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PID Controller Based Thermal Sensor for Cost Effective Cooling

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***Abstract*—By 2050, the electricity demand from the usage of Air conditioning (AC) units will be tripled. This demand for cooling is particularly important in hot environment country like India, wherein it is estimated a 45% rise in usage of AC units. Optimal usage of these AC units, will not only benefit the environment, but also delay the probable installation of new power plants in future. In this paper, an objective function is developed for optimal working of AC. A combination of D6t thermal sensor, PIR sensor and ultrasonic sensor were used for human and ambience detection, upon which a PID controller will tune the desired set value for the AC unit. In this work, three case studies were taken such as Home, Lecture Hall and Commercial Space, where it is compared with and without sensors. From the result obtained, it is observed that the power consumption is very much reduced and also brings the cost saving over a time period.**

***Index Terms*—PID Controller, Air Conditioning, Ultrasonic Sensor, PIR Sensor, D6t Thermal Sensor**

I. INTRODUCTION

The Growing electricity demand for air conditioning is one of the most critical blind spots in todays energy debate, said by Dr Fatih Birol. The usage of Air Conditioner will grow to 5.5 billion from 1.6 billion by 2050 according to IEA report on The Future of Cooling. The global electricity demand for electric cooling account for 10% today and will be second largest demand in future [1]. In literature, there are numerous paper which focused on Air conditioning and its related problems which briefed below. In [2], has investigated energy problem in residential for an Air conditioning with Heating and ventilation management without sacrificing the thermal comforts of a user. The author verified the problem by considering the uncertainties of outside heat and electricity price.

Filip Belic et al [3] has presented a review of methods which improved the efficiency of Heating, Ventilation and Air Conditioning (HVAC) systems and has discussed different methods to estimate the intelligent control for a model. Shufen LI et al [4] has designed a specific method of fuzzy PID controller with self-tuning parameters for controlling the indoor temperature and humidity of an Air Conditioning unit. In [5], the authors has presented an overview of functionalities and tuning methods of PID controller which improved the transient performance. Harikrishna el al has presented a method in [6] for saving power in IT work spots, by using a PIR sensor which can detect human beings.

Filip Cerny et al has presented a Thermal Tracking System for detecting heat by a thermal MEMS sensor (D6T-44L-06), where the sensor has converted the thermal value into binary value which is evaluated by a master computer for further processing [7]. Saad et al [8] has discussed comparison of methods to wireless PIR sensor and Thermal Sensor for control of lightning and Air conditioning. Cheng et al [9] has investigated the development of sensors for smooth functioning of air conditioning systems by reinforcing the interaction of thermal comfort and energy efficiency.

In [10] the authors has presented an ultrasonic sensor for measuring the distance between selected points from ground of a vehicle. The measurement of this sensors mainly depends flight time of reflected ultrasonic pulses from ground. The papers discussed above, in a way contributed to improve the functioning of Air Conditioning but have not addressed the human element in conjunction with thermal factor. The authors in this paper focused on the optimal usage of Air conditioning by developing an objective function which accounts the data inputs by fusing the presence of human in the ambience of sensors range and thermal information. The paper is divided into the following sections: Methodology, PID Controller, PIR Sensor, Ultrasonic Sensor, Thermal Sensors followed by Result and Discussion

II. METHODOLOGY

The modelling of objective function based on human presence and thermal information is given in equation 1.

$$C_{saving} = C_{sensorless} - C_{sensor} \tag{1}$$

where,

C_{saving} = Saving cost from the optimal usage of Air conditioning over a time period.,

$C_{sensorless}$ = Cost incurred by operating Air conditioning without sensors (It is assumed that the system is operating at maximum cooling for 8 hours a day),

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C_{sensor} = Cost incurred by operating Air conditioning with sensors (by considering the presence of human element in conjunction with thermal sensors)

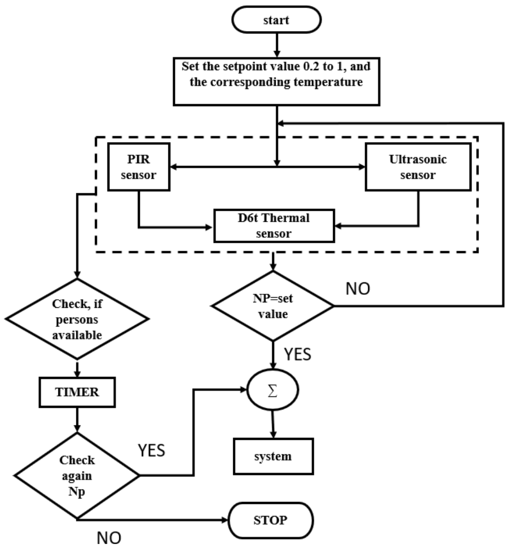

Fig. 1. Flow chart for the proposed algorithm

A. Algorithm

The flowchart for the proposed algorithm is shown in Fig 1

STEP 1:- The system is initialized

STEP 2:- Set the value and its corresponding temperatures were assigned between 0.2 to 1

STEP 3:- The persons count entering home/lecture hall/commercial complex were detected by PIR sensor and ultrasonic sensor which is fed to the d6t thermal sensor.

STEP 4:- If Np = 0, then a timer is initialized for prescribed set time and Go to *Step 5* else Go to *Step 6*

STEP 5:- if Np still equal to zero, then go to *Step 8* . else go to *Step 3*

STEP 6:- if np= set value, the system started functioning.

STEP 7:- if np =! set value, the feedback is generated. Go to *Step 3*

STEP 8:- Stop

III. PID Controller

This controller is found in a wide range of application such as process control industries. In this work PID controller is used to tune the set value for Air conditioning between 0 to 1, where 0 signifies the lowest cooling and 1 signifies highest cooling. The inputs for this controller will be the difference between the error and the data from the feedback loop. The feedback loop is equipped with a combination of sensors such as PIR sensor, D6t thermal sensor and Ultrasonic sensor which is show in Fig 2.

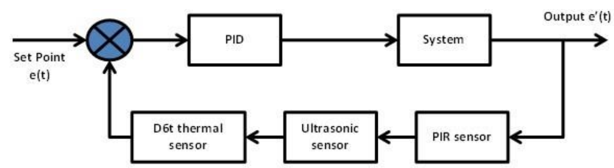

Fig. 2. PID controller for tuning set value of Air conditioning

TABLE I
Set values from controller and its associated cooling temperature

Set point	Persons	Actual Temp.	Temp. by sensor
0.2	1	16	30
0.4	2	16	27
0.6	3	16	23
0.8	4	16	19
1	5	16	16

These sensors will detect the highest possible efficient zone for Air conditioning to work by generating a signal of range 0 to 1. The Table

IV. Sensors

A. PIR Sensor

The prime use of PIR sensor is to detect human presence in the vicinity. This sensor is sensitive to infrared which is compared between two slots for automatically turned on/off if any movement detected

B. Ultrasonic Sensor

This sensor will generate a high frequency signal for detecting the present of objects. These signals will be reflected back from the object when interacted. The time taken for the signal to reach is converted into distance. When this sensor operated along with PIR sensor, it is very much convenient for detecting the human presence in the sensor range effectively and also it has a capability to count number of persons.

C. ORMON D6t Thermal Senosr

This sensor is used for detecting temperature of human body. For measuring temperature either thermocouple or RTD can be employed which generates the electrical signals.

V. Simulation and Case Studies:

In this work, the objective function developed in section 2 is verified on three different cases such as Home, Lecture Hall and Commercial complex. It is assumed that the system is considered operating about 8 hours per day. The cost savings are resulted from the difference of working of Air conditioning with and without sensors.

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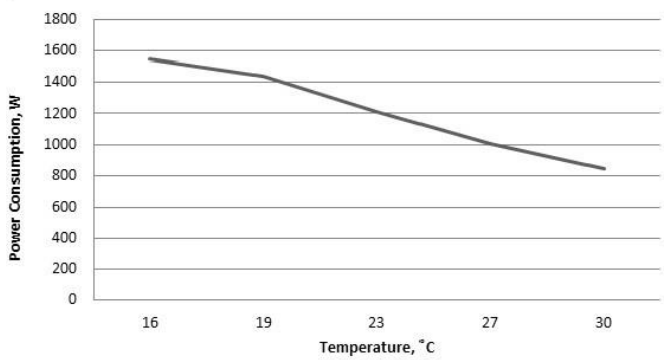

Fig. 3. Power consumption in home at different temperature

TABLE II
POWER CONSUMPTION IN HOME AT DIFFERENT TEMPERATURE

Persons	Temperature	Power Consumption, W
5	16	1550
4	19	1442.9
3	23	1212.1
2	27	1001.3
1	30	844

A. Home environment

In this case, a home is considered for testing the objective function developed where the sensors will predict the presence of persons at different configuration as shown in Table II and Fig 3. A maximum of five persons is considered and their cumulative usage is accounted for 8 hours during the day. The schematic representation for home environment is shown in Fig 4

When a person enters the area the PIR sensor will count along with ultrasonic sensor. Depend upon the ambience temperature (based on thermal sensor); a signal is generated corresponding to the set value for air conditioning which will be tuned by PID controller. This optimised working of AC is compared with base case, to observe the cost saving which is shown in Fig 5.

B. Lecture Hall

In this case, a Lecture hall (shown in Fig 6)is considered for two scenarios such as students greater than 15 and less than 15. The testing of objective function different configuration as shown in Table III and Fig 7. The cumulative usage of air conditioning is accounted for 8 hours during the day and the respective cost saving is shown in Fig 8.

C. Commercial Space

In this case, a commercial space is considered (shown in Fig 11), where it is clustered into sub areas into four nodal points for fitting the blowers which is connected to the centralised AC. The testing of objective function for different configuration is shown in Table IV and Fig 9. The cumulative usage of air conditioning is accounted for 8 hours during the day and the respective cost saving is shown in Fig 10

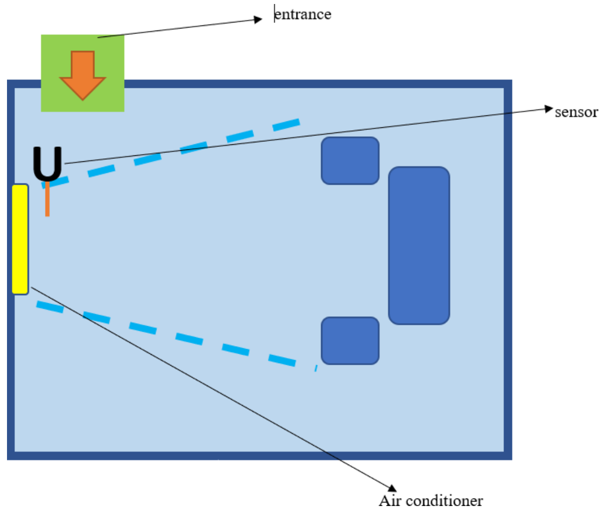

Fig. 4. case study for home environment

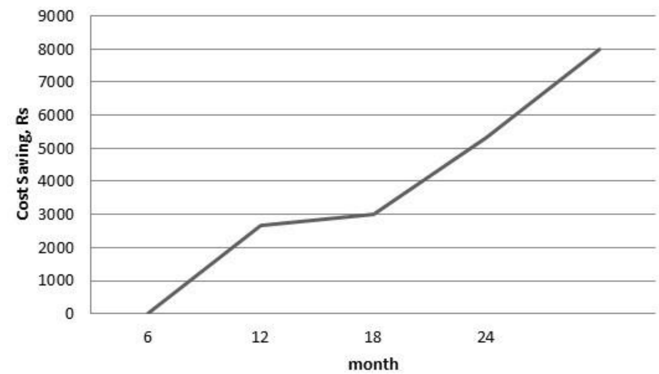

Fig. 5. Cost saving in home environment

The comparisons of number of energy units saved and its corrresponding cost saved for various cases is shown in Fig 12

TABLE III
POWER CONSUMPTION IN LECTURE HALL AT DIFFERENT TEMPERATURE FOR TWO SCENARIOS

Scenario	Persons	Temp. (degrees)		Power consumption			
				Without Sensor		With Sensor	
		AC1	AC2	AC1	AC2	AC1	AC2
≤ 15	3	30	-	1500	-	843.2	-
	7	25	-	1500	-	1054	-
	11	20	-	1500	-	1318	-
	15	16	-	1500	-	1550	-
>15	19	30	30	1500	1500	1500	843.2
	23	25	25	1500	1500	1550	1054
	27	20	20	1500	1500	1550	1318
	30	16	16	1500	1500	1550	1550

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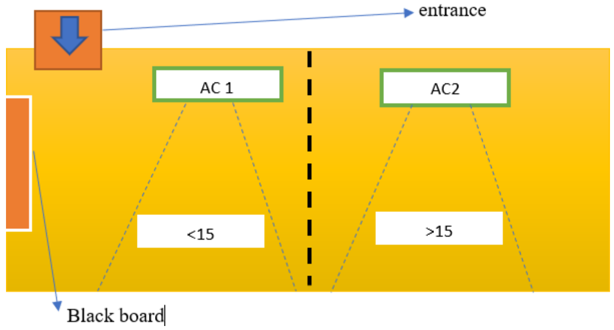

Fig. 6. case study for Lecture Hall

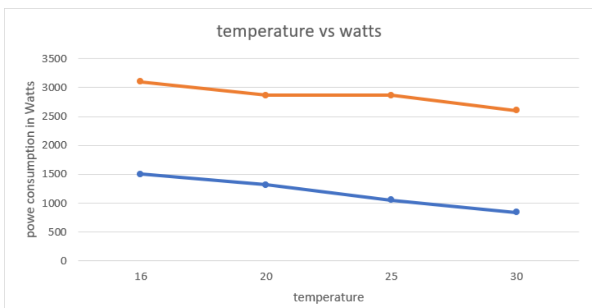

Fig. 7. Power consumption in Lecture Hall at different temperature for two scenarios

VI. CONCLUSION

The functioning of Air conditioning will be feasible when operated based on the objective function developed. The sensors combinations along with PID controller satisfied for all the case studies of air conditioning. It is observed from the result that cost saving is evitable when the set value for air conditioning decided when human element included.

Fig. 8. Cost saving for Lecture Hall case study

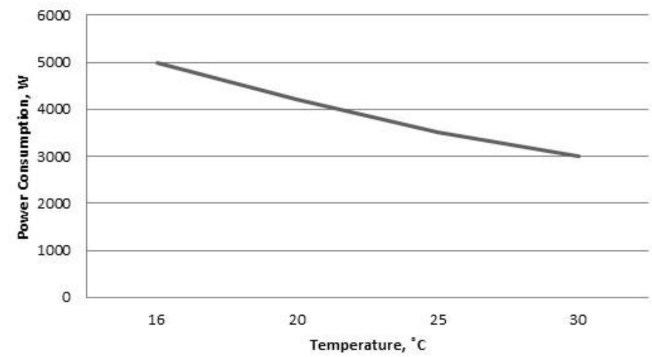

Fig. 9. Power consumption in commercial space for different configurations

Fig. 10. Cost saving for commercial complex

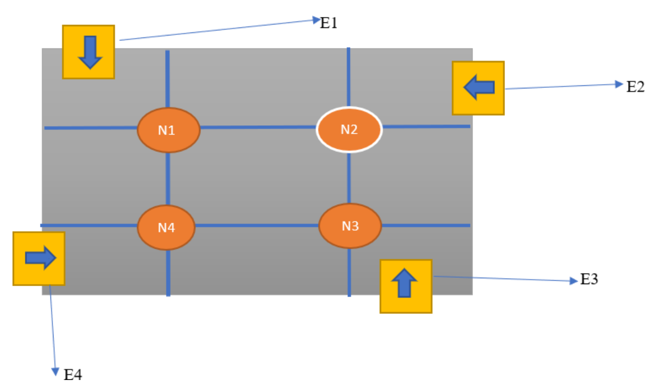

Fig. 11. case study for Commercial Complex

TABLE IV
POWER CONSUMPTION IN COMMERCIAL SPACE FOR DIFFERENT CONFIGURATIONS

No. of Nodes working	Temperature	Power Consumption, W
1	30	3000
2	25	3500
3	20	4200
4	16	5000

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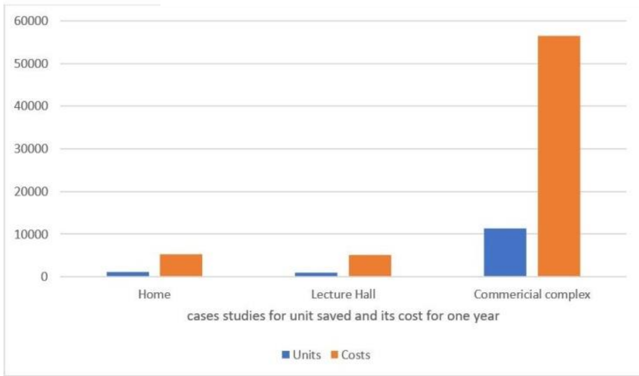

Fig. 12. comparison of cost saving for different case studies

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