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Intelligent Air Conditioning System for Energy Management Using Wireless Control

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Abstract—*A Building Automation system (BAS) is a different purposed application from typical industrial automation applications, which deals with monitoring and control of building services. Energy crisis is the major issue of today's world and research works are being conducted to reduce wastage of energy. The air-conditioning system is a major electrical equipment used in offices, auditoriums, houses etc. . Also a large amount of energy is utilized by this system. In this paper, an intelligent energy management system is developed and implemented for air conditioner's using a wireless controlled centralized system. The centralized monitoring and control centre shall be implemented for the cost reduction,. The wireless system allows the quick detection of failing devices without needing long searches and wasting personal time. An energy management algorithm is developed and implemented to find the operational conditions of the system for avoiding energy wastage by adopting the technique of OLA (Observe Learn and Adapt) Algorithm. The system reduces building energy and maintenance costs when compared to a non-controlled building. An IEEE 802.15.4-based wireless sensor network is used here. This system has been implemented in a hall for testing the efficiency with four air conditioners and successfully tested for 60 days . It is seen that, with this system we can save up to 20% of energy when compared with the normal energy consumption .*

Keywords: Building automation system, energy management, wireless control

I. INTRODUCTION

A building automation system (BAS) deals with monitoring and control of house hold devices, for example lighting, Air conditioning, Heating etc. The system is not bound only to operate in HVAC appliances and lamps, but the control can also be obtained by more natural and efficient ways,

The Primary aim of BAS was to control HVAC systems and some simple devices only. Through time, as the requirement for energy saving is more we have gone through several kinds of complicated devices such as controllers, processors, etc. The comfort of end consumers was the purpose at the initial level and later energy efficiency criteria were also considered. Even though other home systems like lighting should also use automation, they are usually installed in a different system than HVAC. This division of the two subsystems increases the end consumer cost due to additional investment in communication hardware and software for integrating HVAC and lighting in a single control point.

As it was previously stated, building services are usually controlled separately, making Building Automation(BA) the set of control and communication technologies which link those different subsystems and make them work from a centralized monitoring and control centre . The main purpose of having a single control point which provides access to all building services is the cost reduction. A remote monitoring allows the quick detection of failing devices without needing long searches and wasting personal time. Since the system continuously monitors every device inside the building preventive or predictive as well, maintenance can be done very quickly and automatically, which results in a reduction of operational and maintenance costs. We know that that the operational cost of a building equipment is about seven times its initial investment, the

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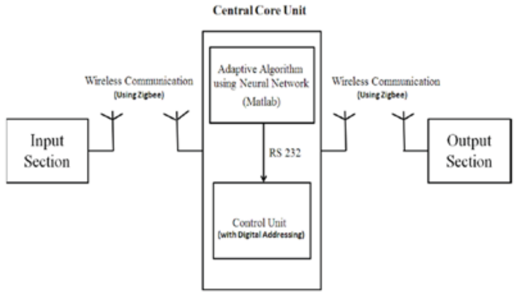

Figure 1. Block Diagram of the energy management system

purpose of automatic maintenance is very advantageous.

The need of a centralized monitoring control centre makes necessary the integration of all BA applications. The number of proprietary solutions has increased since the beginning of BA, but now we have several open standards (BACnet, LonWorks,KNX, DALI, ZigBee) which make the integration process easier.

Here in this paper the aim is to implement an Intelligent Air Conditioning System with digital addressing and wireless control by adopting the technique of OLA (Observe Learn and Adapt Algorithm). The main purpose is to provide the end consumer with an economical fully centralized air conditioning system in which house hold devices are managed and controlled by an IEEE 802.15.4 based wireless sensor network ZigBee. The initial investment is somewhat not reasonable, but by considering the maintenance and energy consumption costs the system is going to be very much efficient. Through this system we are planning to operate an air conditioning system by highly automatic means i.e., without any continuous input from an operator.

II. BLOCK DIAGRAM

The figure shows the basic block diagram of the proposed system. This may avoids the difficulties of the present system, so that power consumption can be reduced. The difference of this proposed system from the commonly used system is that it has a central monitoring system and it uses wireless communication. A central monitoring system is used to control all the functions of the system. A wireless network is used to transmit/receive data.

Then with the help of an IR LED the command is transmitted to the AC system as infrared rays. Now the AC system works accordingly as the adaptive algorithm decide.

It has three sections- an Input Section, a control unit, and an output section. The input section has two units an outdoor unit and an indoor unit. From this section input to the control unit goes.

III. DIFFERENT SECTIONS OF THE PROPOSED SYSTEM

The input section gives the data collected from the external and internal environment to the control unit. Here the input section has two units. They are an outdoor unit and an indoor unit. The outdoor unit is placed outside the room/hall in which we are going to place the Air Conditioning System and this unit continuously measures the ambient temperature level using temperature sensor and also the entry or exit of a person to/from the room. For this purpose a proximity sensor unit is provided. The corresponding data is transmitted into the PIC. Here we are using PIC16F877A.The acquired details are now transmitted to the Control Unit via ZigBee wireless network.

We are also having indoor unit which is placed inside the room in which the AC system is placed. The indoor unit measures the indoor temperature and occupancy level inside the room and that datas are also send to the control unit.

The Control unit is the most important section. The transmitted signal from the outdoor unit and the data from the indoor unit are given to the PIC provided at the Control Unit. These data is now given to the PC through RS232 interface. The adaptive Algorithm is provided in the system and is based on artificial intelligence. The programmed data is now collected and given back to the PIC through the RS232 interface. From there the data is sent to the output unit through the wireless ZigBee for driving the Air Conditioning system accordingly. The PC unit used here is only for the analysis purpose and after the formulation of the algorithm the entire control unit changes into a single hardware unit.

IV. MEASURING PARAMETERS

Start	Date	Time	Ambient Temp	Body Temp	Room Temp	Occupancy level	AC1 Temp	Ac2 Temp	Ac3 Temp	Ac4 Temp	Stop

Figure 2. Code Format

The figure shows the format in which the measuring parameters are appeared inside the analysing system (MATLAB). The temperature of each AC devices, ambient temperature, occupancy level and other details are formed in the system in the given format. And these are appeared as a set of codes and can be utilised for the purpose of observe, learn an adapt algorithm. The formed data is now programmed to obtain the required adapt command in order to control the Air-conditioning system. All the AC device status is not changes with a single command from the control unit. The control unit send certain set of commands that is provided with address of a particular AC system that is to be controlled.

V. SYSTEM EQUATIONS

For each Air Conditioner j, a_j be its arrival time, b_j its deadline. Let a_i and b_i be the arrival time and deadline of a scheduled day and R_j the total amount of work required to complete the job. A speed function for j is given by

$$S_j(t) = \begin{cases} \frac{R_j}{b_j - a_j} & : a_i \leq t \leq b_i \\ 0 & : otherwise \end{cases}$$

Each Job has an arrival time a_j$ and a deadline b_j. We will refer to the interval $[a_j,b_j]$ as j's execution interval. R_j is the number of units of work required to complete the job. A schedule is a pair S =(s, job) of functions defined over $[t_0,t_1]$, where t0 is the first arrival time and t1 is the last deadline. s(t) is the speed of the system as a function of time and job(t) indicates which job is being run at time t. job(t) can be null if there is no job running at time t. A schedule is feasible if all the jobs are completed between the time of their release and deadline. We are including a mathematical Dell function which is a smaller value so that for all jobs

$$\int_{a_j}^{b_j} S(t)\delta(job(t), j)dt = R_j$$

Where

$$\delta(job(t), j) = \begin{cases} 1 & \text{ifjob(t)} \leq j \text{ or} \neq 0 \\ 0 & \text{otherwise} \end{cases}$$

The total energy consumed is

$$Cost(S) = \int_{to}^{t_i} P(S(t))dt$$

Power consumption is now defined by a function P(s, ϕ) where's' is a nonnegative real number representing the speed of the system and ϕ is the state. The power function is then defined as follows

$$P(s, \phi) = \begin{cases} P(S) & \text{if}\phi = on \\ 0 & \text{if}\phi = sleep \end{cases}$$

The total energy consumed by S is

$$Cost(S) = K \int_{to}^{t_i} P(S(t), \phi(t))dt$$

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The speed of the system is always $S_{slow(t)}+S_{fast(t)}$ evaluated at the current time. $S_{fast(t)}$ is chosen as

$$S_{fast}(t) = \begin{cases} S_A(t) & \text{When in fast mode} \\ 0 & \text{When in slow mode} \end{cases}$$

In each case $S_{slow(t)}$ is set as follows .Let R denotes the remaining work of all pending jobs in the system

$$S_{slow}(t) = \begin{cases} S_{crit} & : t_{current} \le t \le R/S_{crit} \text{in fas} \\ 0 & : oth \end{cases}$$

The energy expended in running jobs by keeping the system in the on state is

$$run(S) = \int_{t_0}^{t_1} P(S(t))dt$$

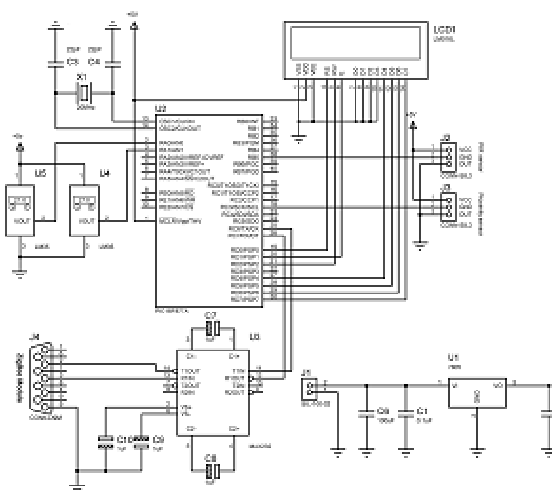

Figure 3: Circuit arrangement of the control system

VI. ALGORITHM

The name of the algorithm that we are using here is the Adaptive Training Algorithm. This is same as adaptive learning algorithm. But importance is given for training. This is normally using in neural networks. Training time is approximately up to 30 days.

- Initialize the system
- Checking the schedule S=(s,ϕ(job))
- If the current day $t_{current}$ is in the scheduled interval
- If occupancy Level is high
- Estimating the effective room temperature TER
- If optimal temperature limit is less than the effective room temperature, TOR <TER
- Run the Job
- If the system completes the job
- System transition to sleep mode (ϕ=sleep)
- If the system is currently running the job
- If occupancy Level is not high
- System completes the job
- System transition to sleep mode (ϕ=sleep)
- If occupancy Level is high
- Estimating the effective room temperature TER
- If optimal temperature limit is greater than or equal to the effective room temperature, TOR >=TER
- System completes the job
- System transition to sleep mode(ϕ=sleep)
- If fast mode Operation $S_{fast\ (t)}$
- If the system is in sleep state ((ϕ=sleep))
- If the wakeup time (t_w) is not reached
- SET WAKEUPTIME()
- If wake up time is reached (t_w)
- If occupancy Level is high
- Estimating the effective room temperature (TER)
- If optimal temperature limit is less than the effective room temperature, TOR <TER
- Run the Job with the Earliest Deadline First
- If the system completes the job
- System transition to sleep mode (ϕ=sleep)
- If $t_{current}$ is in the Scheduled time
- If the system is not currently running the job

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- If occupancy Level is high
- Estimating the effective room temperature TER
- If optimal temperature limit is less than the effective room temperature, TOR <TER
- Run the Job with the Earliest Deadline First
- If the system completes the job
- System transition to sleep mode (ϕ=sleep)
- If the system is currently running the job
- If occupancy Level is not high
- System completes the job
- System transition to sleep mode (ϕ=sleep)
- If occupancy Level is high
- Estimating the effective room temperature TER
- If optimal temperature limit is greater than or equal to the effective room temperature, TOR >=TER
- System completes the job
- System transition to sleep mode (ϕ=sleep)
- Checking the mode of operation
- If Slow mode Operation $S_{slow\,(t)}$ energy
- If the system is in sleep state ϕ=sleep)
- If the wakeup time (t_w) is not reached
- SET WAKEUPTIME()
- If wake up time is reached (t_w)
- If occupancy Level is high
- Estimating the effective room temperature (TER)
- If optimal temperature limit is less than the effective room temperature, TOR <TER
- Run the Job.
- If the system completes the job
- System transition to sleep mode (ϕ=sleep)

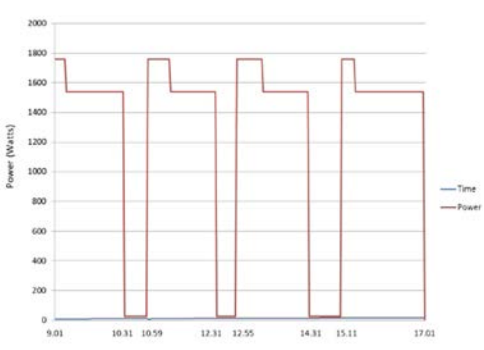

Fig 4 : Energy Consumption by the Existing system in a Working day

- If $t_{current}$ is in the Scheduled time.
- If the system is not currently running the job

VII. CONCLUSION

A new energy management system for Air Conditioning has been designed and developed. The system is going to be an efficient automation system with very low consumption of energy. Moreover since

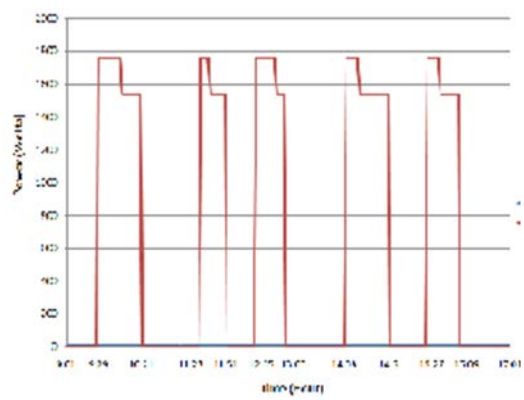

Fig 4 : Energy Consumption by the Proposed system in a Working day

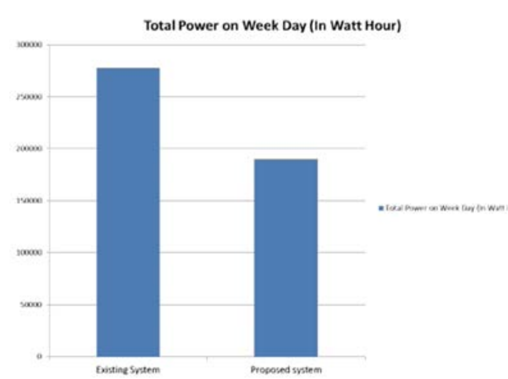

Figure 6 : Energy Consumption Comparison Chart for a Working day

Digital addressing is used, it is possible to implement the system in very large area than a single room. And with the proposed system, it is possible to control all the Air conditioning systems in a hall with a single control unit. Not only is it necessary to focus on the initial investment, but maintenance and energy consumption costs must also be considered. In normal sense, it is important to consider that a systems maintenance and energy consumption cost is very much higher than initial cost. So even though initial cost is somewhat higher, systems energy consumption and maintenance can be reduced with our proposed system. The concept of digital addressing also helps in easy trouble shooting of the device. It is seen that, with this system we can save up to 20% of energy when compared with the normal energy consumption

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