HARDWARE PROTOTYPE OF SMART HOME ENERGY MANAGEMENT SYSTEM

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Abstract

The development of 'demand-side load management' is the outcome of the smart grid initiative. Due to the significant amount of loads in the residential sector, home energy management has received increasing interest. In the country like India, we are lagging behind, in the power sector as the demand is much more than the supply. Moreover, there is not a single initiative, which has been taken for the deployment of smart suppliers and smart users. Here, I propose a hardware design of smart home energy management system (SHEMS). With the help of this proposed design, it is possible to have a real-time, price-responsive control strategy for domestic loads such as electrical water heater (EWH), illumination (Lights), air conditioning (Fan), dryer etc. Consumers may interact with suppliers or load serving entities (LSEs) to facilitate the load management at the supplier side. This system is designed with sensors to detect human activities and the behavior is predicted by applying a machine learning algorithm in order to help consumers reduce total payment on electricity. Finally, for the verification of the hardware system, simulation and experiment results will be checked based on an actual SHEMS prototype.

Keywords: *Demand side load management, Load Serving Entity (LSE), Smart Home Energy Management System (SHEMS), Smart Grid.*

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1. INTRODUCTION

The electricity prices are dependent upon the consumers' demand. However, because of the lack of real-time pricing (RTP) technologies, there are challenges to electricity market operators to optimize the signal usage and respond to scarcity as electricity cannot be stored economically [1]. Few years ago, because of the deployment of advanced metering infrastructures (AMI) and communication technologies, RTP is technically feasible. RTP reflects the present supply-demand ratio and provides a means for load-serving entities (LSEs) in order to solve the issues related to demand side management such as peak-load shaving [2]. Applications of RTP enable consumers and suppliers to interact with each other, which creates an opportunity for consumers to play an increasingly active role in the present electricity market with optimal control strategies at the demand side [3].

It is reasonable to design a smart home energy management system (SHEMS) based on RTP response to reduce the total electricity payment cost for consumers, and meanwhile, to flatten demand peaks. This paper presents a SHEMS hardware design which is integrated with an algorithm to achieve dynamic price response. Thus, this system considers both interests from the electricity supplier side and the customer side. Particularly, this paper presents a hardware design of a SHEMS system with sensing technology, communication and machine learning.

Organization of this paper is as follows. Section 2 analyzes the functions that the proposed SHEMS design needs to implement. Section 3 presents the details of the SHEMS hardware and software design respectively. Section 4 concludes the paper.

2. FUNCTIONAL REQUIREMENTS

In this section, the functions of the proposed SHEMS system are discussed. The essential goal of SHEMS is to reduce their total electricity payment while satisfying consumer's needs. Specifically, the control strategy provided by SHEMS is to adjust the control settings of each load i.e. appliance at home in accordance with the consumer's preference, total payment. As shown in Fig. 1, the primary function of the proposed SHEMS includes:

a) To receive information and messages from various loads for e.g. RTP, human activities at home, consumers' preference etc.
b) After the analysis of the received information, generate the optimal strategy
c) Adjust the settings of the loads according to the strategy generated.
d) To feedback data back to the Load serving entity (LSE).

Moreover, the detailed requirement analyses about data collection, processing and control are discussed below.

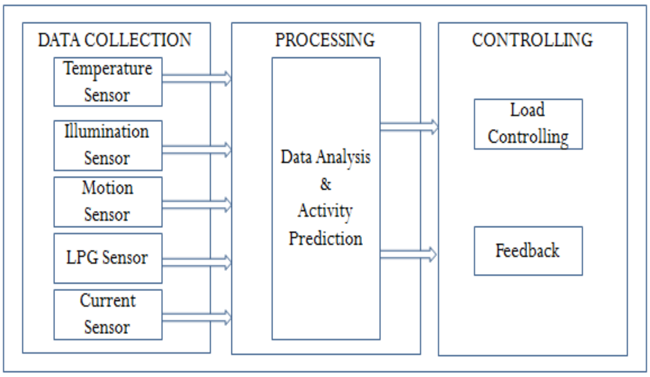

Fig- 1: Functions of proposed SHEMS 1

2.1 Data Collection

Here all the data i.e. the status of all the sensors is received. **Real Time Pricing:** A personal computer is necessary for reading the RTP signals from the sensors or LSE of the residential load. Therefore, ZigBee module should be included in the proposed SHEMS design.

Messages: This function is designed to respond to extreme scenarios. For this LPG sensor will sense if there is leakage of the gas and immediately the consumer will receive an SMS about this. Consumers' Preference: In order to obtain the consumers' preference, a GUI is developed for consumer to manually change the settings at home.

Human Activities: Motion sensors need to be installed to collect useful data of human activities at home. By applying machine learning algorithms in the processing part, the consumer activities related to energy consumption can be predicted.

Status of Loads and Home: Interfaces need to be developed to obtain the status of loads at home. For prototyping we are taking loads such as EWH, fan, hair dryer, and light. Temperature and illumination sensors are also needed and perhaps deployed in a number of, if not all, rooms to monitor the environmental parameters.

2.2 Processing

Receiving Data: Status of all the sensors will be displayed on the GUI in PC. However, as far as the sensors and load interfaces are concerned, they are designed with a wireless connection with the PC.

Event Analysis: The processor reminds the consumer about the messages from the utility supplier through a specific user interface. SHEMS should alarm the consumer about whether the comfort level will be significantly impacted under any inclement event.

Human Activity Prediction: Machine learning algorithms will be implemented to analyze and predict human activities based on data collected by motion and flow sensors. The longer the system is in use, the more accurate the predictions can be. Load Optimal Strategies: Since all the useful information including RTP, special events, consumer needs, and human activities can be obtained, different optimal strategies are applied for each load based on the modes.

2.3 Control

Load Control: Proposed design has load interfaces to obtain the real-time status of all appliances. Load interfaces are also expected to modify the settings of appliances according to the results calculated from the processing part.

Feedback: The status of appliances and the event information will be shown to the consumer on the GUI.

3. DESIGN OF SHEMS

3.1 Hardware Design

The figure 2 presents the 1st part of SHEMS hardware, whereas the figure 3 shows the complete hardware with the lamp as a load interfaced with SHEMS. The details of the hardware components are discussed below:

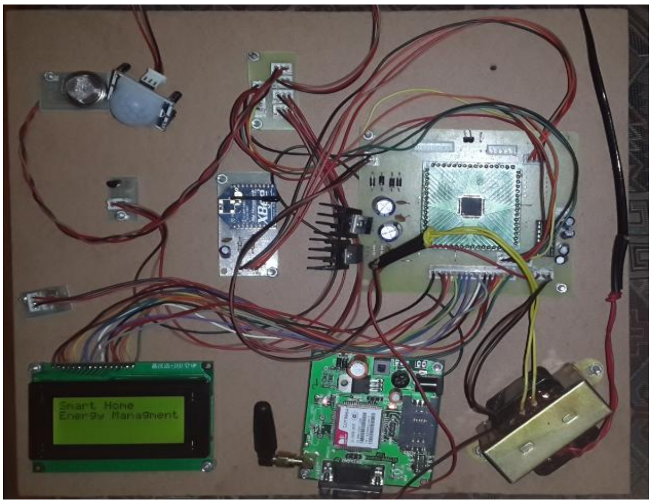

Fig- 2: Hardware Design of SHEMS

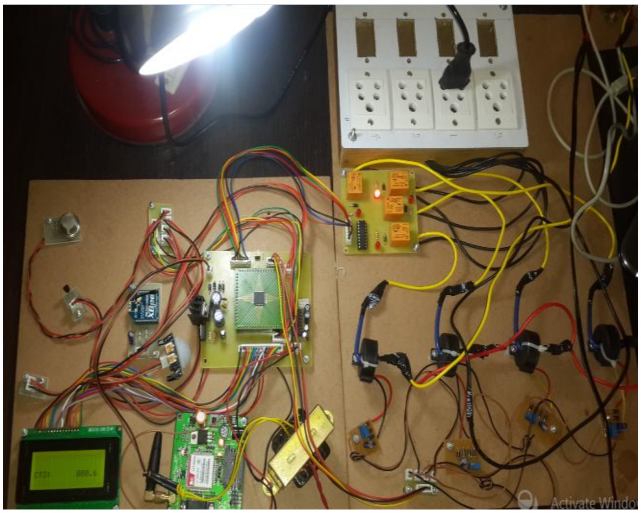

Fig- 3: Complete Hardware with lamp as a load interfaced

Microcontroller: The microcontroller LPC 2138 is used. This controller will work as the brain of the s\SHEMS system

LCD Display: The current status of the system is displayed on the 16*2 LCD display.

GSM Module: SIM900 GSM module is for sending the alert message to the consumer whenever there is LPG gas leakage. This will help the consumer to avoid the hazardous situation.

ZigBee: ZigBee is for the communication of the loads and supplier that is personal computer (PC). Here the PC will act as a supplier. To establish a communication between the individual user and the supplier side, the communication medium is ZigBee.

Sensors: There are following sensors:
Temperature Sensor: To sense the surrounding temperature. In the smart and the energy saving mode, if the person is detected then the fan will be turned ON if the sensed value is greater than 30%.

LPG Sensor: MQ6 to detect the LPG leakage. If the LPG leakage is there, then it will be detected by this sensor and immediately the SMS will be sent to the consumer.

PIR Sensor: To detect the presence of a person nearby. This will come into picture when the system is in the smart mode or in the energy saving mode.

Light Sensor: To sense the amount of luminance. In the smart and the energy saving mode, if the person is detected then the light will be ON if the sensed value is below 30%.

3.2 Software Design

The GUI of SHEMS is designed in Visual Basic 6.0. Figure 4 shows the snapshot of the GUI. There are three different modes namely, Comfortable Mode, Smart Mode and Energy Saving Mode. The function of these modes is described as under:

Comfortable Mode: In this, the user is free to operate any load regardless of the total consumption. This is compulsory ON mode. By default the system will be in this mode.

Smart Mode: In this mode, the operation of loads will depend upon the sensors and the previous database of the system. According to the consumer's previous behavior the system will automatically set the loads. If in case the predicted activity and the actual activity does not match then the user can train the system accordingly by setting it into new train mode.

Energy Saving Mode: Here, the priority is to save the total energy consumption. The system will operate the loads only if the PIR sensor detects the person. If not, then all the loads will be turned off and if the person is detected then the system will check the Temperature sensor and the Light sensor value. If they are above 60% range then only the light and fan will be turned ON.

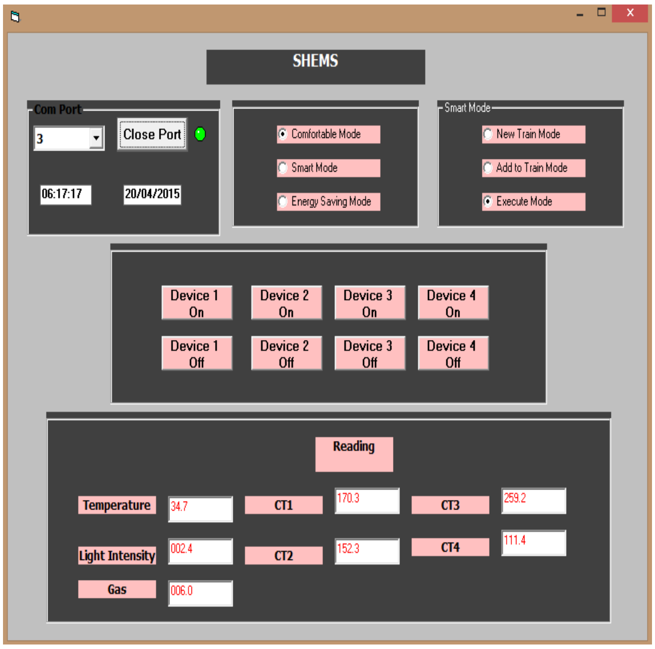

Fig- 4: GUI of SHEMS

In the first frame, the current date and time is displayed. There is the option button from where you can select the communication port, it is 3 here. From the close port option, you can stop the communication between the PC and the microcontroller system. There are four devices connected in the system as loads, which can be operated ON/OFF through the option buttons. Further, the reading of all the sensors is displayed in the last frame.

4. CONCLUSION

This paper presents a hardware design of a smart home energy management system (SHEMS) with the incorporation of sensing technology, communication. The proposed design will help the user to participate in optimizing the energy consumption. The load management at the supplier side is facilitated by making the user to interact with suppliers or load serving entities (LSEs). Further, SHEMS is designed with sensors to detect human activities and then apply machine learning algorithm to intelligently help consumers reduce total electricity payment without much involvement of consumers. In order to verify the effort, the paper also includes the hardware testing and the simulation, which show the validity of the hardware system of the SHEMS prototype. The hardware design of SHEMS can be extended. Thus it is able to make it fit to houses regardless of its size or number of appliances. The further expandable modules are the sensors and load interfaces.

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BIOGRAPHIES

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