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Demand Response Based Home Energy Management System

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Abstract— **In this paper we present a home energy management system with energy demand management. The proposed system will have control of different 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.**

Index Terms—**Demand response, dynamic pricing, home energy management system, load priority.**

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[1]. DR also plays an unique role in load shifting that can help increase reliability and efficiency in operation.

We propose a home energy management algorithm for the utility company and the customers to jointly compute the optimal prices and demand schedules. Then, we present simulation results that illustrate several interesting properties of the proposed method, as follows. 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. Here we also use the energy consumption data for the previous four years to speculate and fix the energy consumption at different times. 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. The formulas for most of these kinds of optimization algorithms are nonlinear, so we consider using a genetic algorithm to solve these problems easily. At last, simulation results for the proposed system are presented to show the effectiveness and feasibility of working in home energy management system.

II. PROPOSED SYSTEM

A. Algorithm

In 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. Distributed algorithm find 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.

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B. Block diagram

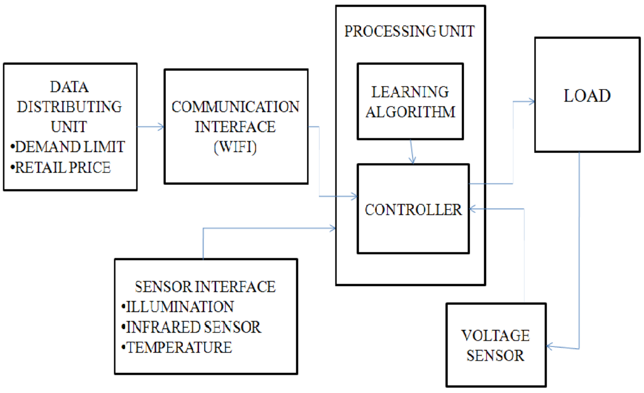

Fig 1: Block Diagram

The above block diagram describes our proposed system. The operation of the various components used are described further.

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. Algorithm used

The two algorithms used in the system to estimate demand response are Prediction algorithm and neural algorithm. It is used to calculate the real time cost price from the demand response obtained from the utility side. Also the previous year data are used as reference to make accurate evaluations. The Greedy algorithm and Distributed algorithm are being used to achieve load switching operations.

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.

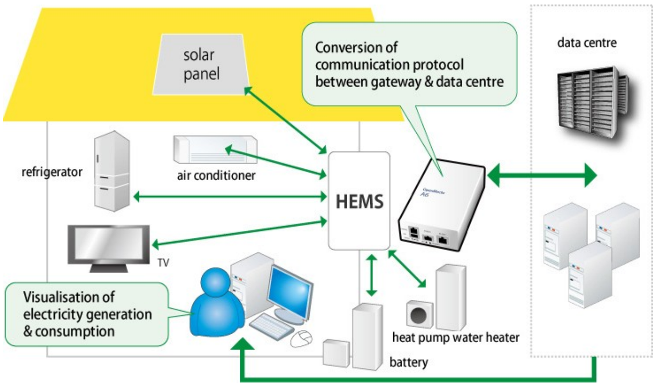

Fig 2: Home energy management system

V. RESULT

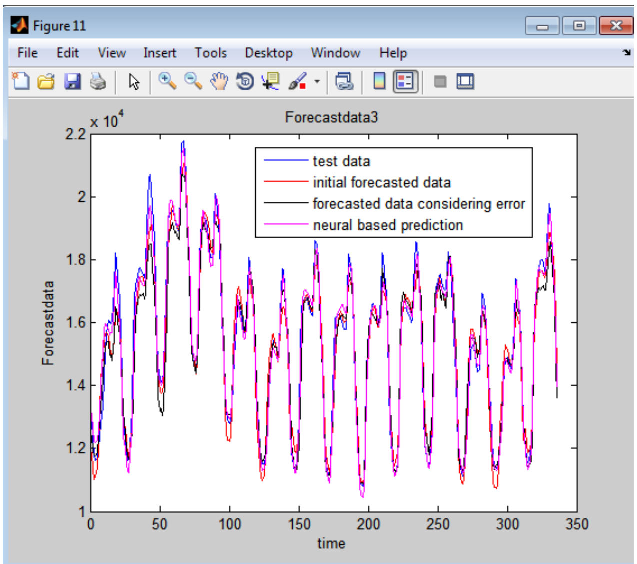

Fig 3: Forecast data

The above figure gives the simulated output using MATLAB. Here the comparison between test data, initial forecasted data, forecasted data considering error and neural based prediction are being made. Depending on the time these data actually changes. And it is noted that using our proposed system there is only a least difference between the forecasted data and neural based prediction data. The forecasted data with error is also considered to make the performance of the system more reliable.

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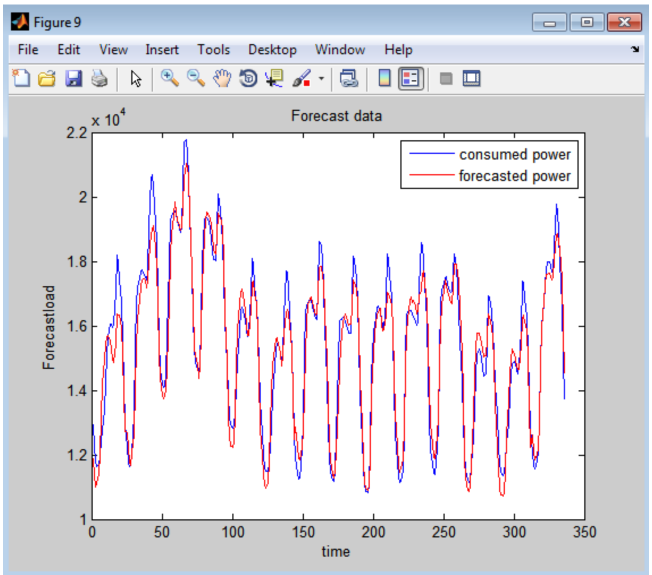

Fig 4: Forecast and consumed power

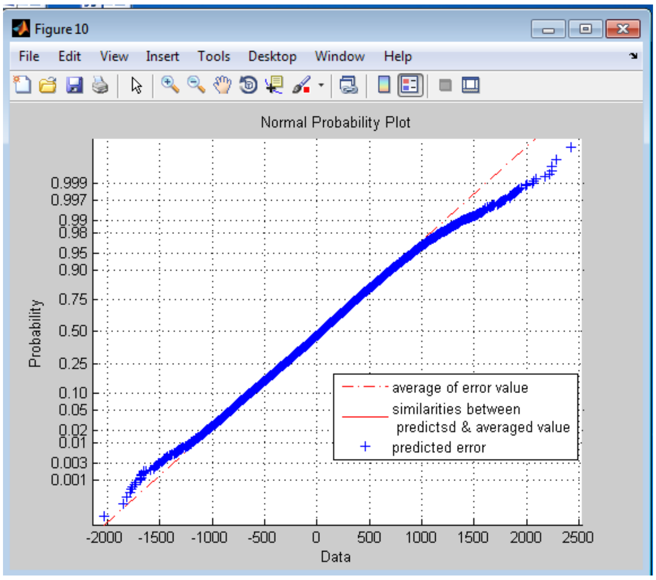

Fig 5: Average error value

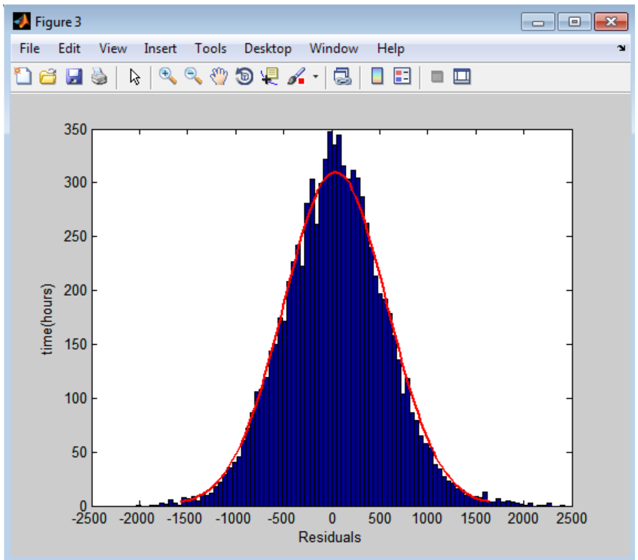

Fig 6: Power consumption by the residuals

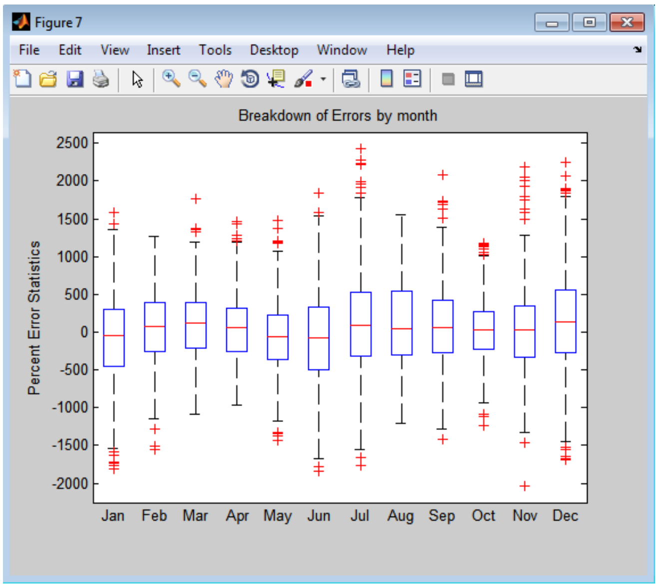

Fig 7: Breakdown of Errors by month

Fig 4 gives the simulated output of forecasted load for various time intervals. The difference between the consumed power and forecasted power is described. Fig 5 gives the similarities between predicted and averaged value with prediction error. It is noted that with our system there is only a minimal average of error value[8]. Fig 6 gives the power consumption by the residuals at various timings from which the average power consumption is obtained by adjusting to the nearby values by approximation. Fig 7 gives the breakdown of errors by month.

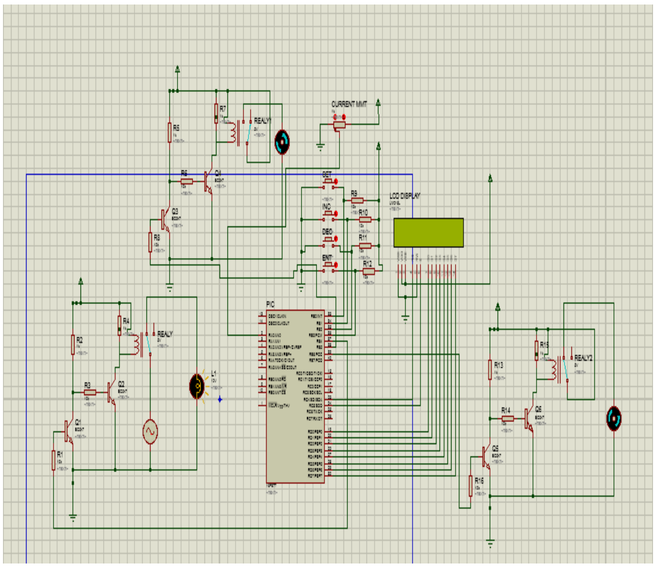

Fig 8: Simulated output using PROTEUS

The above figure gives the simulated output of the same system using PROTEUS. Here to demonstrate the washing machine and air conditioner two motors are used. Then the high priority load which is the lighting system is given by the incandescent lamp connected. Now when the controller receives a low peak to average signal then it will turn ON the motors corresponding to washing machine and air conditioner. The time the demand at the utility side increases the home energy system will be given the signal of high peak to average ratio. Thus it will turn OFF the least priority loads.

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VI. CONCLUSION

This paper presents an intelligent home energy management system for 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.

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