Scheduling of Air Conditioner Based on Real Time Price And Real-Time Temperature

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Abstract: The smart grid initiative and the market operations drive into the new concept of control able loads. This particular Paper presents a smart scheduling device of an air conditioner which demonstrates the general architecture along with practical implementation of the hardware that could be use to schedule the air condition based on real time price and temperature in order to reduce the cost of electricity bill ,devoid of compromising the user comfort. The proposed architecture of overall system comprise of three parts, Data collection Part, Scheduling Part and Control part. The system collects outdoor temperature as well as dynamic price in real time. Scheduling part serves as brain of proposed system and is responsible for taking decisions based on input parameters. It determines an optimal choice of energy consumption scheduling which keeps into consideration the user comforts and formulated as nonlinear programming. Results were then applied to the air conditioner in the form of on/off and setting thermostat with help of the control unit which consisted on the infrared transmitter and receiver. At last a test bed was designed and experimental results shown that the electricity expenditure is reduced, along with that the overall suitable temperature is also maintained.

Keywords: price prediction, real time price, advance meter infrastructure, demand response, user comfort.

1. Introduction

It is expected that in the coming years the demand for power supply, when it comes to homes especially for heating/cooling appliances will greatly increase .As there is a huge gap between the available and the generated power supply due to factors such as global warming and modernization[1], as a result the conservation of energy can be significantly increased by integrating smart and energy efficient appliances into the smart grid. Consequently, for this reason the demand and response concept is integrated in smart grid. According to the definition of demand response, it is the change in the electricity consumption by the end user from their normal consumption pattern in response to change in the price of electricity over time[2]. The main focus of demand response enables the smart grid to shave the peak demands, which refer to shift load from the on peak times to the off peak times. This will bring great benefit to the user and utility as the already installed capacity can be utilized efficiently. Utilities adopt this strategy to distribute load of whole day in a uniform manner and to reduce the risk of contingency occurring.

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The residential loads can be categorized into the following three types [3]. 1) Thermostatically controlled load such as the air conditioner and water heater whose power consumption is directly related to the temperature. 2) Non thermostatically controlled load like the PHEV, washing machine, cloth dryer, which can certainly complete their work in the given time. 3) Critical Load: Such loads which are unable to be shifted in time e.g. the lighting which must be turned on for the given amount of time when necessary. The heating, ventilation and air conditioning systems can consume over 50% of the total energy consumption in homes [4]. In this paper we will focus the first kind of load like air conditioner. The contribution of this paper is to develop the prototype hardware which can be used to control the air conditioner with the real time pricing scheme and also to acquire the parameters like the outdoor temperature. The user finds it hard to schedule the air conditioner based on the Real time pricing scheme as well as the outside temperature so there should be some kind of automated device which can perform this action for the user. Therefore this paper concerns this issue. Emphasis is placed on the device working and the setup.

This rest of paper is organized as follows: Section 2 analyzes the general architecture of the system. Section 3 describes the proposed hardware which is used to implement the architecture and it's working. Experimental setup and case study are explained in section 4. Conclusion and the future works are presented in Section 5.

2. Overall Structure

A framework for the overall cost reduction system based on real time electricity prices is proposed. The functional requirements of each part in the system, data collection, scheduling module and the Control module, are explained. Information flow of the overall system is shown in the Figure. 1. Data collection module is responsible for collecting the real time outdoor temperature and also the real time electricity price from the electricity company through Advance Meter infrastructure (AMI).

The most important module of system, scheduler, analyzes the data from data collection module. Based on the user input it determines an optimal choice of energy consumption scheduling, while user comfort kept into consideration. The results are then applied to the air conditioner in the form of on/off and setting thermostat with the help of the control unit which is an infrared transmitter and the receiver. The user can enter its input to the scheduler with the help of the GUI (Graphical user interface) programmed in C sharp. It also helps the user **to** monitor the real time price on GUI and ultimately set the threshold value for the price. Higher than this value the system will automatically turnoff the air conditioner.

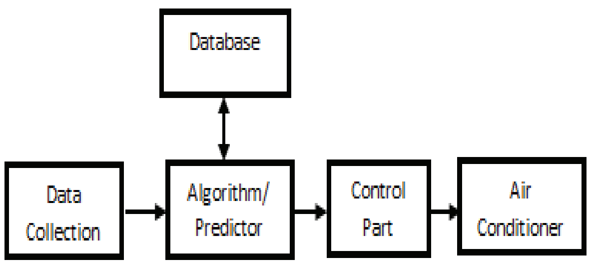


Fig. 1. Flow diagram of overall structure

The electricity cost of user will be reduced with the help of proposed system. Particularly, this system also has ideal applicability for the central air conditioner environments as it manages itself to reduce the overall cost.

3. DETAILED STRUCTURE OF SYSTEM

A. Data Collection Module

Data collection part consists of the temperature sensors, AMI and raspberry pi. Temperature sensor collects the outdoor temperature in real time. The raspberry pi, which is a single motherboard computer, is interfaced with the AMI to get the real time electricity prices from the electricity company. The working procedure of data collection part is shown in Figure 2. The data collection part primarily comprises of three functional modules: python script, Server and database. The sensors are interfaced with the GPIO (general purpose input/output) pins of the raspberry pi. After that by using python code system will be able to receive the outdoor temperature after 60 minutes interval .So all the input data such as real time price and outdoor temperature will be recorded in SQLite database which not only retains the record of the current data but also stores historical data. Finally a python code is written again to query the database and to load it on the apache server installed on the raspberry pi. Hence the scheduling part receives data from server after every hour.

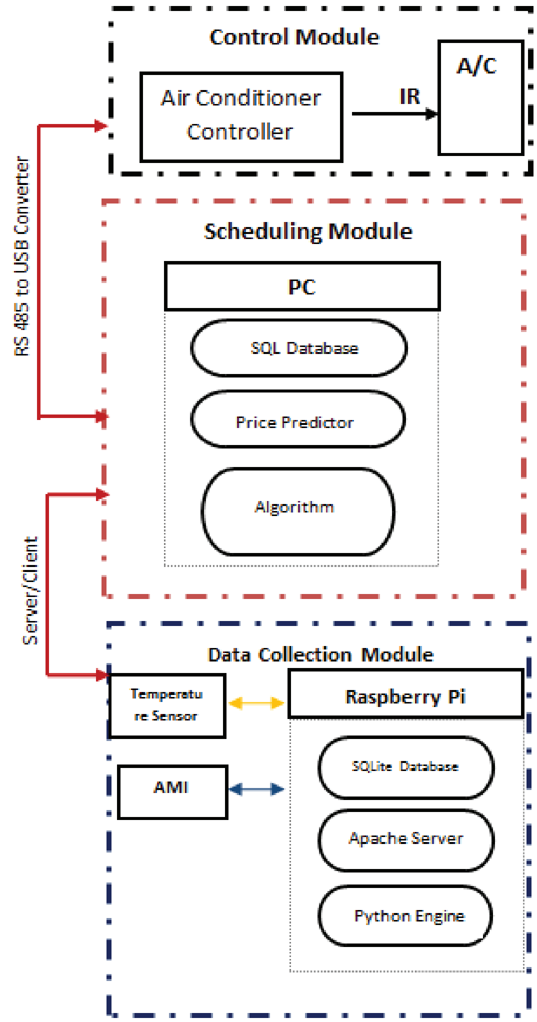


Fig. 2. Detailed architecture.

B. The Scheduling Part

Scheduling part of the system coded in C Sharp is shown in fig. 3. It is essentially the most important part and serves as a brain of whole system. It constitutes of three components database, price predictor and algorithm. The flow diagram of Scheduling part is shown in figure 2.

In order to formulate the problem a nonlinear programming formulation is needed as shown below:

$$\text{Minimize } C = \sum_{t=1}^{24} P_t . E_t \qquad (1)$$

$$\text{s.t.: } 0 \le E_t \le E^{\max}, T_{lower} \le T_t \le T_{upper} \quad (2)$$

Where $T_{lower} = T^{ideal} - d$, $T_{upper} = T^{ideal} + d$ where d represents the temperature deviation, t represents the time slot, P_t represents the cost of electricity in the hour t, C is the cost of over all day, E_t represents the energy consumed in hour t, $E^{\max}$ represents the maximum energy consumed by the airconditioner.

The energy consumption at hour is modeled as a function of the temperature of the present and last hour, and the present outdoor temperature [6]

$$P_t = \frac{T_t - T_{t-1} - \alpha(T_{out,t} - T_{t-1})}{\beta_t} \quad (3)$$

Where α and β are the temperature related parameters which specify the heat transfer and thermal efficiency respectively. It is assumed that Power consumed remained constant during one hour then the total energy consumption in that area during the hour t is as follows $E_t = (P_t) \times (1hour)$ So the total energy cost consumption is shown in equation (1).

C. Database

The Structure Query Language (SQL) performs the action of storing all input data, that is, it collects temperature from the server of the raspberry pi and real time price from utility company. Moreover it keeps track record of current and the historical data. Program collects the data from Database when needed.

D. The Price Predictor

The price predictor is needed to predict the future price rates by applying the weighted average filter to the past prices. The best possible coefficient values of the price predictor filter along with different coefficient at different week days are discussed in detail [5]. So an efficient predictor is possible by looking at the prices of yesterday, the day before yesterday and the same day last week. The mathematical model of price predictor is shown below.

$$Y^h(n) = A_1 Y^h[t-1] + A_2 Y^h[t-2] + A_7 Y^h[t-7] \quad (3)$$

$Y^h[t-1]$, $Y^h[t-2]$ and $Y^h[t-7]$ denotes the previous values of the parameters of yesterday, the day before yesterday and the same day last week respectively. The coefficient of the average price predictor are represented by A_1, A_2 and A_7.

E. Algorithm

The algorithm for air conditioner is designed for turning on/off and for temperature setting approach on the basis of real time price and predicted price. The algorithm works 24 hours a day. The program starts collecting the outdoor temperature, RTP and the predicted price from the price predictor in every hour.

Second parameter that is_to be set by user is the threshold value for the price with the help of GUI .The RTP is directly taken from the AMI and the outdoor temperature from sensor is shown in the graphical form in the GUI in Figure.3.

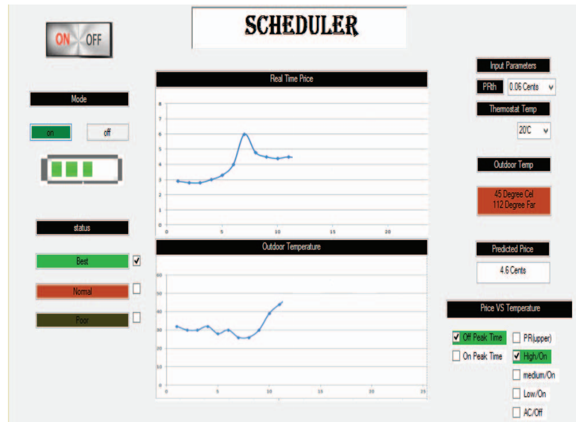


Fig. 3. Dashboard for scheduler

If PR_{real} and PR_{pred} are less than the threshold value (PR_{th}), then the output temperature is to be considered and the control automatically shifts to the thermostat setting, shown in fig.4. Threshold temperature is already programmed at the moderate temperature for the human body, (i.e. 23C) [6]. In case the outdoor temperature is much higher as compared to threshold temperature the algorithm will set the thermostat at high/on, that is at lower value. If the outdoor temperature is near the threshold value it will set thermostat at Medium/on and in the same way if it is equal to the threshold value it will set the thermostat at Low/on that is higher values. Provided that the outdoor temperature is below the threshold value it will turn off the air conditioner. Range of temperature values adjustments with respect to the threshold value is to be set according to the ASHRAE summer comfort zone [6]. If the first condition is not satisfied it will check the second condition and again shift to the thermostat setting. Hence will follow the same procedure. Now if PR_{real} and PR_{pred} are higher in comparison to the threshold price in both cases, it will turn off the air conditioner.

F. Control Part

Control part comprises of an infrared transmitter and receiver. Transmitter is an emitter which is used to transmit infrared signals and also to transmit the same data received by the receiver using and its wavelength, around 940nm. The IR receiver, TSOP38238, is to read the command from IR remote control and connected by a personal computer through USB using Rs- 485 convertor.

When it receives the signal from scheduler, it has the ability to turn On/Off and adjust the thermostat temperature of air conditioner.

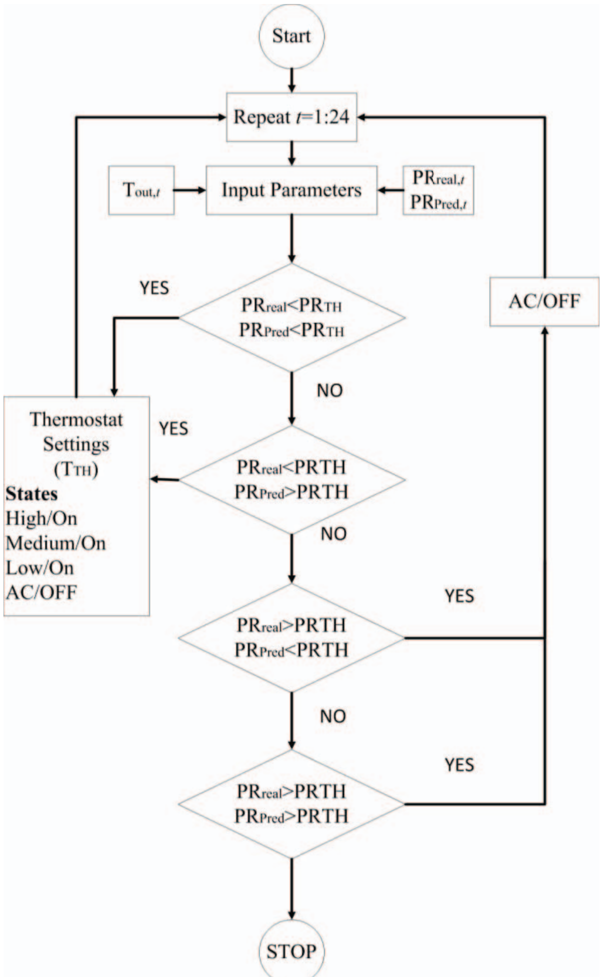


Fig. 4. Algorithm for summer

4. Experimental Setup and Case Study

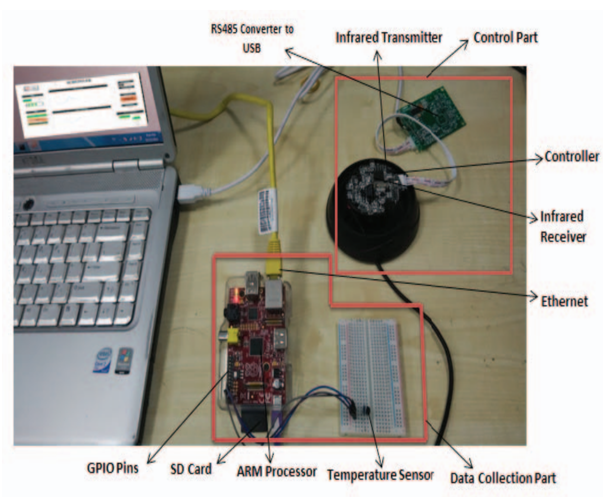
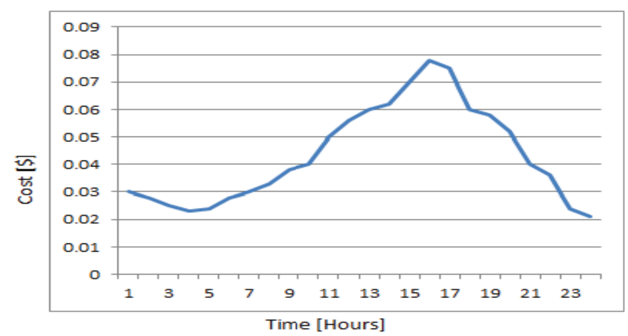


Fig. 5. Hardware design of overall system

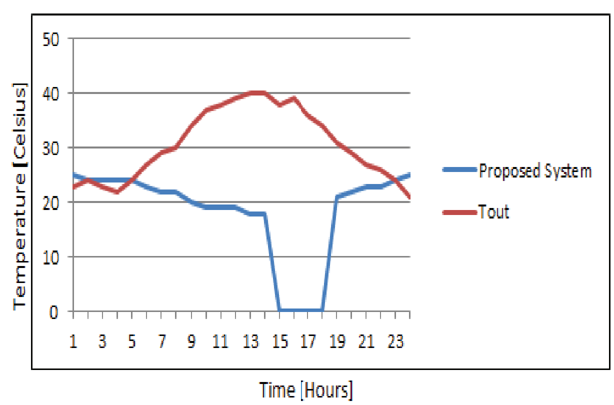
The experimental setup of proposed system is presented in Figure.5. Sensor collects the outdoor temperature values and after that raspberry pi, which acts as a Server, these temperature values and the price is displayed on the web browser of PC. PC acts as a Client and after every hour scheduler receives the input data from it upon requesting. Data in terms of temperature and price is provided to the user on GUI as shown in fig .6. Next, the program makes decisions based on algorithm and price predictor. Eventually control part gives commands to air conditioner to Turn Off/On and set thermostat setting temperature accordingly.

A comparative study is made between the proposed, high and low systems in which the thermostat values are kept constant on 18, 24 respectively and the heuristic demand response strategy [8], shown in Figure 6. .For the proposed system user set the threshold cost value as 0.06 dollar per KWh.

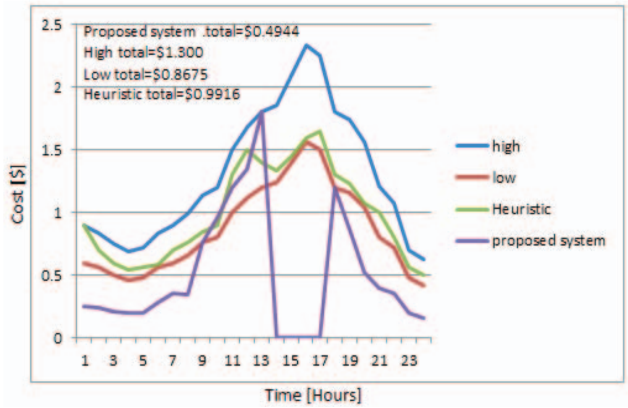
The temperature related parameters are specified as α=0.9, β = -0.008 [7]. All systems are operated for 24 hours and it is assumed that temperature does not change much in one hour .Furthermore the indoor temperature is same as thermostat temperature of air conditioner. So it is clear from graph that the proposed system after 24 hour is most effective in terms of cost saving and user comfort.



a) Day ahead electricity price



b) Outdoor temperature VS Thermostat setting



C) Hourly and total cost

Fig. 6. Comparison of Cost using Different Algorithms for the highest DAP Tariff Day in summer 2014

5. Conclusion and Future Work

This Paper presented a smart scheduling device of air conditioner which shows general architecture with practical implementation of hardware which can be used to schedule the air conditioner based on the real time pricing scheme and the temperature in order to reduce the cost of electricity bill of user while taking user comfort into consideration. This system automatically ON/OFF and adjusts the thermostat (indoor temperature) according to the price and outdoor temperature. That is when there is shifting of degrees in the outdoor temperature, the thermostat values increase or decrease accordingly as programmed. These thermostat values for the indoor temperature are adjusted carefully by considering the "human comforts standard". A test bed was constructed to evaluate the performance of the system which shows that the user can reduce the daily expenditure and well suited temperature is maintained. One of the future directions is to integrate the weather forecast system with the proposed system and to include the building thermal models to make it more accurate and efficient.

6. References

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