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Simulation of Demand based Energy Management System

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Abstract

Peak demand is a more severe problem in the energy management system and it was resolved by distribution side management in the past. But, nowadays the demand side management sources have drawn attention due to the economic and environmental constraints. Demand side management in the sector of domestic, which can play an important role in reducing the peak demand on the power system network. It can help in reducing stress and overloading on the transmission and distribution lines. The smart home energy management system (HEM) for efficient load management is performed based on consumer demand response (DR), scheduling and presetting the priority for all the house hold appliances. This proposal work consists of mainly two modes. One is the normal mode of operation wherein, the consumer can operate household appliances manually according to their comfort level. Second part is the demand mode, which is controlled by the MATLAB GUI according to the specified demand limit and priority of the home appliances, units consumed by each appliance, heating temperature of the water and current consumption is given by load controller through ZigBee as an input to the HEM unit. Based on the electricity consumption of loads the load analysis is done.

Keywords: *HEM, DR, MATLAB GUI, ZigBee.*

1. Introduction

The Home Energy Management (HEM) system is a tool for achieving Demand Response (DR) of residential appliances into smart grid applications. The system provides an option for a home owner to control all the house hold appliances automatically based on utility signals sent by communication network ZigBee and according to consumers load priority preference. The paper presents the demonstration of the HEM system for managing household appliances such as water heater and clothes dryer. Two different rating bulbs are used for representing water heater and clothes dryer in the demonstration. It also includes an intelligent HEM system which is MATLAB GUI for managing high power consumption household appliances at normal mode and demand mode operation. In United States of America, many DR programs are widely developed and implemented for commercial and industrial purposes. DR are mainly real-time pricing, interruptible load, time-of-use programs and direct load control [1]. These has been visualized to deal with unpredictable supply limit events by selectively cutting down system loads, whereby regaining balance between electricity supply and requirement [2]. For residential purposes the DR programs are yet to be developed. Most of them are direct load control programs like for geysers. The focus is on DR for residential and commercial purposes. The DR can also be implemented in a home for electric vehicle thereby avoiding any overloading problems for distribution transformer [3].

2. HEM System Purpose

Within smart grid the rapidly developing sector is home energy management system. Energy efficiency and DR are the key players which are moving to smart grid environment for the utility business. A common problem across the globe is high energy cost and demand not meeting the supply requirement has forced the consumers to think on the efficient usage of energy and to keep it as simple as possible. The possible solution to this problem could be solved by HEM System, which in real time gives the feedback to the user for monitoring and controlling of their electrical appliances thereby ensuring proper utilization of electricity and saving cost. Already energy efficient systems for houses are beginning to become smarter. Combining energy monitoring and managing with an area network and home control unit will surely increase efficiency.

3. Conspectus of the HEM system

The basic idea about the HEM system is shown in Fig 3.1, which includes the HEM unit to collect information such as current consumption, temperature of water and units consumed by selected loads. These all information is sent by load controller through ZigBee communication. Based on the command signals from utility HEM unit receives

the real time data and controls accordingly. The MATLAB GUI consists of user appliance control panel, where he/she can manage loads with considering their comfort levels.
This model mainly concentrates on controlling mainly non-critical loads such as water heater and clothes dryer(for demonstration purpose bulb's have been considered), other critical loads such as fans, TVs, computers will not be considered, switching off these loads will violate consumers access levels.

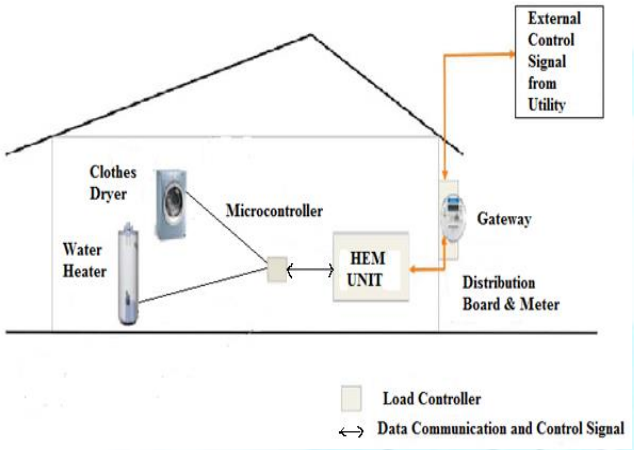

Fig. 3.1: Conspectus of HEM system

4. The Overall System Setup

The HEM system installation in laboratory environment is shown in Fig.4.1 with two loads 100W bulb-1 representing water heater and 60W bulb-2 representing clothes dryer. The DR GUI focuses on controlling power-intensive loads, bulb-1 and bulb-2. Due to limitation in using actual loads such as water heater and clothes dryer, a bulb with soldering gun as heating coil of the water heater is used for the demonstration purpose.

GUIDE(Graphical user interface development environment). By using layout Editor, we can click and drag GUI components, such as axes, buttons, panels, sliders, text fields, and so on into the layout area.

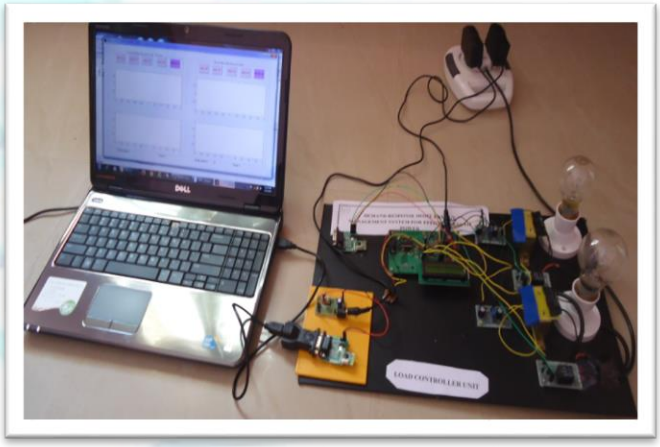

Fig 4.1: Hardware Demonstration of Home Energy Management System.

This is embedded in the laptop computer, which receives the real time current consumption, units consumed and temperature of heating coil from the controller and gives it to laptop HEM system through ZigBee communication module. The GUI displays the status of each load with respect to time interval and units consumed are monitored continuously. The HEM GUI provides a display for a homeowner to monitor appliance status; total units consumed by loads, as well hot water temperature i.e. soldering gun temperature if it goes maximum beyond 500C. A home owner can also change his/her load priority and preference settings from the HEM GUI. There are two operations, one is the normal mode operation, here there is no priority for loads, no demand limit and no time limit for all appliances this mode can be operated when any guest visits the home and need change in their daily scheduled appliance. The second one is the demand mode; here according to the house owner's load priority preference

settings all the devices will operate which includes the demand limit, priority settings and time limit.

5. Simulation Result Analysis

The simulation results have been compared for normal mode and demand mode of operation in MATLAB GUI. The different pushbuttons will perform different operations based on command (ON/OFF particular bulb) given. The graphs for individual load current consumption and overall current consumption versus different time interval for each load been compared.

5.1 Normal mode operation

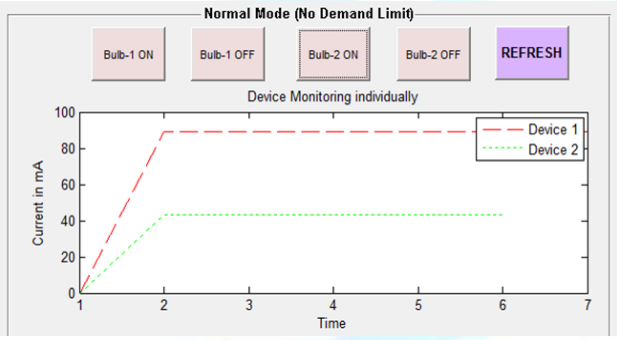

Fig.5.1: Current consumption of Bulb-1(as water heater) and Bulb-2(as clothes dryer) in normal mode operation.

In this mode of operation, consumer can directly switch ON/OFF different appliances there is no demand limit, time schedule and priority for both the loads. This mode is useful when consumer require more electricity than the actual demand limit. The above Fig.5.1 shows the graph of normal mode of operation (Device monitoring individually), here the two different rating bulbs used are 100W as bulb-1 and 60W as bulb-2. The above Fig.5.1 shows graph of current in mA versus time for device-1 and device-2. At particular time interval 2, the both the devices will turn ON and consume current of 88mA and 43mA respectively.

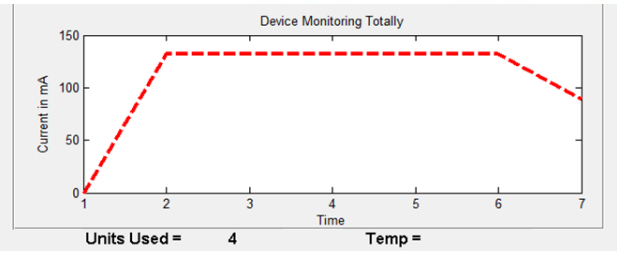

Fig.5.2: Total current consumption of Bulb-1(as water heater) and Bulb-2(as clothes dryer) in normal mode operation.

The total current consumption of both the devices is around 131mA is shown with red thick dotted lines as in above Fig.5.2 The total units consumed by both load during their ON state for some time interval.

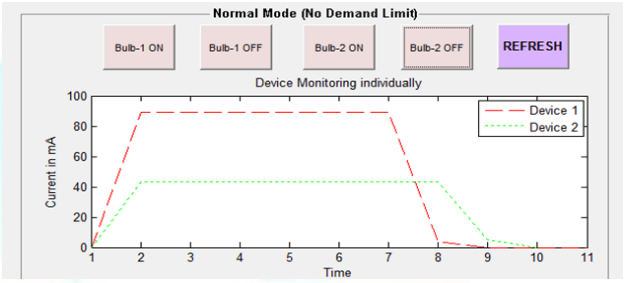

Fig.5.3: Individual current consumption

The above Fig.5.3 shows graph of current in mA versus time interval for device-1 and device-2. At particular time interval 2, the both the devices will turn ON and consume current of 88mA and 43mA respectively. After some time at interval 7 the device-1 is turned OFF and device-2 will be turned OFF at time interval 8 as shown in the Fig.5.3.

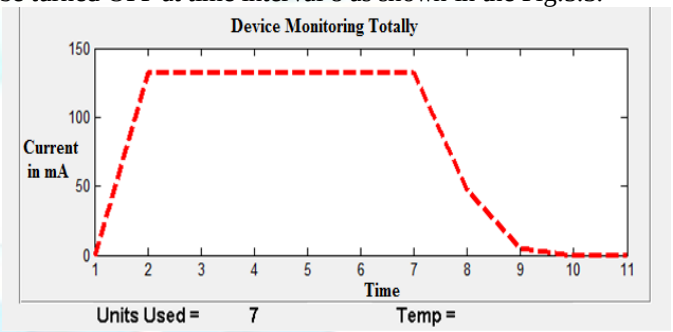

Fig.5.4: Total current consumption of Bulb-1(as water heater) and Bulb-2(as clothes dryer) in normal mode operation.

The both the devices are turned On at time interval 2, for some time intervals total current consumption of both the devices is around 131mA till time interval 7 at this point device-1 goes OFF and at time interval 8 device-2 goes OFF is shown with red thick dotted lines as in above Fig.5.4. The total units consumed by both load during their ON state for some time intervals.

5.2 Demand mode operation

In this mode of operation, consumer can switch ON/OFF different appliances at particular time scheduled, where there is demand limit of 10 units is set, time schedule and

priority for each load is set. This mode is designed depending on the consumer's daily time schedule in their routine work. The time to access each load and water heating temperature is predefined so it will follow the house owner preference settings, here also two different rating bulbs 100W and 60W for bulb-1 and bulb-2 used respectively. The time to operate each load is set based on the consumer comfort as per our project is considered, device-1 can be operated within morning time 6.00 AM to 8.00 AM and for device-2, morning 9.00AM to 10.00AM.The below Fig.5.5 shows the graph of demand mode of operation (Device monitoring individually), if the consumer will try to access the device-1 at other than the time scheduled for it then in the below Fig.5.5 shows dialog box message saying "Not allowed to switch ON at this time" the same case will also apply to device-2. This feature of project will reduce the units consumed than normal mode operation by helping the consumer to reduce their electricity bill.

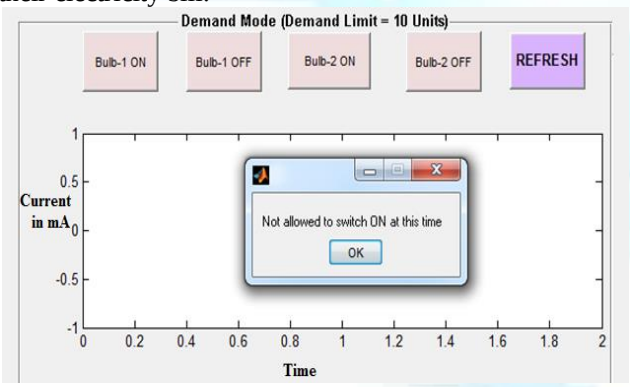

Fig.5.5: Demand mode response shows dialogue message box if the consumer operates device-1(Water Heater) at non scheduled time

The Fig.5.6 show below is the demand mode operation when consumer operates device-1 at correct scheduled time. It is switched ON at time interval 2 consumes current of 88mA and device-2 can't be operated same time because priority set is high for device-1 (Water Heater) than device-2(Clothes dryer), the purpose of doing so is to consume uniform power consumption and also to avoid transformer overloading at substations. The current consumed by device-1 is 88mA and since device-2 is OFF, so current consumed is zero.

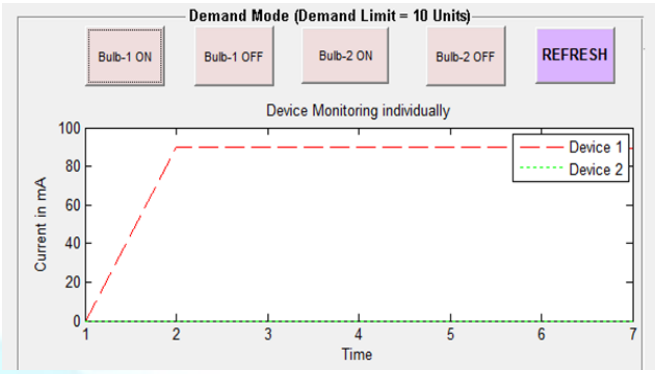

Fig.5.6: Demand mode operation (Device Monitoring individually) when device-1 is ON and device-2 is OFF

The Fig.5.7 shows demand mode operation (Device Monitoring Totally) when device-1 is ON at time interval of 2, so the current consumed by it is 88mA and device-2 is OFF so current consumed is zero.

Thus the total current consumption by both the devices is 88mA. It also show the units consumed by both devices below the graph.

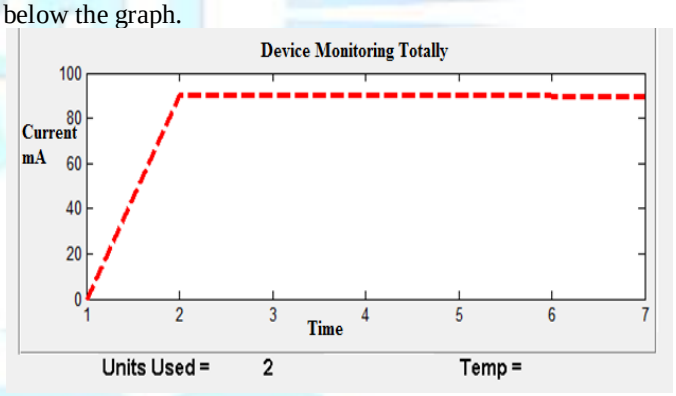

Fig.5.7: Demand mode operation (Device Monitoring Totally) when device-1 is ON and device-2 is OFF.

The below Fig.5.8 shows graph of current in mA versus time interval for device-1 and device-2. At particular time interval 2, the device-1 will turn ON and consume current of 88mA and device-2 is OFF. After some time interval 7 the device-1 is turned OFF and device-2 will be OFF from beginning.

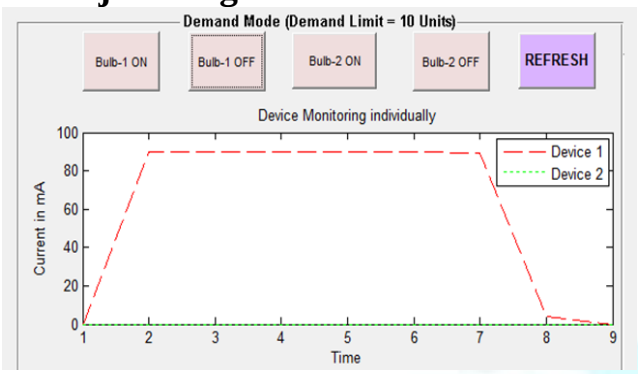

Fig.5.8: Demand mode operation (Device Monitoring individually) when device-1 is ON for some time interval and goes OFF at interval 7 and device-2 is OFF.

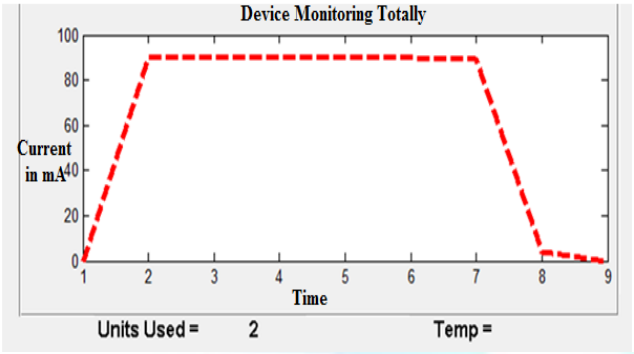

Fig.5.9: Demand mode operation (Device Monitoring Totally) when device-1 is ON for some time interval and goes OFF at interval 7 and device-2 is OFF.

The Fig.5.9 shows demand mode operation (Device Monitoring Totally) when device-1 is ON at time interval of 2, for some time and goes OFF at time interval 7, so the current consumed by it is 88mA and device-2 is OFF so current consumed by it is zero. Thus the overall current consumption by both the devices is 88mA. It also show the units consumed by both devices below the graph. If the water heating temperature goes above the limit specified in the code then it will turn OFF the device-1 and indicating temperature reached its maximum limit.

The Fig.5.10 shows the individual load operation at demand mode, device-1 is ON for some time interval 7 and consumes current of 88 mA, it is turned OFF at time interval 8. Then the laptop clock is set to scheduled time for device-2 (Clothes dryer), switch ON the device-2. It will switch ON at time interval 9 which consume the current of 43 mA at some time interval.

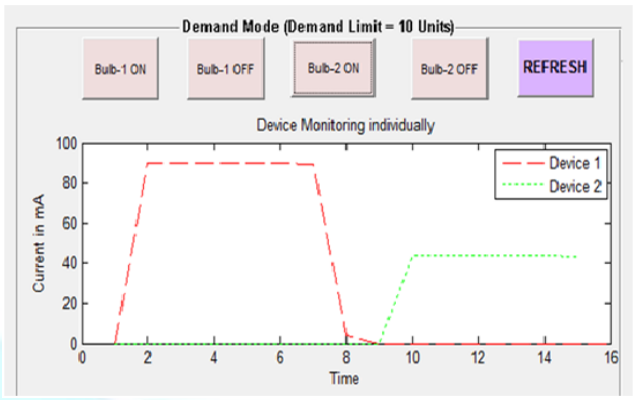

Fig.5.10:Demand mode operation (Device Monitoring individually) when device-1 is ON for some time interval and goes OFF at interval 8 and device-2 is ON at time interval 9.

The Fig.5.11 shows demand mode operation (Device Monitoring Totally) when device-1 is ON at time interval of 1,so the current consumed by it is 88mA.The device-2 is OFF initially because priority for device-1(water heater) is high so current consumed is zero. The device -2 is ON at particular interval where device-1 goes OFF. Thus the total current consumption by both the devices is 88mA till time interval of 8. The device-2(clothes dryer) is turned ON at interval 9 and consumes current of 43mA till time interval of 15 and goes OFF at interval 16.It also show the units consumed by both devices below the graph. If the water heating temperature goes above the limit specified in the code then it will turn OFF the device-1 and indicating temperature reached its maximum limit.

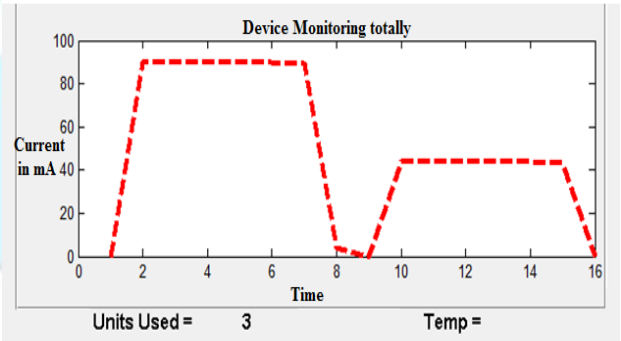

Fig.5.11: Demand mode operation (Device Monitoring Totally) when device-1 is ON for some time interval and goes OFF at interval 8 and device-2 is ON for some time interval and goes OFF at interval 16.

5.3 Comparison of Normal mode and Demand mode

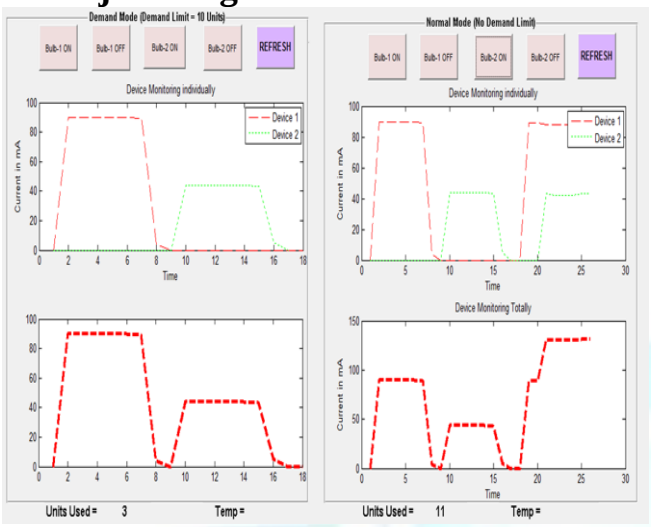

Fig 5.12: Comparison of current consumption in case of Normal mode and Demand mode

So far we have seen the different cases for normal mode and demand mode. By observing the above Fig 5.12 which is for both the modes of operation, it has been clearly seen that the current consumption in case of demand mode operation is less within the demand limit and also there is normal flow of power without much overloading the distribution transformers (from above graph device monitoring totally current consumption will be 88 mA maximum). At the peak hours if we schedule the time for all the appliances the power can be saved and also by achieving reduced electricity bill. As in case of normal mode of operation, the number of devices can be operated at any time this will cause more stress and overloading at peak hours(from above graph device monitoring totally current consumption will go up to 132 mA maximum).

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