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Load Measurement in Home Energy Management System with Demand Response

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Abstract: In this paper we present a load measurement scheme for home energy management system with energy demand management. The proposed system will have control of various appliances that are available in the home. It manages household loads according to their predefined priority and guarantees the total household power consumption below certain levels. The home energy management system will receive the demand response from the utility side. The goal of the system is to encourage the consumer to use less energy during peak hours or to move the time of energy use to off peak times such as nighttime and weekends. Thus the high peak-to-average ratio (PAR) of power will be avoided and also we adopt real time pricing. The utility company use real time dynamic pricing to coordinate demand responses to the benefit of the overall system. Hence for this purpose we need to measure the power consumed by the various appliances that are available in the home.

Keywords: Load Measurement, Home Energy Management System, Demand Response, Real Time Pricing

I. INTRODUCTION

The increasing demand of electrical energy has made electric power systems to encounter more frequent stress conditions. The common cause of system stress conditions include transmission line outages, which are likely to occur during critical peak hours. Such events will cause a supply-limit situation where cascading failures and large-area blackouts are possible. Demand response (DR) has been visualized to deal with such unexpected supply limit events by selectively imposing a restriction on system loads, whereby regaining balance between electricity supply and demand. DR also plays an unique role in load shifting that can help increase reliability and efficiency in operation[1].

We propose a home energy management algorithm for the utility company and the customers to jointly compute the optimal prices and demand schedules. First, different appliances are coordinated indirectly by real time pricing, so as to flatten the total demand at different times as much as possible. Second, compared with traditional no demand response flat-price schemes, real-time pricing is very effective in shaping the demand: it greatly reduces the peak load, as well as the variation in demand. Third, the real-time pricing scheme can increase the load factor greatly and thereby save a large amount of generation cost without affecting customers' benefit. Finally, as the number of the households increases, the benefit of our demand response also increases and will eventually saturate[2].

With the application of the proposed system, residents can reduce their electricity cost according to the scheduling pattern of their home electricity usage, based on the real-time electricity prices. There are several schemes for scheduling in home power consumption. An appropriate target total power consumption for all appliances is measured and noted. Then the power usage for both interruptible and non interruptible loads are scheduled so that the electricity cost has to be reduced along with not interrupting the high priority loads. It was found that peak power demands emerged when the electricity price was low. As a result both the electricity cost and the peak demand values will be reduced simultaneously. The power consumption of each appliance should be nearly constant over time[3]. In general demand response refers to actions taken to change residents' electricity demand in response to variations in the price of electricity over time. As the basis for home energy management scheduling, DR information will be delivered to each home. Then the residents can make use of this information via the in-home energy management controller, which uses both real time prices and user preferences to schedule the power usage[4]. With a home area network, the controller is able to transmit the control signal to smart appliances in the home. The purpose of DR is not only to lower electricity demand from customers at peak demand times but also to prevent higher power demand peaks even if the price is higher. For this purpose we need to measure the load consumed by the various appliances that are connected with the home energy management system. Then only the system will be able to send the information to the utility to make effective energy management with demand response. There are various methods available to measure the power consumed by a device. These methods are discussed in our paper.

II. PROPOSED SYSTEM

A. Algorithm

The algorithms that are considered in the proposed system are Prediction algorithm and Neural algorithm for load

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sensing and measurement. Then with the Greedy iterative algorithm, Consumer will adjust their load according to the cost price. Programmable Logic Controller (PLC) is used to implement the demand response algorithm and provides an interface between the appliances, sensors and the controller. And distributed algorithm finds the optimal energy consumption schedule. This algorithm no longer converges, as every user tries to schedule the appliance to minimize his own cost, thereby increasing the overall cost of the electricity due to an aggregated impact of their personal behavior[9].

B. Block Diagram

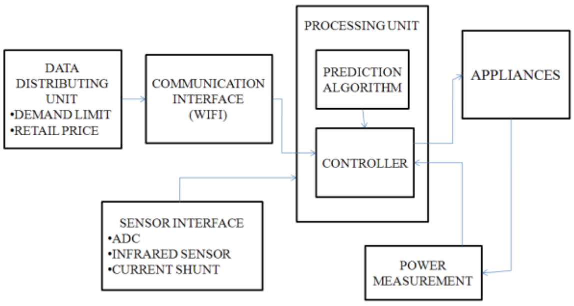

Fig 1: Basic Home Energy Management System

The above block diagram describes the operation of the proposed system. Here the load measurement is carried out at the appliances side with power measurement unit.

III. COMPONENT DESCRIPTION

A. Data distributing unit

The data distributing unit is used to transfer the demand response information from the utility company to the end user. The home energy management system is fed by the data from the data distributing unit. The real time pricing details will be calculated by the energy management system with the received demand response details.

B. Communication Interface

Here we use Wi-Fi as the communication interface. Wi-Fi is a local area wireless technology that allows an electronic device to exchange data or connect to the internet using 2.4 GHz UHF and 5 GHz SHF radio waves. A Wi-Fi-enabled device can connect to the Internet when within range of a wireless network which is configured to permit this. The coverage of one or more (interconnected) access points called hotspots can extend from an area as small as a few rooms to as large as many square kilometers. Coverage in the larger area may require a group of access points with overlapping coverage.

C. Controller

The controller is used in the proposed system to turn ON and OFF various appliances used as per the demand response received from the utility side. To demonstrate the simulation we have here used PIC16F877A. The various loads like washing machine, air conditioner, lights, heater, etc., are controlled using the proposed system.

Here lights are given with higher priority whereas the rest of the appliances are given least priority. These least priority appliances will be operated when there is low peak to average ratio. Thus the effective demand response management is obtained with our system[5].

D. Isolator

In electrical engineering based automatic systems, an isolator is also called as a disconnector, disconnect switch or isolator switch. It is used to ensure that an electrical circuit is completely de-energised for service or maintenance. Such switches are often found in electrical distribution and certain industrial applications, where machinery must have its source of driving power removed for control or repair operations.

But here to turn OFF the various appliances that are connected to the energy management system we use the isolator switch to disconnect the loads during peak times. The disconnector is usually intended for normal control operations. Isolators can be operated either manually or automatically[6].

E. Current Sensor

A current sensor is a device that detects electrical current (AC or DC) in a wire, and generates a signal proportional to it. The generated signal could be analog voltage or current or even digital output.

It can be then utilized to display the measured current in an ammeter or can be stored for further analysis in a data acquisition system or can be utilized for control purpose.

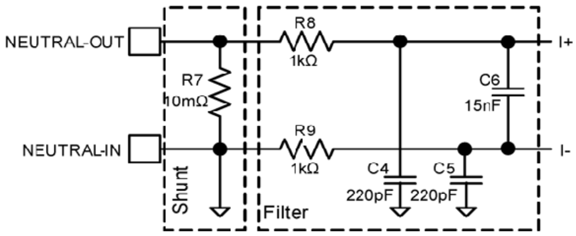

Fig 2:Basic current sensor unit

F. Data Acquisition

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal.

G. ADC

An analog-to-digital converter (ADC, A/D, or A to D) is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude.

The conversion involves quantization of the input, so it necessarily introduces a small amount of error.

Instead of doing a single conversion, an ADC often performs the conversions periodically.

The result is a sequence of digital values that have been converted from a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal.

IV. WORKING

The simple home energy management system is given in the following block diagram. The home energy management system receives the demand response signal from the utility side. The data centre collects the information from both utility side and user side. By using prediction and neural algorithms it calculates the effective real time price. The time when there is least demand, the price also will be low and vice versa. Thus the home energy management system will switch the appliances based on their priority[7]. When there is low peak to average ratio certain least priority loads will be turned ON thereby making effective utilization of power with managed demand response.

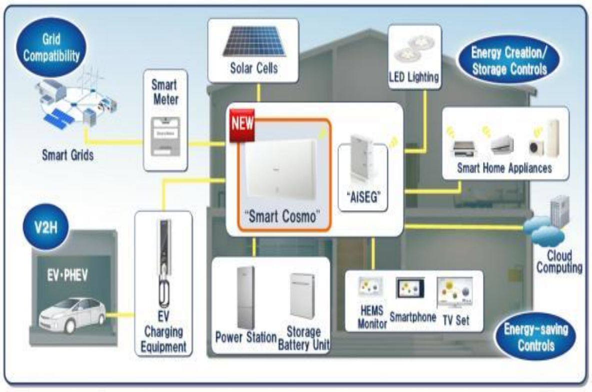

Fig 3: Home Energy Management System

Now the following figure describes the operation of the load measurement scheme of the proposed system. It consists of current sensing unit and current shunts. The micro controller takes control of all these units.

ADC is used to sense both the outputs from current shunt and channel output. Finally the wireless radio is used to transmit the load consumption data from the appliance to the central home energy management system.

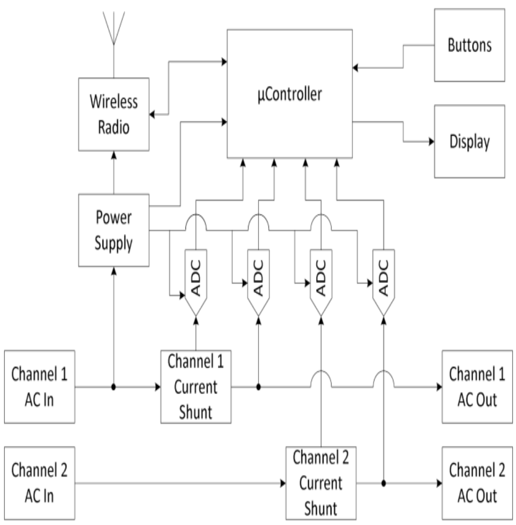

Fig 4: Current sensing unit

V. RESULT

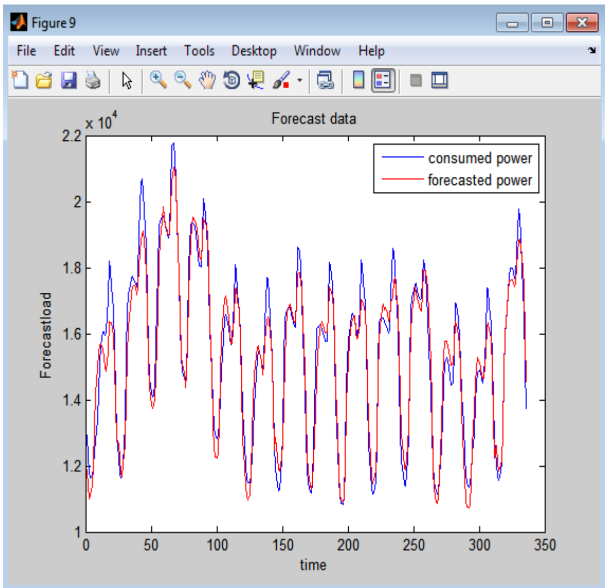

Fig 5: Forecasted power and Consumed power

The above result gives the simulated output of difference between forecasted power and consumed power with respect to time. The load consumed by different appliances varies with respect to time. Then the actual difference between forecasted power and consumed power is small[8].

The following fig gives the power consumption by a number of available residuals connected to an utility grid. It is noted that during certain peak times alone the demand is higher. Hence the home energy management system will work out to reduce the load during such peak times.

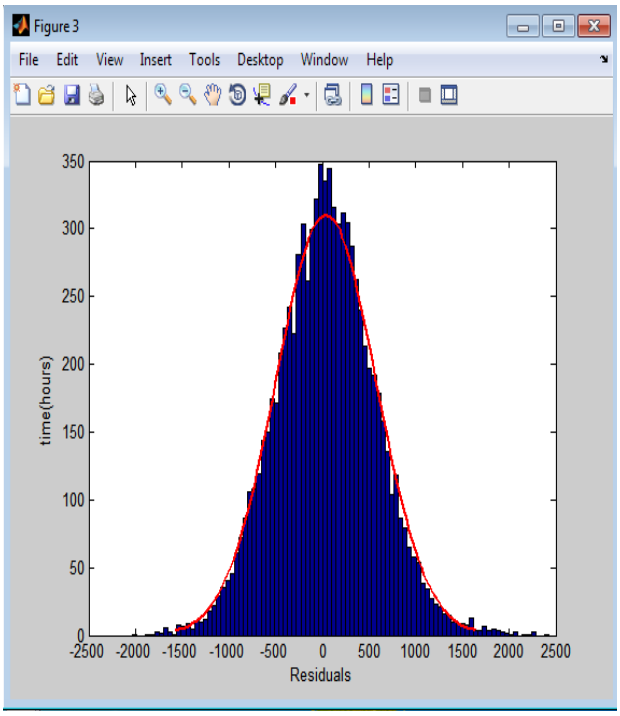

Fig 6: Power consumption by Residuals

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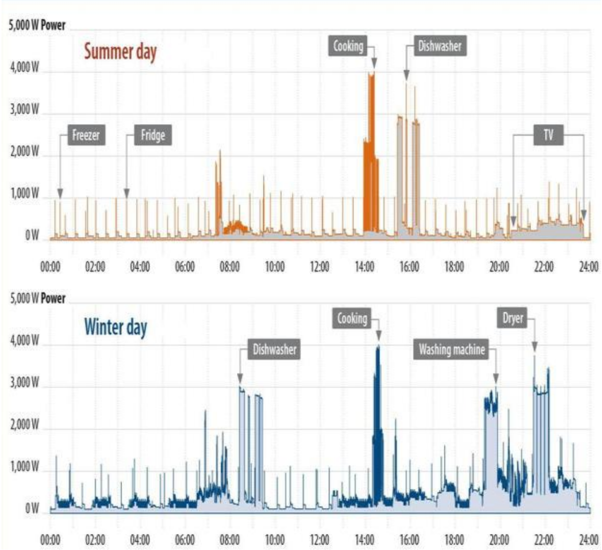

Fig 7: Load consumed by various appliances in summer and winter

The fig gives the power consumption by various appliances during summer and winter. The load measurement unit proposed by our system is effective in finding load consumption which will be useful to have demand response based home energy management system
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VI. Conclusion

This paper presents an load measurement scheme for intelligent home energy management system with demand response applications. Simulation results show that the proposed home energy system algorithm can effectively and proactively control and manage the operation of various appliances to keep the total household consumption below a specified demand limit. The proposed algorithm takes into account both load priority and customer comfort level settings. Simulation results indicate that at a low demand limit level, the system is able to keep the total household demand below the limit, but customers may need to sacrifice their comfort level to some extent. Also, it is possible that a DR event could create a high off-peak demand due to load compensation. This implies that there is a limit on how much DR that can be performed. However it is expected that the results of work will benefit electric distribution utilities and DR aggregators in providing an accurate and deep understanding into the limits and potentials of DR available in residential markets. The load measurement made by the system is thus effectively utilised by the home energy management system to have better demand response management.

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