AN APPROACH TOWARDS DEVELOPMENT OF PMV BASED THERMAL COMFORT SMART SENSOR

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Abstract

ASHRAE 55-2004 and ISO 7730 standards failed to predict actual comfort level and lead to oversize design of HVAC system. So proper thermal environment monitoring is an important subject to have right size of HVAC systems. A prototype thermal EM system has been developed. Thermal environment parameters such as: temperature, relative humidity, CO and CO_2 are measured by using the developed system. These data are used to calculate the thermal comfort index. The subjective judgments and the calculated PMV are compared with the results. The results showed the possibility of using PMV based thermal comfort smart sensor.

Index terms*:* Predicted mean vote (PMV), Environment monitoring system (EMS), Indoor environment quality, Thermal comfort index.

I. INTRODUCTION

Thermal comfort and indoor air quality are important factors for energy efficient buildings design [1]. Indoor environment has become an important area of research because of its influence on human health and energy consumption profile [2-4]. The indoor environment affects indoor physical environment, subsequently health and quality of life of its occupants.

The problem has become acute in recent past because of the rapid un-sustainable growth in building sector. This is primarily due to changes in lifestyles, increased dependence on artificial energy and also health related issues [5-7].

Achieving comfort is the result of combination of various environment conditions, such as air quality, air temperature, relative humidity, mean radiant temperature, air velocity, illumination, sound etc. [7]. A widely accepted definition of thermal comfort is that '*it is a state of mind that expresses satisfaction with the thermal environment*' (ASHRAE 55-

2004) [8]. Across the world, research on indoor thermal environment monitoring is gaining importance. A recent study has put forth that 30 to 40% of total natural resources are oppressed by the buildings and almost 50% of energy resources are used in accustomed buildings in industrialized countries [2, 3, 5]. ASHRAE 55-2004 and ISO 7730 standard are widely used for indoor thermal environment assessment. However, it has been observed that these standards futile to envisage actual comfort level and lead to enormous design of HVAC system [4, 9, 10]. This intern leads to high energy consumption. Henceforth, proper monitoring of indoor thermal environment has become the need of time and also consequently has an enormous potential in energy savings [11, 12]. The major contaminants of indoor environment pollution include carbon monoxide and carbon dioxide. In real cases indoor air can be up to 10 times more polluted than outdoor air [13, 14]. Although healthy people can tolerate CO_2 level up to 10,000 ppm without serious health effects [15] and a tolerable level of CO_2 should be kept below 1000 ppm [16]. CO levels in laboratory without gas stoves vary from 0.5 to 5 ppm. However, healthy people can tolerate a CO level up to 10 ppm without serious health effects and a tolerable level of CO is below 6 ppm [17]. Relative humidity is unswervingly associated to temperature (warm air can hold more moisture than cool air) and the comfortable range of the relative humidity is 40 to 70% [18].

Table 1 Specifications of the sensors used for the monitoring systems [26]

Manufacturer	Type of material	Measured gas	Range	Model number
Figaro gas sensors	Semiconductor SnO_2	CO	30 to 1000 (ppm)	TGS2442
Figaro gas sensors	Solid Electrolyte (Electrochemical)	CO_2	Ambient to 4000 (ppm)	TGS4161
National Semiconductor	Resistive type Semiconductor	Temperature	-40 to110 (^{0}C)	LM35CAZ
Honeywell	Capacitive sensing material	Humidity	0 to 100 (% RH)	HIH 4000

In this paper, it has been tried to develop a thermal comfort smart sensor using a DSP processor (TMS320C6455). The acquired data from the monitoring system are used to calculate the PMV value. The output of the monitoring system is compared with the subjective responses and calculated PMV value. It has been found that the output of monitoring system is overestimate as compared to subjective responses collected during the experiments. However, this clearly put forth the possibility of using thermal comfort smart sensor.

II. THERMAL COMFORT INDEX

The predicted mean vote (PMV) is a well recognized thermal comfort index and is used for measuring comfort levels inside a conditioned space [7, 8]. In case of built environment, occupants always try to achieve a thermally comfortable environment [19]. Due to the increasing expectation of the occupants from the indoor environment, the comfort standards have become more and more stringent. This has lowered the tolerance limit of occupants who live in the conditioned space and has tremendously increased the running energy cost of the buildings [9]. There is a huge potential for energy saving, if real time assessment of the indoor environment has been done. So, it has been attempted to measure the PMV in real time using major environmental variables (temperature and relative humidity) and indoor air pollutants CO_2 and CO through a thermal comfort smart sensor. These values are different for different people corresponding to the thermal environment. PMV index can be determined when the metabolic rate and the clothing label are estimated and the environmental parameters air temperature and relative humidity are measured [6]. The PMV is calculated by the followings relations:

$$\begin{aligned} PMV = {} & \left(0.303e^{-0.036M} + 0.028\right)\{(M-W) - 3.05\times10^{-3}\left[5733 - 6.99(M-W)P_a\right] \\ & - 0.42\left[(M-W) - 58.15\right] - 1.7\times10^{-5}M\left(5867 - P_a\right) - 0.0014M\left(34 - t_a\right) \\ & - 3.96\times10^{-8}F_{cl}\left[(t_{cl}+273)^4 - (t_{mr}+273)^4\right] - F_{cl}h_c\left(t_{cl} - t_a\right)\ \} \end{aligned} \tag{1}$$

where

$$t_{cl} = 35.7 - 0.028(M-W) - I_{cl}\{3.96\times10^{-8}F_{cl}\left[(t_{cl}+273)^4 - (t_{mr}+273)^4\right] - F_{cl}h_c(t_{cl} - t_a)\ \} \tag{2}$$

$$h_c = \begin{bmatrix} 2.38(t_{cl}-t_a)^{0.25}\ for 2.38(t_{cl}-t_a)^{0.25} > 12.1(v_{ar})^{1/2} \\ 12.1(v_{ar})^{1/2}\ for 2.38(t_{cl}-t_a)^{0.25} < 12.1(v_{ar})^{1/2} \end{bmatrix} \tag{3}$$

$$F_{cl} = \begin{bmatrix} 1.00 + 1.290 \times I_{cl}\, for I_{cl} < 0.078 m^{2o} CW^{-1} \\ 1.05 + 0.645 \times I_{cl}\, for I_{cl} > 0.078 m^{2o} CW^{-1} \end{bmatrix} \tag{4}$$

$$V_{ar} = v_a + 0.005\left(M / A_{DU} - 58.15\right) \tag{5}$$

Where-
t_a- Air temperature (^{0}C), t_{mr} - Mean radiant temperature (^{0}C), v_{ar} - Relative air velocity with respect to human body (m/s), p_a - Partial water vapor pressure (N/m^2), t_{cl} - Surface temperature of clothing (^{0}C), h_c - Convective heat transfer coffecient (w/m^2 - ^{0}C), I_{cl} - Thermal resistance of clothing (clo), F_{cl} - Ratio of man surface area while clothed to that of nude (dimension less), A_{DU} - Dubious area (m^2), V_a - Air velocity (m/s), M -Metabolic rate (met), W - External work (w/m^2)

The PMV index is derived for steady state conditions but can be applied with good approximation for minor fluctuations of one or more of the variables [20]. However, the influence of humidity on thermal sensation is small at moderate temperature close to comfort and may be neglected while determining the PMV value.

III. SENSORS

A sensor is a device that measures a physical quantity and converts it into a signal [21]. In this study, temperature, relative humidity, CO and CO_2 sensors are used. A gas sensor detects particular gas molecules and produces an electrical signal whose magnitude is proportional to the concentration of the gas [22]. No single type of gas sensor is 100% selective to a single gas [23]. The semiconductor gas sensors, capable of detecting more than 150 different gases, are being used to monitor the target gas concentrations [24]. Gas sensors works on the principle of change in resistance of n-type and p-type semiconductor in oxidizing and reducing environment [25]. Table 1 represent the specifications of the different sensors that have been used for the development of environment monitoring system [26]. These sensors are selected because all produced strong signal for the selected variable, especially at high gas concentrations with adequate sensitivity. These sensors also have a fast response time, high stability, long life, low cost, low dependency on humidity, low power consumption and compact size [25].

The conductivity of a sensing element, which is formed by the metal-oxide semiconductor material changes according to gas concentration. The relationship between output voltage and gas concentration (ppm) is [27];

$$c = [(\frac{(V_C R_L / V_{OUT}) - R_L}{R_0} - 1)\frac{1}{K}]^2 \tag{6}$$

Where - R_0- Electrical resistance of sensor at zero ppm (Ω) , R_L - Load resistance (KΩ), V_{OUT} - Output voltage (volt), V_C - Input voltage (volt), C - Gas concentration (ppm), K - Gas proportionality factor (dimension less)

National semiconductor’s LM 35CZ has been used for sensing the temperature. It is an integrated circuit sensor that is used to measure temperature with an electrical output proportional to the temperature (°C). The output voltage is converted to temperature (^{0}C) by this relation [26].

$$Temp.(°\mathrm{C}) = (V_{out} \times 100)/1°\mathrm{C} \tag{7}$$

The humidity sensor (HIH 4000) circuit develops a linear voltage vs. RH output that is ratio metric to the supply voltage. When the supply voltage varies, the sensor output voltage follows in the same proportion. It can operate between 4V to 5.8V supply voltage range. At 5V supply voltage and at room temperature, the output voltage ranges from 0.8 to 3.9V as the humidity varies from 0% to 100% (noncondensing). The output is an analog voltage proportional to the supply voltage. Consequently, converting it to relative humidity (RH) requires that both the supply and sensor output voltages (at 25°C) [26]

$$RH = \left(\frac{V_{out}}{V_{\mathrm{supply}}} - 0.16\right) / 0.0062 \tag{8}$$

IV. PROTOTYPE INDOOR ENVIRONMENT MONITORING SYSTEM

The real time indoor environment monitoring system has vast prospects in human thermal comfort assessment and energy conservation opportunities [28]. Tse *et al.* developed a real time measurement system for thermal comfort by using an open network topology. They used six smart sensors with networking capabilities to perform practical measurement of the real time PMV values inside an air conditioned environment considering temperature and relative humidity and comparing the result with standard PMV sensor [29]. Day *et al.* developed an ANN based temperature and humidity measurement [30]. In this work, it has been tried to measure the thermal comfort in unconditioned environment. This is important because in India, most of the buildings and houses are unconditioned and operates under free running mode. Thermal comfort status in these environment are evaluated by three procedures and compared viz. result from proposed thermal comfort smart sensor with thermal sensation votes and PMV calculated according to ISO 7730 calculation procedure. It is now well accepted fact that PMV fails to predict the actual comfort status in unconditioned indoor environments of free running buildings. So it is assumed that thermal sensation votes are true judgments of thermal votes. In this study, it has been also tried to incorporate the effects of the concentration level of CO and CO_2 with temperature and relative humidity to evaluate the thermal environment. Block diagram of the proposed system is presented in Figure 1. In the proposed system semiconductor based gas sensor, temperature sensor, and capacitive based humidity sensor are used in an array with DSP board. These sensors are considered because of quick response, ability to produce continuous measurements, low cost and low maintenance.

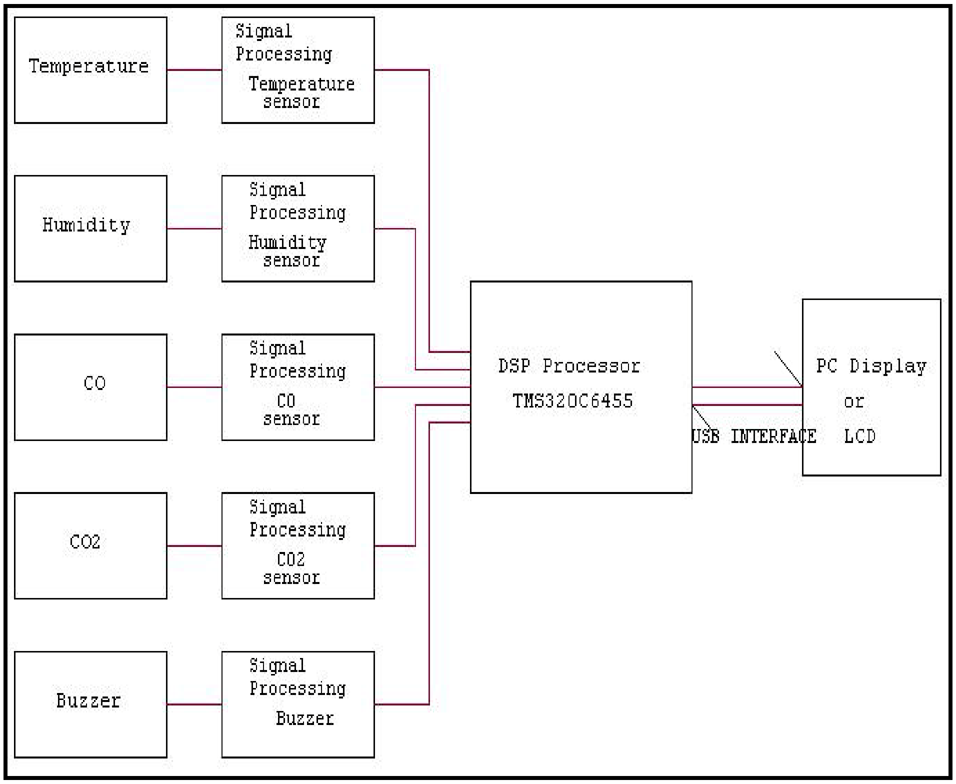

Figure 1 Block diagram of indoor Environment Monitoring System

The functioning of the DSP board is shown in Figure 2. An analog multiplexer, filter and signal transformer for level shifting are included on the DSP board. These sensors give output in analog form. The analog signals are amplified and fed to analog multiplexer. The output of the multiplexer is then fed to analog to digital converter (ADC) to get the output in digital form. The output of ADC is stored in the DSP board memory. Since these signals contains noise. So for further processing like the removal of noise, amplification and analysis of the recorded signals are done by feeding these signals to digital signal processor. For real time processing, the data collected by temperature, humidity and gas (CO and CO_2) sensor are processed according to above mentioned procedure and the resultant PMV value is displayed on LCD or monitor. A photograph of the PMV based thermal comfort smart sensor is shown in figure 3.

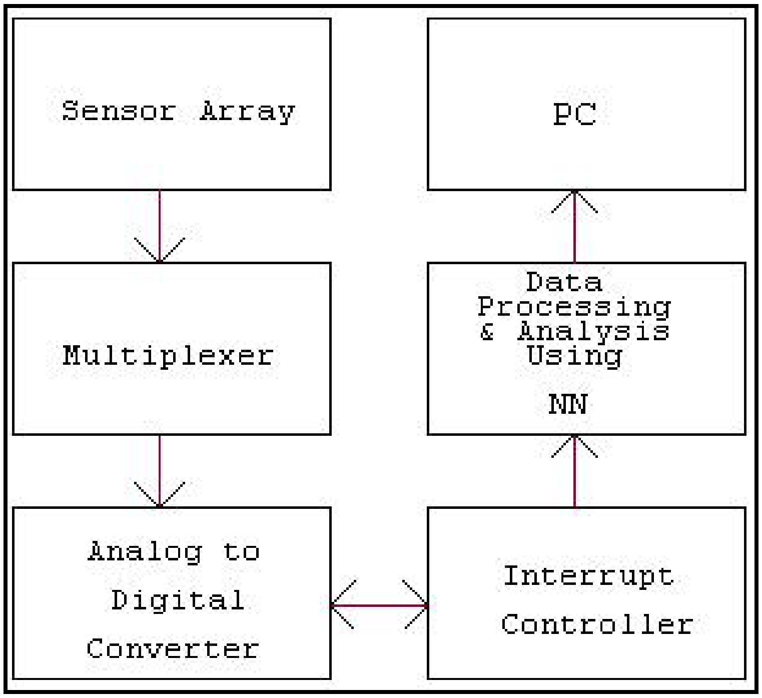

Figure 2 Functioning of the DSP Board

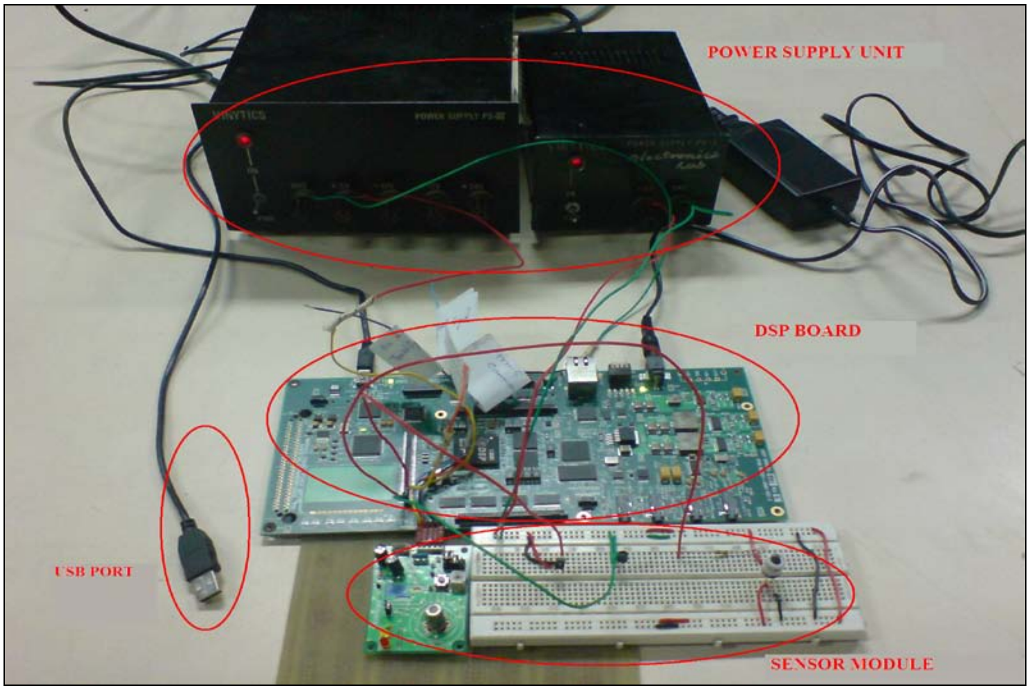

Figure 3 Developed PMV based thermal comfort monitoring system

V. METHODOLOGY OF THE STUDY

This study tried to investigate the thermal comfort and indoor air quality of Electronics laboratory, IDDC, IIT Delhi by means of both objective and subjective approach. The study was performed during the pre-summer period in the month of April 2009. The mean outdoor temperature and relative humidity are 29°C and 40% respectively during this period. Model of the laboratory where the study was carried out, has been made in TRNSYS software. Simulation of the model is carried out to compare the temperature fluctuation and profile for the month of April 2009. Two zones were made because of the orientation of the laboratory. In zone 2 of the laboratory experiments related to subjective and objective measurements were carried out. For zone 2, the PMV values are also plotted for comparative study. Table 2 represents the thermo- physical properties of the building construction materials used as input for modeling of the laboratory. Figure 4 represent the CAD drawing of the laboratory.

Table 2 Thermo-physical properties of building material

Layer	Arrangement/ thickness (cm)	Thermal conductivity (KJ/m-K)	Density (Kg/m^3)	Specific heat (KJ/Kg-K)
External wall	Outside plaster (2)	2.6	1762	0.84
	Brick (35)	3.0	1820	0.88
	Inside plaster (2)	2.6	1762	0.84
Internal wall	Outside plaster (1.5)	2.6	1762	0.90
	Brick (23)	3.0	1820	0.90
	Inside plaster (1.5)	2.6	1762	0.84
Roof	Outside plaster (2)	2.6	1762	0.84
	Brick (11)	3.0	1820	0.88
	Inside plaster (2)	2.6	1762	0.84
Falls ceiling	Wood (2.5)	0.7	900	2

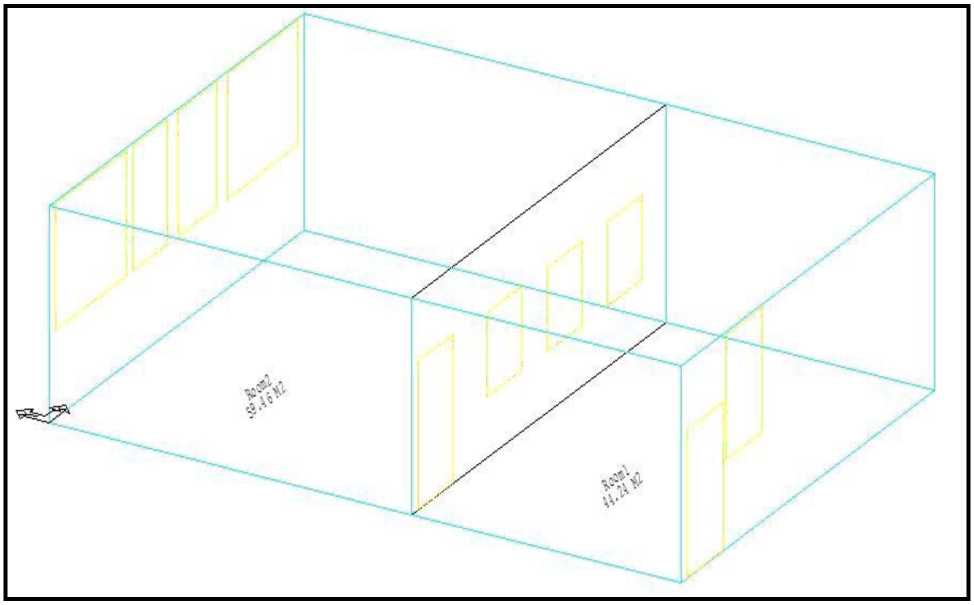

Figure 4 3D drawing of the laboratory

a. Subjective approach

It is defined as the judgment of the habitats about the acuity of the thermal comfort in terms of acceptability and preference of colder or warmer environments. It was also tried to access the students and staff observation on indoor air quality (IAQ) and investigate how people, perhaps with health problems, react to the existing indoor environment. Questionnaires were used to investigate the thermal comfort and indoor air quality perception. The questionnaire was specifically prepared for the assessment of thermal comfort and indoor air quality of the laboratory. The questionnaires was divided into three section concerning, general information, thermal comfort and indoor air quality. Total 70 graduate students, 2 staff and 3 research student use to visit the laboratory per week. Survey was conducted in between 13.00 hours and 15.00 hours during laboratory experiment timings. Every time not more than 20 students were present and doing experiments in the laboratory. Since, these were electronics based experiments students sit on the chair and perform the experiments. Very rarely they move around, so it is assumed that the metabolic rate is 1.2met (as per ASHRAE Standard 55, ISO 7730, the metabolic rate allocated to subject sitting on the chair doing mild work). Each time 20 questionnaires were distributed to the students present during the laboratory timings to conduct these experiments and were also asked to fill it and also register their thermal sensation and indoor air quality and randomly 5 questionnaires were selected for carrying-out analysis. This process was continue till all the 70 graduate students, 2 staff and 3 research students were covered through this questionnaires. Out of 75 subjects, 72 were male and 3 were female. Table 3 represents comfort survey parameters.

The study was conducted during the month of April 2009. Since in April, the summer starts, so people wear light clothing. During the survey, the respondents were asked to vote on seven point ASHRAE thermal sensation scale about their perception regarding the existing thermal environment. On the thermal sensation scale -3 stands for cold, zero for neutral and +3 stands for hot thermal condition. For indoor air quality assessment, subjects were provided with to point scale to register their vote for acceptable and unacceptable indoor air quality. Corresponding temperature (°C), relative humidity (%) and level of CO and CO_2 concentration were recorded simultaneously with respective votes. During the survey, all the respondents were interacted extensively. Interaction with the respondents also helped us in recording adaptive opportunities to make them comfortable in the indoor environment.

Table 3 Comfort survey parameters

Clothing level (clo)		0.3
Metabolic rate (met)		1.2
Number of subjects		75
Location		Electronics Laboratory, IDDC, IIT Delhi
Survey time		April 2009
Respondent age (numbers)	<20 years	16
	>20-40 years	57
	>40 years	2
Respondent gender (numbers)	Male	72
	Female	3

b. Objective approach

The thermal comfort index and indoor air quality were analyzed by means of field measurement techniques. The thermal comfort parameters such as; air temperature, relative humidity and concentration level of CO and CO_2 gases in indoor air are measured at the height of 1.2 meters above the floor. The environmental parameters and concentration level of CO and CO_2 gases in indoor air are monitored for 24 hours for the whole month of April at an interval of 10 minutes by using portable environment monitoring system with data loggers. The recorded data were evaluated for thermal comfort index according to International Standard ISO 7730.

VI. MEASUREMENT ERROR

The thermal comfort index is based on the four physical and two subjective measurements. In this study, it has been tried to incorporate the indoor air quality with thermal comfort index in predicting the thermal comfort in indoor environment. To minimize the measurement error, clothing level and activity level are assumed from the data base available in ISO 7730. In the field measurements, it is more difficult to accurately measure physical and subjective variables. In the following sections, errors related to physical variable measurements, clothing and activity level are discussed.

a. Physical Variable

The reality of the two physical inputs to the PMV model and air pollution contents depends on the system for collection of data and to the measurement strategy adopted. The various sources of errors of the prototype indoor environment monitoring system occur from the large noise exists in: (i) sensor output (because the sensors are very sensitive to environmental parameter) (ii) the base line of sensors shift with time (iii) sources of error signal due to current overload circuit (iv) signal quantization error (v) when the output digital to analog converter resolution is less than the internal resolution of the DSP, its also adds a certain amount of noise to the output signal and (vi) discretization process in the implementation of a digital filter. A DSP system can easily adapt to some change in environmental variables and used in noise cancellation of adaptive signal processing. Adaptive systems are usually operates in a real time environment with stringent computational complexity, storage requirement and parameter variations due to the environment changes.

b. Clothing insulation

Clothing insulation measurement is a time consuming and a detailed process usually done in laboratory. For survey and field study, it is advisable to assume these values using table provided in ASHRAE 55-2004 and ISO 7730 standards. Researchers assume that the clothing value for the occupant based on season, climate and geographic region of the study. Clothing insulation has a good agreement with occupant heat balance to environment during sedentary activities (metabolic activity ranges 1.0 to 1.9). The most appropriate value for metabolic activity is 1.2 to get good result for PMV based calculation. Havenith *et al.* concluded that air movements around the human body has affect on clothing insulation [20]. Clothing insulation value given in ISO 9920 over estimates the actual insulation and do not fully reflects the effects of body posture, clothing material and dynamic heat transfer over the body. The clothing level today, in most of the thermal comfort study is still roughly estimated and these estimates fail to reflect the difference between people change in clothing and social and cultural constraints on clothing preferences. The importance of clothing value in PMV calculations is a source of concern because of its contribution to the discrepancies between predicted and actual thermal sensation. PMV analysis provides best results in predicting neutral temperatures for clothing insulation level in the range of 0.3 to 1.2.

c. Activity level

Activity level is one of the least well described parameters in PMV calculations. Activity level has a strong influence on human thermal sensation, comfort and indoor temperature preferences. Current database provide the information for an average person, so it fails to consider the differences between people and context and many times underestimates the actual *met* value. As *met* rate increases, activity of the person increases resulting change in relative air velocity between body surface and surroundings, change in body surface area exposed to air and change in evaporation rate from the exposed body surface area.

These all parameters ultimately affect the thermal sensation. Goto *et al.* suggested that subjects took around fifteen minutes to return to pre-activity level of thermal sensation [18]. So it is advised, that each subject must be allowed to be in particular *met* for at least 20 minutes before recording thermal sensation vote. Humphreys & Nicol, using ASHRAE RP-844 data base, showed that the PMV model provides best results for activity below 1.4 [10].

VII. RESULTS AND DISCUSSIONS

The various results obtained towards the development of PMV based thermal comfort smart sensor for indoor thermal environment assessment are presented in this section. Figure 4 represents the 3D CAD drawing of laboratory with floor area of each room. Room 2 is defined as zone 2. In zone 2 all the experimental work related to subjective and objective measurements were carried out. Temperature data is recorded at five different positions by placing temperature sensor at body height (1.2 meter from floor). Similarly humidity sensors were also placed at body height at five positions. Data recorded at the interval of 10 minutes for the entire month of April of the year 2009. Figure 5 represents the temperature profile at different position of zone 2; it is observed that the temperatures varies from 28°C to 37°C representing the swing of 9°C. Figure 6 represents the relative humidity profiles, it is obtained that the relative humidity also varies from 23% to 53%. Similarly CO_2 and CO concentrations in zone 2 are also measured for the entire month at an interval of 10 minutes. Figure 7 represents the concentration level of CO_2 and CO in zone 2. From this profile, it is observed that CO concentration remains all most constant throughout the month. This is because no gas stoves were used during the laboratory experiments. However, there is a fluctuation in CO_2 level. The CO_2 concentration varies from 600 ppm to 420 ppm on working days and from 420 ppm to 425 ppm on non-working days. On working days the concentration of CO_2 rises to maximum during 13.00 hours to 15.00 hours. In this time, the lab is occupied by 25 persons. The concentration of CO_2 decreases to minimum at 17.00 hours and rest of the time the concentration of CO_2 remains almost constant. Also CO_2 concentration and average temperature of zone 2 represents a weak correlation.

To validate the temperature profile, model of the laboratory is generated in TRNSYS 15.1. Thermo-physical properties of building materials listed in Table 2 are used as input for this analysis. The simulation of the model is carried out for the month of April 2009 by applying weather conditions in TMY (Typical Metrological Year) format. Figure 8 represents the simulation plot for the month under condition infiltration 1ACH (air change per hour) and ventilation 5ACH. From the simulation plot, it is observed that the maximum temperature in zone 2 is 39°C and minimum temperature is around 22°C. So there is a temperature swing of 17°C at ventilation 5ACH. At reducing ventilation rate, the minimum temperature rises to 26°C or temperature swing comes down from 17°C to 13°C. This TRNSYS model results are in good agreement with the experimental data.

During the subjective measurement each respondent is asked to fill the questionnaires followed by interaction with the respondent. This interaction helps us to record the preferences and expectation about the thermal environment leaving to behavioral adaptation. Before recording thermal sensation vote, the subject was advised to be in the same environment and to maintain the same activity level for around 20 minutes. This is done to maintain the uniformity and to minimize the error. The subjective responses are plotted in Figure 9 and 10. Figure 9 represents the acceptability of the thermal environment that 68% subjects feel '*hot*', 13.33% feel '*warm*', and 18.66% feel '*slightly warm*'. Figure 10 represents the acceptability for the indoor air quality in the laboratory, 53.33% of the users feel '*normal*', 26.66% feel '*bad*', 13.33% feel '*good*' and 6.66% feel '*very bad*'. Temperature and relative humidity are measured simultaneously at the time of voting. These measurements are done at three different heights (0.5m, 0.8m and 1.2m from the floor). Average of these three temperature and humidity values are used to calculate the PMV values. The clothing level and metabolic level values are used according to ISO7730.

Three PMV values for same environmental conditions are calculated by three different techniques. One by subjective response method on ASHRAE 7 point sensation scale, second by mathematically calculating according to ISO7730 calculation procedure and the third one PMV based thermal comfort smart sensor. All these the three values for 75 subjects plotted in Figure 11. From the figure 11, it is observed that the PMV values from the smart sensor and the value calculated by using ISO7730 calculation procedure are very close but these two values deviate from PMV values calculated from subjective responses. This happens mainly due to two reasons (i) ISO7730 PMV calculation procedure does not takes into account the adaptive opportunity available to the subjects and (ii) ISO 7730 standard is best suited for conditioned environment, but here the measurement are carried out in unconditioned indoor environment. However, as it is assumed that the thermal sensation vote recorded during subjective measurements are more close to reality, so our proposed PMV based thermal comfort smart sensors must also represents the readings close to PMV values calculate by subjective measurements.

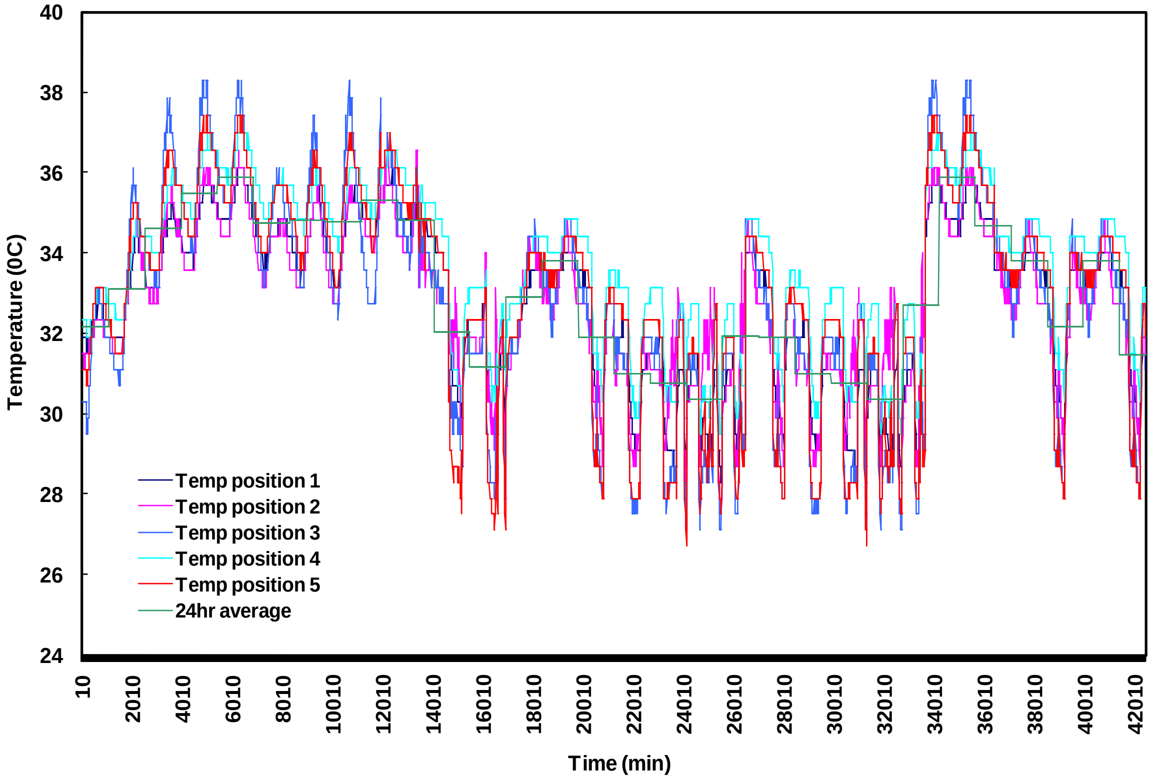

Figure 5 Temperature profile at different locations at Zone 2

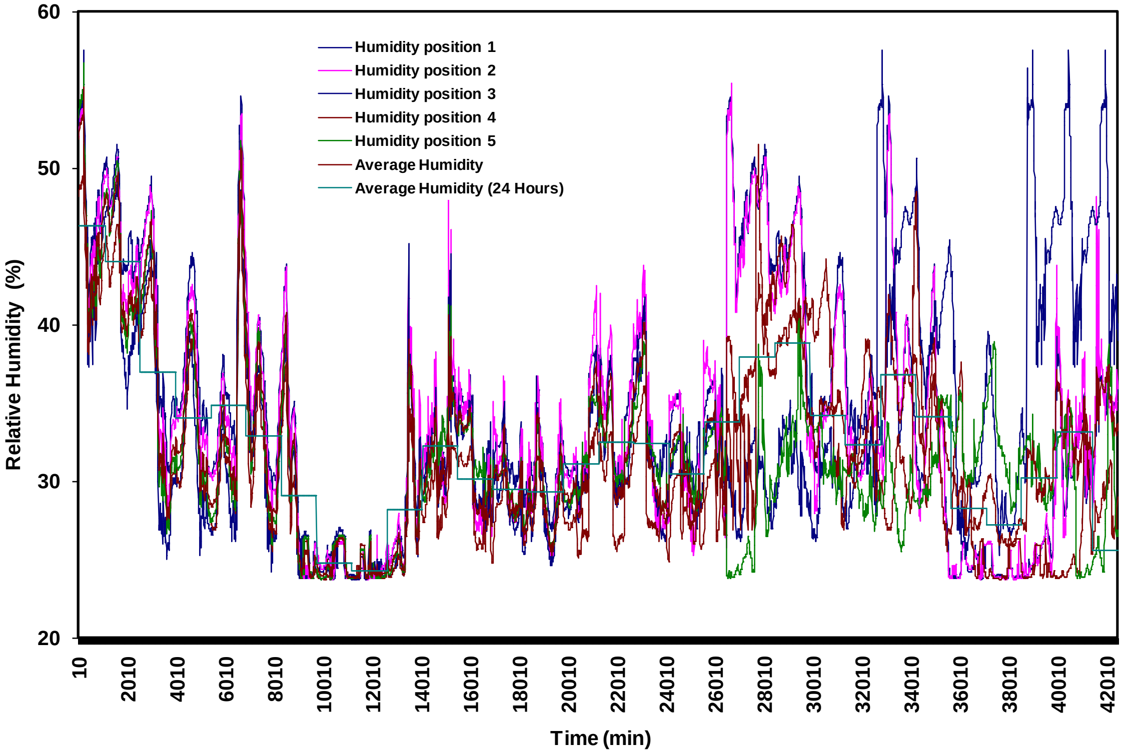

Figure 6 Humidity profile at different locations at Zone 2

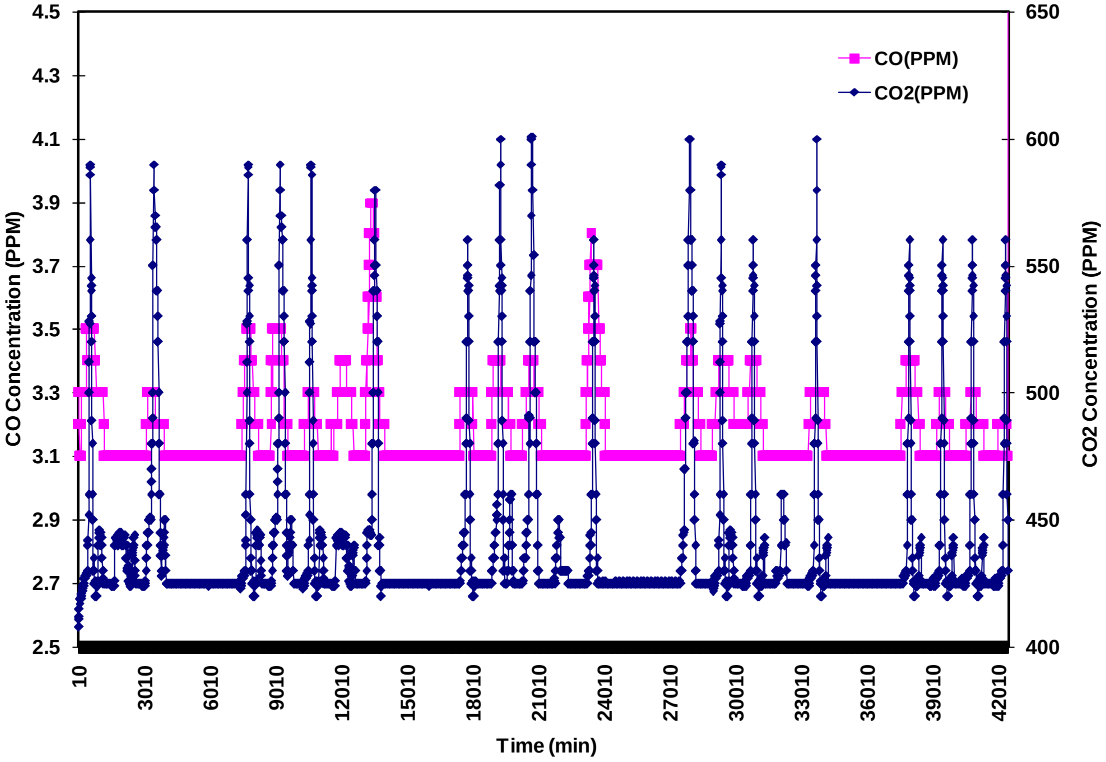

Figure 7 CO and CO_2 profiles at Zone 2

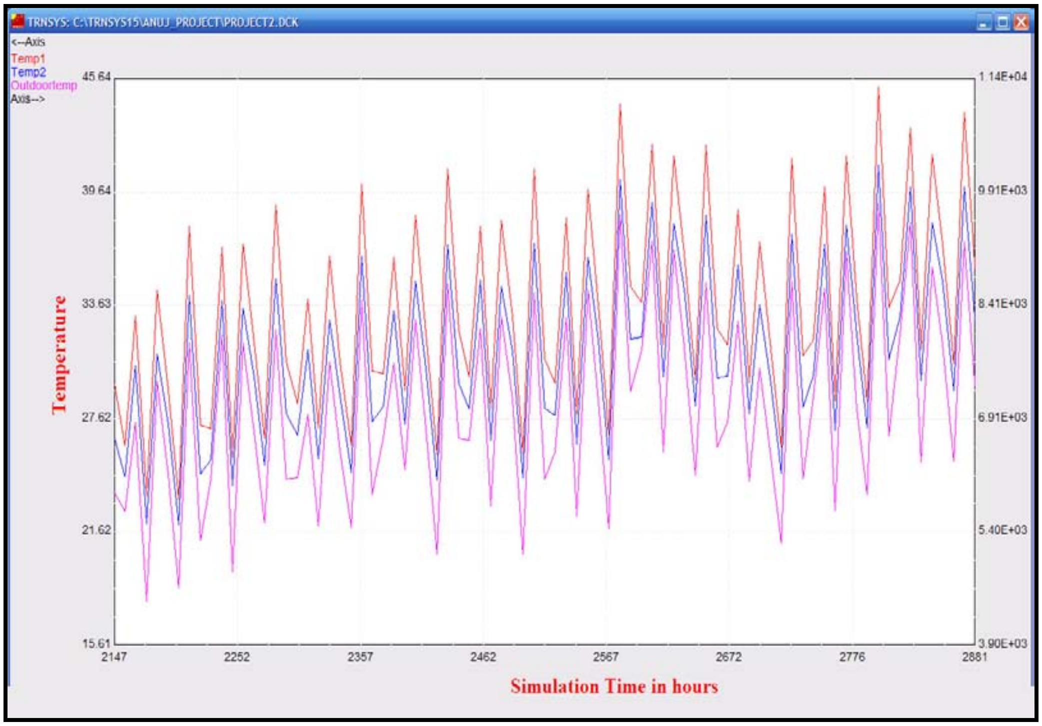

Figure 8 Temperature profile in pre-summer from TRNSYS simulation

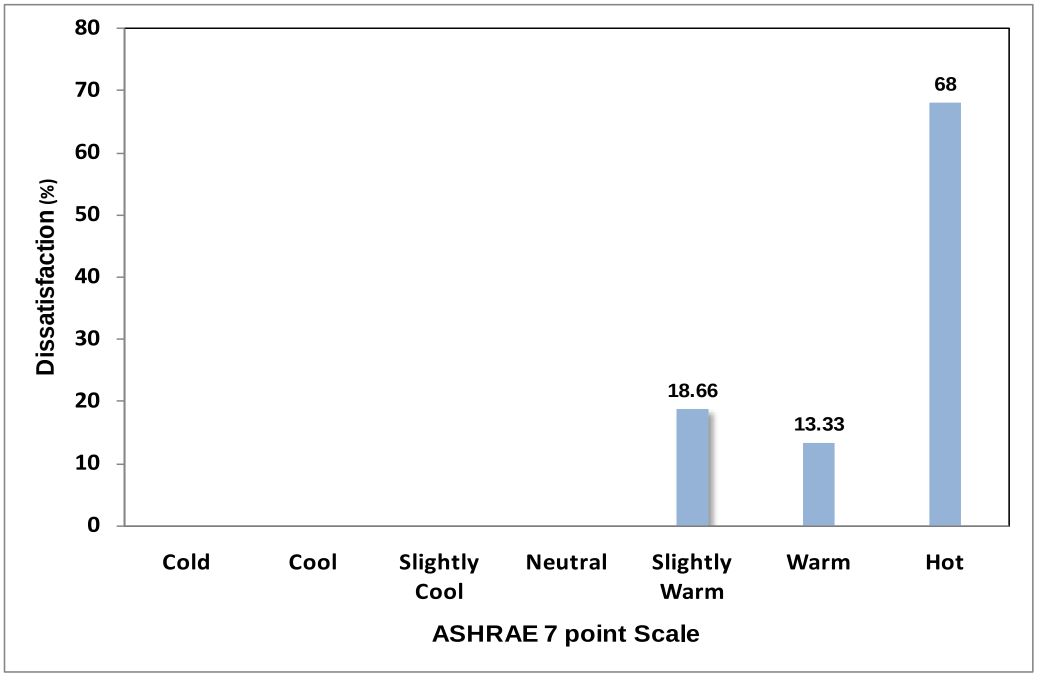

Figure 9 Subjective judgments about acceptability of the thermal environment

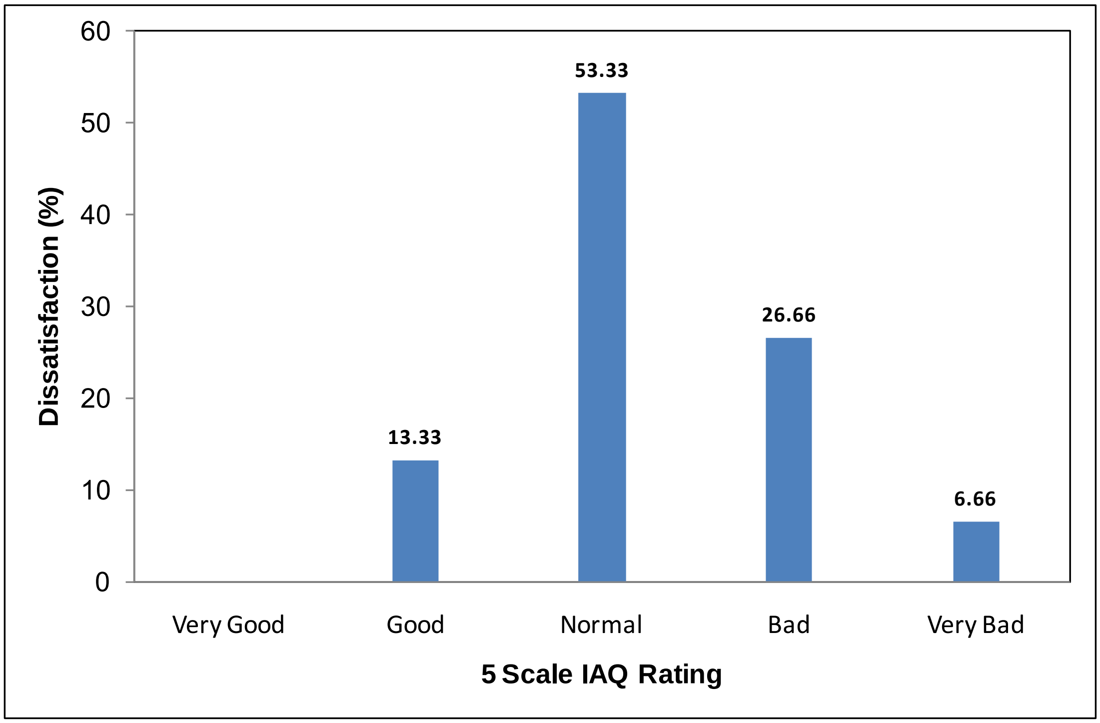

Figure 10 Subjective judgments about the acceptability of the IAQ

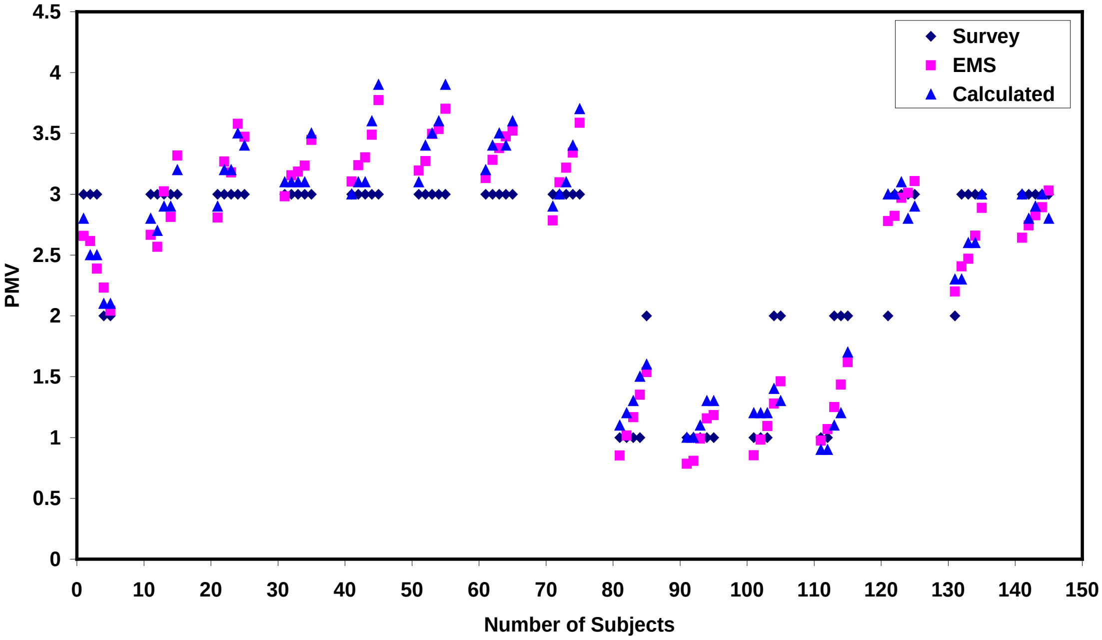

Figure 11 Comparative PMV values from three different methods

VIII. CONCLUSIONS

Thermal comfort in built environment is maintained by regulating temperature of indoor air at pre-determined value which may not be necessary to make indoor environment comfortable with respect to occupant. Without proper determination of the desired indoor air condition to HVAC system, it may not be feasible to provide occupants with thermal comfort and acceptable air quality simultaneously. This makes HVAC system highly energy intensive since thermal comfort conditions for the occupant is dynamic in nature and is influenced by outdoor conditions. So it has become necessary to do real time assessment for comfort conditions for energy savings. To address this issue an approach towards development of PMV based thermal comfort smart sensor for indoor thermal environment assessment is proposed. Monitoring of four physical parameters, temperature, relative humidity, CO_2 and CO has done for one month using this monitoring unit. Selection of sensors were done based on adequate sensitivity, fast response time, high stability, long life, low cost, low dependency on humidity, low power consumption, and compact size. Calculation of PMV has done by three different methods viz. survey, using ISO 7730 calculation procedure and through the prototype monitoring system. Results shows that values calculated by ISO 7730 and proposed monitoring system are close but deviate to that of survey. This deviation is mainly due to adaptive nature of occupants, which is very difficult to define and derive mathematically. But this problem can be overcome by carrying out large experiments spreading over year and applying these data for the training of neural network. This work reveals the possibility of development of PMV based thermal comfort smart sensor.

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