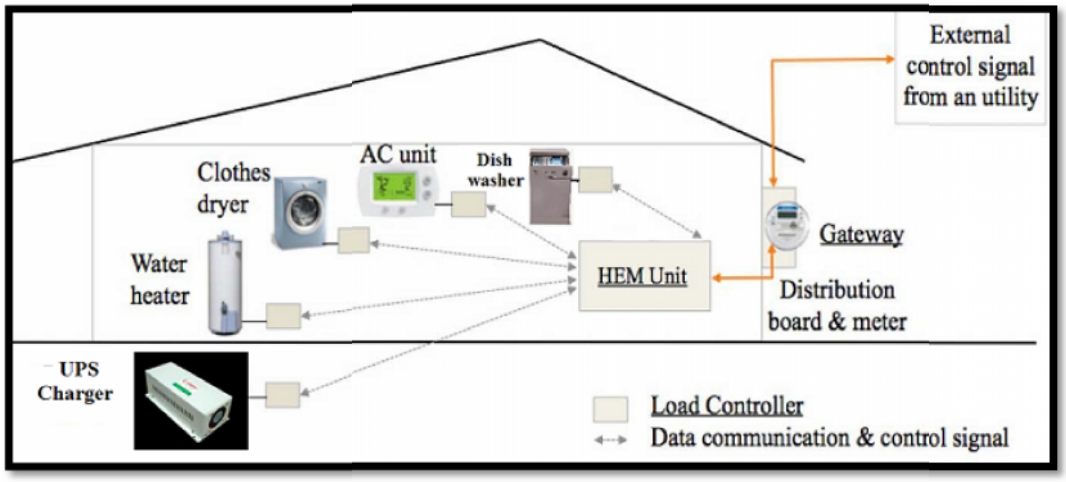

Fig.1 HEM Architecture

TABLE 1 Example of Load Priority and Operating Mode

LOAD NAME	LOAD ID	AUTO PRIORITY	AUTO TIME	MANUAL PRIORITY	RUNNING TIME	POWER
Air Cooler-1	1	2	0	2	6	1500
Air Cooler-2	2	2	0	2	6	1000
Air Cooler-3	3	2	0	2	6	1000
Air Conditioner-1	4	3	20	2	6	3000
Air Conditioner-2	5	3	0	2	6	2500
Air Conditioner-3	6	3	0	2	6	2500
Water Heater-1	7	3	0	2	2	2000
Water Heater-2	8	3	5	2	2	2000
Water Pump	9	3	10	2	1	1000
Dishwasher	10	4	7	3	1	1000
UPS Charger	11	4	0	3	6	2000
Washingmachine	12	4	0	3	1	1000

E. Consumer Load priority and Operating Mode Settings

Before implementing the proposed HEM demand response algorithm the homeowner will set their load priority such as (manual priority, automatic priority) and load ON operating mode. The priority can be represented based on peak hour, mid peak and off peak. An example of load priority and operating mode is shown in Table I. The appliances such as Air conditioner, Air coolers, Water pump, Water heater, Washing machine, Dish washer and UPS charger are considered for this system, for the water pump the load ON time can be set e.g., 10 A.M similarly for the water heater the load ON time can be set as 5.0 A.M.

II. Hem Software Implementation

A simulation tool is developed in MATLAB that developed the proposed HEM demand response (DR) algorithm. The input data consist of load ID, ON time and Load status (automatic/ manual priority) is represented in Fig.2 The proposed HEM system does not considered the critical loads such as bulb, fan, television etc, it mainly considered the high power consuming equipments such as water heater, water pump, washing machine, UPS charger ,Dish washer etc. All this equipment can be set as three types of priority such as manual, automatic and immediate according to this priority and demand response signal from utility center will decide the equipments operation .It will helps to reduce the power consumption during the peak hours and can able to provide open the doors for Distributed Power Generation. The main advantages of the HEM system are:

- Effectively controls the load without reducing customer comfort to great extend.
- Easy to operate and can be reprogrammed.
- Any number of high power home appliances can be controlled.
- It supports the smart grid operation.
- It can be used as digital meter with communication unit which automates the distribution system and reduce power thefts.

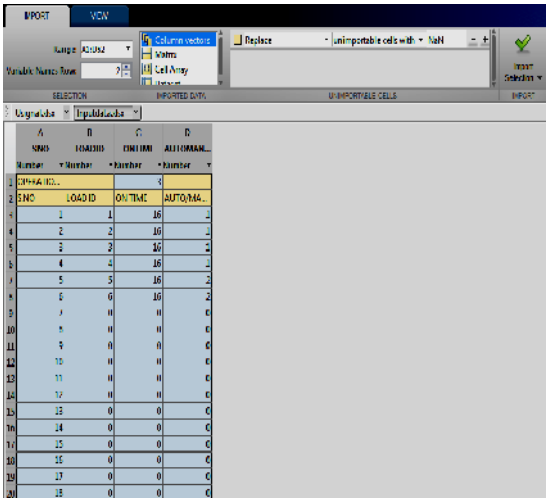

Fig.2 Input Data Sheet of Equipment

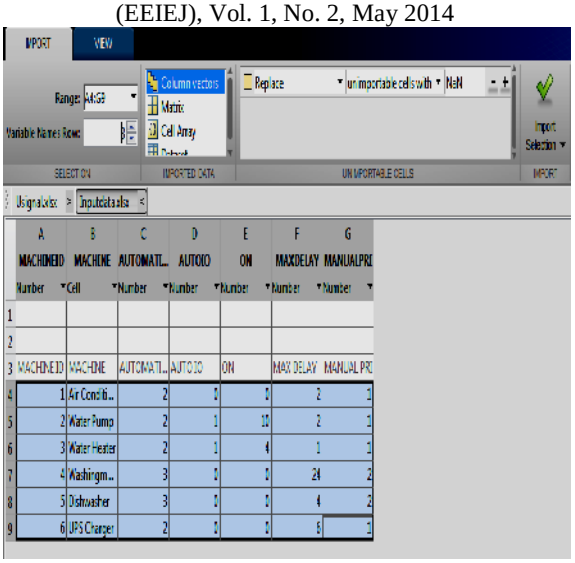

Fig.3 Equipment Datasheet

The Fig .3 shows the equipment datasheet it shows the machines name, machines id, maximum delay, automatic input, and manual priority. This makes the analysis of the equipment easy. The Fig.4 shows the utility signal, with the help of this utility signal only we can able to determine the peak hours, mind peak and off peak. The Fig 4 shows the (0) for off peak and (5) for on peak. This shows the status of the status of the power Grid. With the help of the demand response from the utility signal can able provides the peak, off peak and mid peak to the consumers.

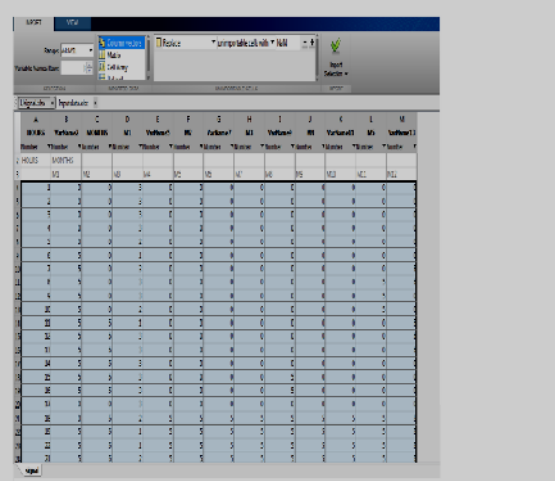

Fig.4 Utility signals

II. HEM HARDWARE IMPLEMENTATION

The main objective of the home energy management system is to encourage the consumer to use less energy of household appliances (power intensive appliances) during the peak hours or to move the use of power intensive household appliances at OFF peak hours. The entire block diagram of the Home Energy Management hardware system is shown in the Fig 5. The working

of the system is based on some assumption and it is classified into four hours based on the grid status they are:

- OFF peak hour -1
- Peak hour -1
- OFF peak hour-2
- Peak hour-2

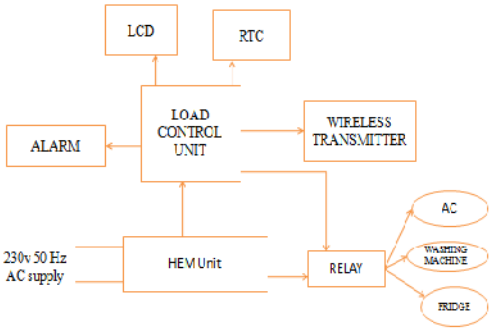

Fig.5 Hardware Block Diagram of HEM

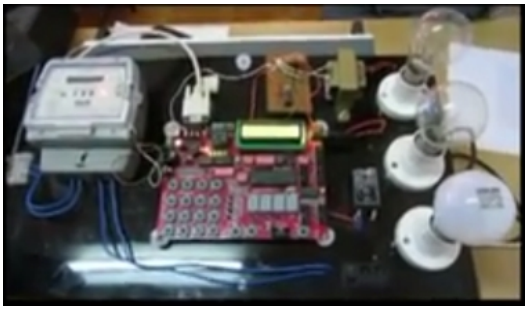

Fig.6 Hardware Architecture of HEM

The Fig 6 shows the entire hardware architecture of the home energy management system. Here we consider the load as a bulb with various rating. The demand response signal from the utility signal will be given as the input to the home meter; with the help of the communication unit the DR signal will be send the signal to the load controller unit. It will check the status of the load and send the signal to HEM unit The HEM unit will take the decision of the equipment ON and OFF time without affecting the customers comfort level.

III. RESULT AND DISCUSSIONS

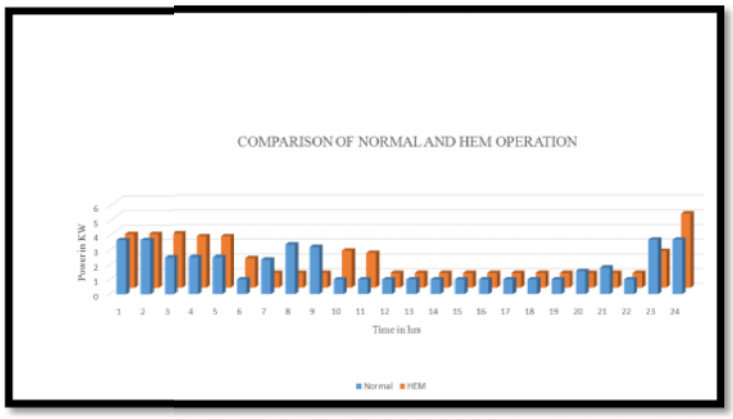

Fig.7 Comparison of Normal Operation and HEM Operation

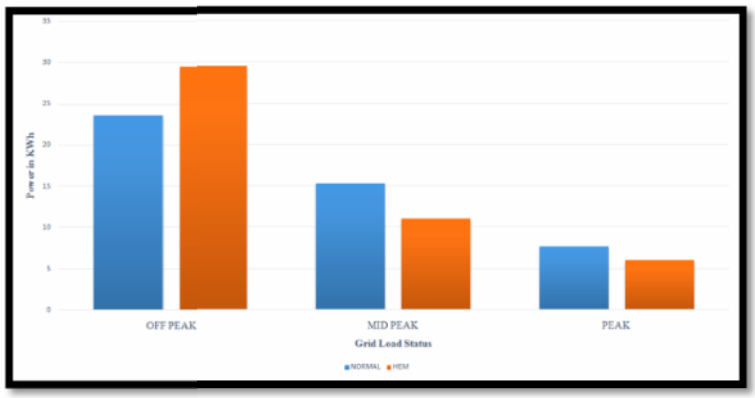

Fig.8 Power consumption at Different Grid Load Status

The proposed HEM demand response algorithm can effectively reduce the total household power consumption (high power intensive loads) without affecting the customer comfort level during the period of peak hours. The Fig.7 shows the operation of the normal and HEM operation. The Fig .8 shows the power consumption of different grid load status of HEM system.

IV. CONCLUSION

The proposed Home Energy Management demand response algorithm can be effectively control and manage the operation of home appliance to keep the total household power consumption during peak hours below a specified demand limit from the utility center signal. There is a significant change in the load consumption of the average house which allows providing power for more houses during peak hours. The HEM algorithm takes into account for both load priority and customer comfort level settings.

V. ACKNOWLEDGMENT

The authors would like to thank the Department of Electronics and Communication Engineering, Hindustan Institute of Technology, Coimbatore Tamil Nadu for providing laboratory facilities and opportunity for experimental setup.

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