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REAL TIME THERMAL COMFORT SENSING USING A COMPUTER AIDED MODULE

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***Abstract*— This project presents the design of an intelligent comfort control system by combining the minimum power control Strategies for the air conditioning system both in buildings and industries. For human-centered automation, a wireless sensor network using the predicted mean vote (PMV) is adopted as the thermal comfort index to improve indoor comfort level by considering six comfort related variables, whilst a genetic algorithm optimization is done to overcome the nonlinear feature of the PMV calculation for better performance of the feedback controller. In solving inverse PMV Models, the genetic algorithm is more accurate than particle swarm algorithm since it consumes less memory. It quantitatively evaluates the thermal sensation, and adopts a range of sensation levels, numbered from −3 (cold) to 3 (hot) for quantization and minimum power control Strategy is proposed to minimize the energy consumption further using different controllers such as fuzzy controller, PID controller and fuzzy PID controller and their performances are evaluated.**

Index Terms— ***Processcontrol; nonlinear dynamics; genetic algorithm(GA);Proportional Integral Derivative (PID) controller; predicted mean vote (PMV);***

I. INTRODUCTION

Due to the increasing use of unitary air-conditioners, there has been an increase in electricity consumption during summer substantially. Therefore, the use of better control techniques for steady temperature control and energy saving has become a major topic in the study of air-conditioning systems. Unitary systems mainly use the ON/OFF method as temperature control, which causes unstable room temperatures. The changes in room temperatures, from various unitary systems working at the same time, create large surges in energy consumption; therefore, this paper proposes various control schemes to achieve both energy savings and steadiness in the temperature of air-conditioning systems. Thermal comfort and indoor air quality are important factors for energy efficient buildings design. It has become an important area of research due to its influence on human health and energy consumption profile, it uses a wireless sensor network using predicted mean vote (PMV) proposed by fanger, as a thermal comfort index around occupants in buildings. The network automatically maintains thermal comfort by means of changing compressor's speeds & control the opening of expansion valves and control fan speeds in air conditioners based on computed thermal comfort levels. Compared with conventional fixed temperature settings, the present control methods effectively maintain the PMV value within the range of and energy is saved more than 30% in this study.

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II. PMV MODEL

The PMV model includes four environmental variables such as air temperature, relative humidity, air velocity, and average radiation temperature and two human factors such as thermal load on the body. It can quantitatively evaluate the thermal sensation, and adopt a range of sensation levels, numbered from −3 to 3 for quantization. The thermal load on the body varies with personal factors and environment factors. The personal factors consist of activity and clothing insulation. The PMV model is a nonlinear and multivariable model and it is not easy to find the analytical solution of the PMV model. There are many optimization techniques available both traditional and non-traditional. But in this study only non-traditional optimization techniques are considered. The traditional optimization techniques fail to converge on a feasible solution in many cases. The Non-traditional optimization techniques differ from the conventional traditional optimization techniques in that it produces optimal results in a short period of time. Most of the traditional optimization techniques based on gradient methods have the possibility of getting trapped at local optimum depending upon the degree of non-linearity. Hence, these traditional optimization techniques do not ensure global optimum and also have limited applications. The problems considered are Non Linear optimization which is single objective where the constraints are only bounds for environmental variables and the problems are continuous. Artificial intelligence strategies such as ant colony optimization, genetic algorithms, particle swarm algorithms, neural networks or the combination of the above strategies are useful for modeling nonlinear characteristic and solving complicated problems. PMV can be computed using the following equation.

PMV= [(0.028 + 0.3033e-0.036m)*(M-W) 0.000699(M-W) - Pa – 0.4(M-W) – 58.15 – 0.0173M (5.867 – PA) –0.0014M*(34 – Ta) – 3.96.10-8 fcl (Tcl + 273)4 – (Tmrt + 273)4 – fcl. hc (Tcl –Ta)]

Tcl = [35.7 – 0.28(M – W)-0.155Icl 3.9610-3 fcl (Tcl + 2273)4 - (Tmrt + 273)4 - fcl.hc (Tcl – Ta)]

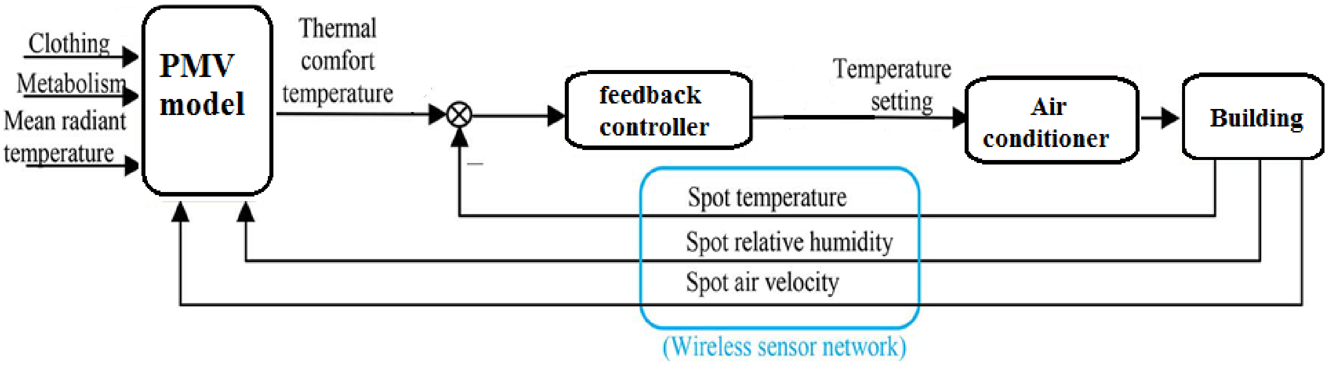

Fig. 1. Control block diagram of PMV model with feedback control

$hc=[2.38(Tcl-Ta)0.25]$ for $[2.38(Tcl-Ta)0.25 \geq 12.1\sqrt{vair}]$
$[12.1\sqrt{vair}]$ for $[2.38(Tcl-Ta)0.25 \leq 12.1\sqrt{vair}]$

The parameters are defined as follows:

PMV : Predicted mean vote.
M: Metabolism (W/m^2).
W: External work, equal to zero for most activity
I_{cl} : Thermal resistance of clothing (Clo).
Fcl : Ratio of body's surface area.
T_a: Air temperature.
T_{mrt} : Mean radiant temperature.
V_{air} : Relative air velocity (m/s).
P_a: Partial water vapour pressure (Pa).
H_c: Convection heat transfer coefficient (W/m^2).
T_{cl} : Surface temperature of clothing.

A. *Genetic Algorithm*

It is inspired by DARWIN'S APPROACH Based on Population of individuals. Each individual is characterized Fitness function. Higher fitness is better solution. Based on their fitness, parents are selected to reproduce and offspring for a new generation. Fitter individuals have more chance to reproduce and fitness scaling is done using f = f - (2*avg. - max.). New generation has same size as old generation. Off spring has combination of properties of two parents and if well designed, population will converge to optimal solution.

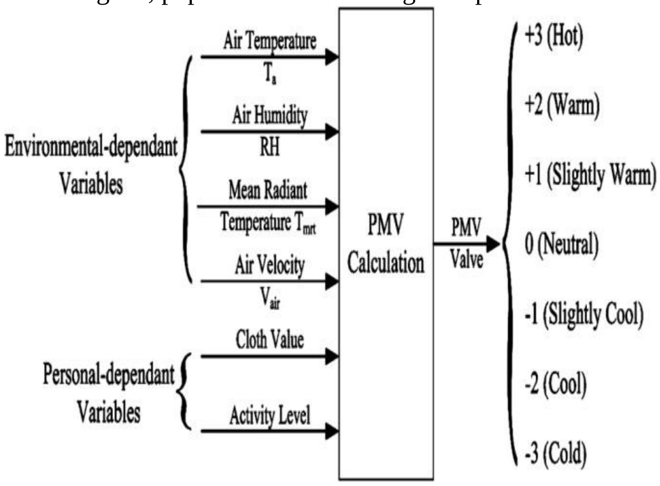

Fig.2. THERMAL SENSATION SCALE OF PMV

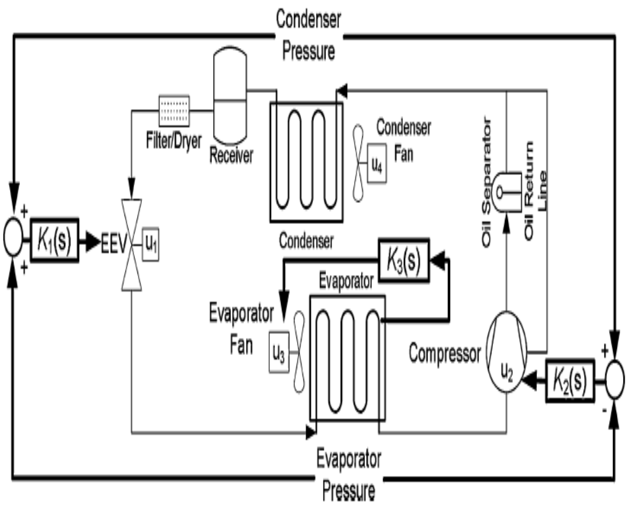

Fig.3. Control block diagram of output parameters with feedback control

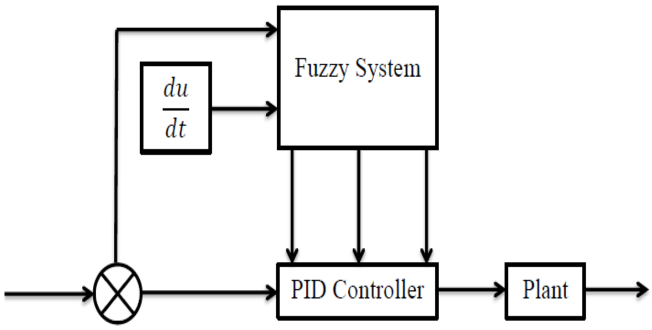

Fig 4 Fuzzy PID Structure

B. *Heat Balance*

At steady state the rate of heat production in the body, by metabolism and by performance of external work is the heat loss from the body to environment by evaporation,respiration,convection and by conduction. The metabolic rate and the clothing insulation of people are difficult to measure in real time. In general, the values of the metabolism and the clothing insulation are assumed as constants. The metabolic rate is assumed as 60 W/m for the office activity and the clothing insulation is assume d to be 0.57 clo due to the requirement of multiple sensors and the difficulty of measurement. The heat balance is given as

$$M - W = (C + R + E_{sk}) + (C_{res} + E_{res})$$

The parameters are defined as follows:
M= rate of metabolic heat production, W/m
W= rate of mechanical work accomplished, W/m
C+R= sensible heat loss from skin, W/m
Esk= rate of evaporative heat loss from the skin

C. PID controller

PI controller will eliminate forced oscillations and steady state error resulting in operation of on off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of controller.

The PID control algorithm remains the most popular approach for control. Tuning of gain values are done ziegler nichols tuning method. Ideal PID controller in continuous time is given as

$$Y(t) = KP\,(e(t) + T_i \int e(t)\,dt + T_d\, de(t)\,dt$$

D. Fuzzy Control

Fuzzy control based on the fuzzy set theory was developed initially by Mamdani. Fuzzy control was also adopted to improve the performance of air conditioning systems. In this study, input variables are the temperature error (E) and the temperature error change (CE). The difference between the desired and the indoor measured temperatures is E, where e(n) is the current temperature error, is the previous temperature error and T is the sampling time. The output variable is the temperature change in temperature setting

E. hybrid PID-fuzzy control scheme

This control scheme is built on the basis of a PID controller. With the aim of both taking into account-energy buildings, a hybrid PID-fuzzy controller is proposed, as the combination of the two just-mentioned control structures based on PID and fuzzy controllers: the "parallel" structure. With this combination one can take advantage of the properties of the two structures, filling in their respective gaps. The PID controller will be in charge of the main air conditioner while the fuzzy.

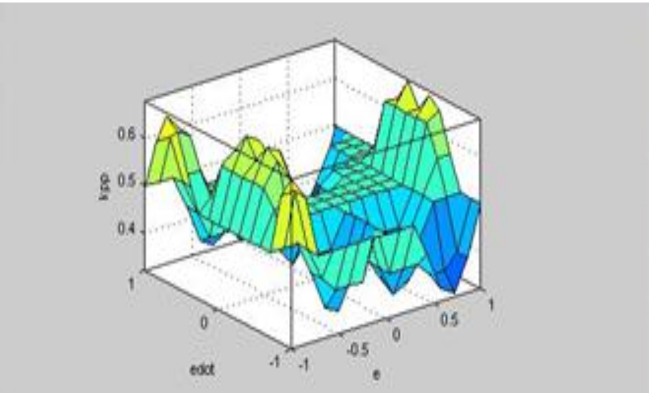

Fig5 . fuzzy PID surface for error and change in error

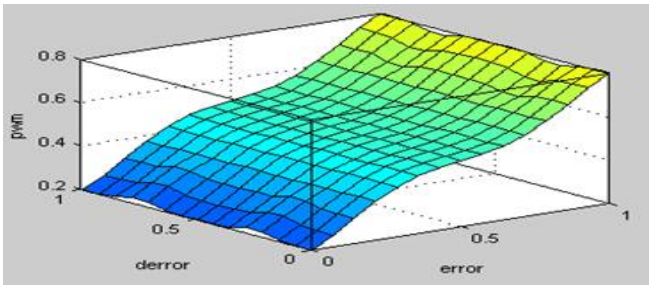

Fig.6. fuzzy surface for error and change in error

III. CONTROL METHODS

The feedback controller is responsible for automatically adjusting the indoor temperature, compensating the difference between the temperature measured by wireless sensor network. Here, fuzzy control and Proportional-Integral-Derivative (PID) control are adopted as the feedback controller. The genetic algorithm is adopted for optimization of PMV model so as to determine optimized thermal comfort temperatures. In optimizing PMV models, the genetic algorithm is more accurate than particle swarm optimization. Their performance for saving energy cost is evaluated. The network automatically controls air conditioning by means of changing compressor's speeds & control the opening of expansion valves and control on solved PMV model. The feedback controller is responsible for automatically adjusting the indoor temperature, compensating the difference between the temperatures measured by wireless sensor network. The wireless sensor network module measures the existing thermal comfort from the building through temperature sensor, relative humidity sensor, man radiant sensor and air velocity sensor. Also their specification and range are tabulated above.

The simulation and visualizing the results are presented. The heat cost and indoor versus outdoor temperatures is plotted on the scope. Heat gain is defined as energy transferred from conditioner to room and heat loss is defined as energy transferred from to room external environment. Room temperature is also taken in consideration. The model defines geometry of room which takes length, breath and width of room. No of windows and area of wall is used to model equivalent resistance. Cost is defined as the ratio of unit energy consumed. Fuzzy logic system and fuzzy PID system is constructed and simulated to run for 48 hours using previous stated rules and member ship function stated before and cost is determined as rupees. Error and change in error is given as input to the fuzzy inference system and pulse width is obtained as output to control the operation of conditioner. Error and change in error uses Gaussian membership function and pulse width uses triangular membership function. Defuzzification method used is here is centroid method. It takes centre value of input functions. The ranges are in values of 0 to 1 for elimination complexity in computation. The performances of different controllers and their corresponding energy efficiency is being tabulated above. It is infered that the cost saving of self tuning fuzzy PID controller is maximum about 21% and fuzzy logic controller cost efficiency is about 17 % while comparing to closed loop system. Also mathematical model for the system is not obtained. The entire approach is not about obtaining a transfer funtion for the system. This makes tuning of the feedback controller easy.

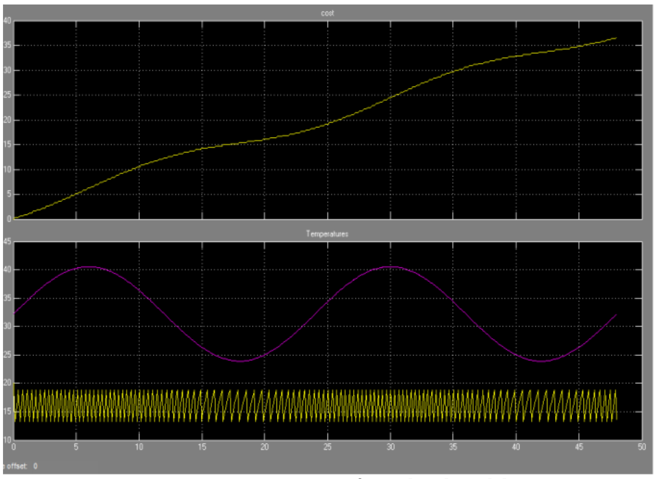

Fig. 7. Output response of simulated model

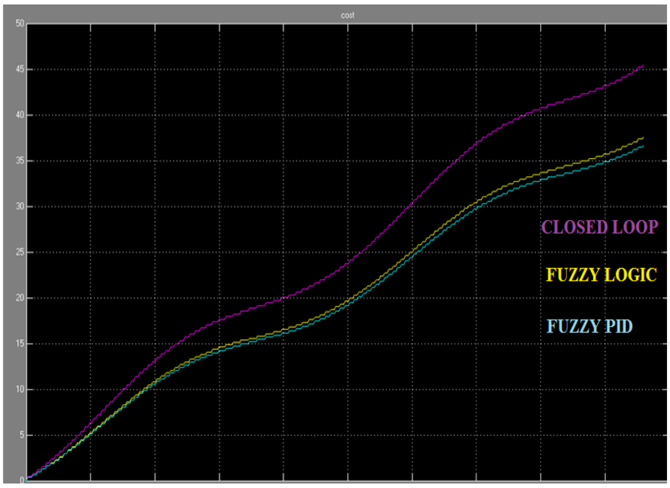

Fig. 8. Response of PID and fuzzy controller and closed loop systems

IV. Conclusion

Thermal comfort or sensation (PMV) is considered to be acceptable if the value lies between -0.5 to + 0.5. In the experiment conducted using fuzzy logic and non-traditional optimization techniques the thermal sensation takes the value 0.129 and -0.5 respectively. Hence the thermal comfort of the office and residential buildings is found to be optimum. From the above we can conclude that the thermal sensation and indoor environmental quality is within the acceptable range. Experiments have been carried out by using three control methods. PMV response curves of every controller fluctuate due to 1 C increment of air-conditioner temperature commands. Therefore, it remains to develop methods and devices to maintain PMV near 0 and smooth responses while saving energy. Thus by implementing the present control method can maintain thermal comfort and saves 30% more energy than the conventional method. For accurate estimation, the clothing insulation can be determined by measurement on heated mannequins, and the metabolic rates can be estimated from measuring CO and O2 in a person’s Exhaled air. Therefore, it is desired in future work to devise wearable or non-contact sensors to measure the values of metabolic rates and clothing insulation and improve the human factor measurement process. Also advanced controllers such as model predictive controller can be implemented for further optimization and to reduce power consumption. Also performance evaluation of model can be computed using artificial neural network or adaptive neuro fuzzy inference system for solving PMV models.

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