World Applied Sciences Journal 21 (8): 1200-1206, 2013
ISSN 1818-4952
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DOI: 10.5829/idosi.wasj.2013.21.8.27

Empirical Validation of Simulation Software with Experimental Measurement of Self Shading Room in Term of Heat Gain

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Abstract: In order for using building simulation tools, validation of building simulation should be evaluated. Integrated Environmental Solution<Virtual Environment> (IES<VE>) is an environmental design tool which couples an intuitive 3-dimensional modeling interface with extensive performance analysis function covering different criteria such as day lighting, heat gain and energy. The validity of IES has been investigated by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and Chartered Institution of Building Services Engineers (CIBSE) in term of different criteria. The objective of this study is to test IES simulation software in self shading room in term of heat gain through comparison the simulation result with experimental measurement of office room in actual self shading building in Kuala Lumpur Malaysia. Comparative method was used to find out the differences between experimental measurement and simulation result in term of heat gain. Finding of this study reveals that the differences between simulation result and empirical measurement is not more than 10%, It can be concluded IES<VE> has enough validity to calculate the amount of heat gain in self shading rooms. Therefore IES<VE> can be used for developing the design of self shading buildings especially in pre-design stage of self shading office buildings.

Key words: Heat gain · Empirical Validation · IES(VE) · Dry Bulb Temperature · Pchycronmetric Chart

INTRODUCTION

Building performance can be accurately predicted using building energy simulation programs [1-2]. Integrated Environmental Solution (IES) is an environmental design tool which couples an intuitive 3- dimensional modeling interface with extensive performance analysis functions covering shading, thermal, lighting, energy, resource use and cost aspects. IES provide performance analysis which is simple, accurate, interactive and visually responsive [2]. IES has ability to assess thermal analysis through determining conduction, convection and radiation heat flows. It can estimate energy consumption. In order for using building simulation tools, Validation of building simulation programs should be evaluated.

Morbitzer (2003) stated data with closer assumption of reality can be recognized as a factor for evolution of simulation. the development of simulation tools has ability to predict energy use accurately [3]. The performance of a building performance simulation tool can be evaluated by three different types of validation. Empirical Validation is one way to test the building simulation software.

Empirical validation is about the comparison between calculated or simulated results and monitored data from a real building. There is always a level of uncertainty in the empirical studies but it can deal with any involvedness. The measurements that have to be done are time consuming and can be very expensive [4]. Empirical tests compare simulated data with experimental data for validation [5].

Advancement of building design tools was evaluated by Clarke [6]. Clarke (2012) developed tools based on calculation methods that were easy to apply but difficult to interpret [7]. The calculation process behind dynamic thermal simulation was clarified by Clarke (2012). Clarke (2001) states some equations must be solved to accurately represent results. Heat transfer has interrelated processes Therefore it is essential to apply concurrent solution techniques to keep accuracy [6].

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IES<VE> software can simulate numerous results for the energy flow and environmental conditions within a building. Beevor, 2010 validated the accuracy of the real world testing and of the ability of IES<VE> simulations to provide accurate building performance data [8].

IES (VE) is a system of integrated building analysis simulation tools. It has ability to determine heating and cooling loads and it can calculate energy consumption. IES (VE) provides a 3 dimensional form of the building and characteristics of building elements can be attached. ApacheSim is considered as the simulation engine. It is a dynamic thermal simulation tool which provides the mathematical modeling of the heat transfer processes. Simulations may be carried out in a variety of time steps.

Beevor (2010) proposed that IES can be used for estimating the energy performance of buildings. Beevor (2010) compared the result of experimental measurement and simulation in term of air temperature, solar heat gain and heating and cooling load and found out the accuracy of IES results [8].

Validation refers to the process of validating the results against a series of standard tests. This validation procedure can range from the simplistic procedures set out by Chartered Institution of Building Services Engineers (CIBSE) to verify that programs produce results within practice ranges. Such a procedure as set out by CIBSE may be used on steady state and dynamic procedures. However, dynamic calculation procedures, have complex calculation algorithms and require a more complex process of validation. A variety of validation exercises exist. Experimental measurement can be compared with mathematical results [9]. The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) and Building Environmental Performance Analysis Club (BEPAC) have experimental measurement methods for buildings [10].

Jan Hensen (2009) compared given models with simulated models. Jan Hensen (2009) revealed the validation of IES<VE> with BESTTEST [4].

The IES (VE) energy analysis software tool offers high accuracy and interoperability with Building Information Modeling (BIM) tools. IES has potential for integration different performance. Furthermore IES (VE) has the capability to store the thermal information about the building. IES (VE) calculates the heat gain calculations and cooling load calculations for a selected design day of the week and for a range of design months. IES (VE) includes thermal, solar, lighting, energy costs and heating/cooling load calculations [11].

The value /cost analysis function in IES (VE) assess the life cycle costs. Previous study concluded that IES (VE) is a better tool for performance analysis when compared with Green Building Simulation and Autodesk Ecotect Analysis tools [12]. Chinnayeluka (2011) compared simulation result of IES with measuring data using statistical tests such as normality and variance. In the case of the total energy values, the analysis concluded that there was no statistically significant difference in the mean values between simulation result and measuring data [11].

Validation is an important issue in thermal simulation program. IES (VE) carries out the most comprehensive analysis of thermal characteristics and air tightness; it offers 2 conduction solution methods and a range of internal and external convection coefficient options. IES (VE) demonstrate the best ability to model indoor climatic conditions. IES (VE) have the best ability to model natural lighting [13].

Crawley *et al*., 2008 investigated some parameters and stated that the best simulation program is IES (VE) for different criteria such as load calculation, HVAC system calculation, infiltration, ventilation and airflow calculation and results reporting [14].

In addition, IES (VE) also performs well in terms of reporting of environmental aspects and life cycle costing. widespread validation procedures against measured data have been carried out on IES (VE) [14-15].

IES is a complete and widespread simulation with integration of analysis. IES (VE) has been tested and verified by both ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) and CIBSE [16].

It has been demonstrated that the IES (VE) model is capable of making estimates and predictions to a reasonable level of accuracy for the purpose of examining design changes. It is unreasonable to expect any model to provide perfect predictions, but through the comparison of model predictions against real measurements, a reasonable level of confidence in the IES (VE) model estimates has been achieved [16].

The IES (VE) ASHRAE Loads method also performs heat loss and heat gain calculations according to the Heat Balance Method for one design day per month based on ASHRAE weather data. The IES results are depend on design day. Moreover for calculating the energy consumption, cooling load should be determined hourly [17].

Values for direct normal and diffuse radiation are readily available from IES (VE), so these were compared. Hourly Design-day results from IES (VE) for direct radiation were very similar to hand-calculated values. Weather data has direct and global radiation. The instantaneous solar gain is the total solar transmission (including direct beam, direct absorbed, diffuse beam, diffuse absorbed) into the space before the heat balance calculations are performed. IES (VE) report window heat gain which includes the outward flowing fraction due to convective and irradiative heat transfer [17].

IES has enough validity for calculating thermal analysis and humidity in spaces. The research outcome show that IES (VE) could perform accurately in nearly all the analyzed hour in the difference is not more than 10% to 20%. Therefore air temperature and humidity ratio can be obtained from IES simulation result as accurate data in pre design stage of buildings [18].

Attia and De Herde (2011) stated that IES APACHE Thermal Analysis has high accuracy and it has been validated by ASHRAE.

However validity of IES<VE> simulation tools was investigated by several methods by researchers. But validation of IES<VE> should be evaluated in term of heat gain for using in specific form of building (self shading) under climatic condition of Malaysia as a tropical region.

MATERIALS AND METHODS

Dry bulb temperature and humidity ratio were recorded in individual office room in Energy Commission Diamond Building then after 5 minute dry bulb temperature was recorded again in office room. Therefore the amount of heat flow into the air (W) can be calculated using the following equation.

$Q = \rho\alpha \, Vd(h2-h1) / dt$

Q is the heat flow

$\rho\alpha$ is the density of air

Vd is the air volume

h1 is the enthalpy of air at first time of dry bulb temperature measurement

h2 is the enthalpy of air at the second time of dry bulb temperature measurement

dt is the time differences between two measurement

In other hand the office room was simulated in IES<VE>. Dimensional properties, orientation and construction type of materials were set like the actual room. Simulation result reveals the amount of heat gain for the office room then the differences between the amounts of heat gains can be calculated to evaluate the validation of simulation result in term of heat gain.

RESULTS AND DISCUSSION

Experimental Measurement: An office room in Energy Commission Diamond building as self shading building was selected for measurement. This office is located in 6th floor of Energy Commission Diamond Building. The length, width and height of this office are 6650 mm, 5000 mm and 3600 mm respectively. The cill height is 900 mm and window height is 2150 mm. the orientation of window is East (N 10°) and window glass is low e-glass (Figure 1). Self shading strategy in energy Commission Diamond building reduced Overall Thermal Transfer Value by 41.37 W/m^2 [19]. In this study the amount of heat gain was calculated using an equation based on experimental measurement. Dry bulb temperature and humidity ratio were 23.8°C and 60% in office room in Energy Commission Diamond Building at 12 p.m. 60% Humidity ratio means 11 grams moisture per kilogram dry air when dry bulb temperature is 23.8°C. After 5 minute dry bulb temperature was 26.3°C in office room in Energy Commission Diamond Building. With this assumption that the humidity ratio 11 grams moisture per kilogram dry air is constant. Therefore the amount of heat flow into the office (W) can be calculated.

h_1 and h_2 are the enthalpy of air at time t_1 (first time of measurement) and t_2 (second time of measurement) which comprises of the sensible heat and latent heat. The enthalpy scale in psychrometric chart is located outside the main body of the psychrometric chart. To find the value of the enthalpy of the any given air, two parameters of air should be specified. Figure 2 shows how the value of enthalpy of air in different dry bulb temperature can be calculated. The enthalpy of air equal to 52.05 KJ/Kg. when dry bulb temperature is 23.8°C and humidity ratio is 11 gram moisture per kilogram air. The enthalpy of air equal to 54.60 KJ/Kg. when dry bulb temperature is 26.3°C and humidity ratio is 11 gram moisture per kilogram.

Furthermore Website (http://www.sugartech.co.za/psychro/index.php) is as a tool for psychrometric calculation. The website calculation demonstrates that the enthalpies of air are 52.05 KJ/Kg and 54.60 KJ/Kg when the air have 23.8°C and 26.3°C dry bulb temperature respectively. Concurrently humidity ratio for both conditions was considered constant with 11 gram moisture per kilogram dry air inside room (Figure 3 and 4).

Fig. 1: A view of office room in Energy Commission Diamond Building for experimental measurement

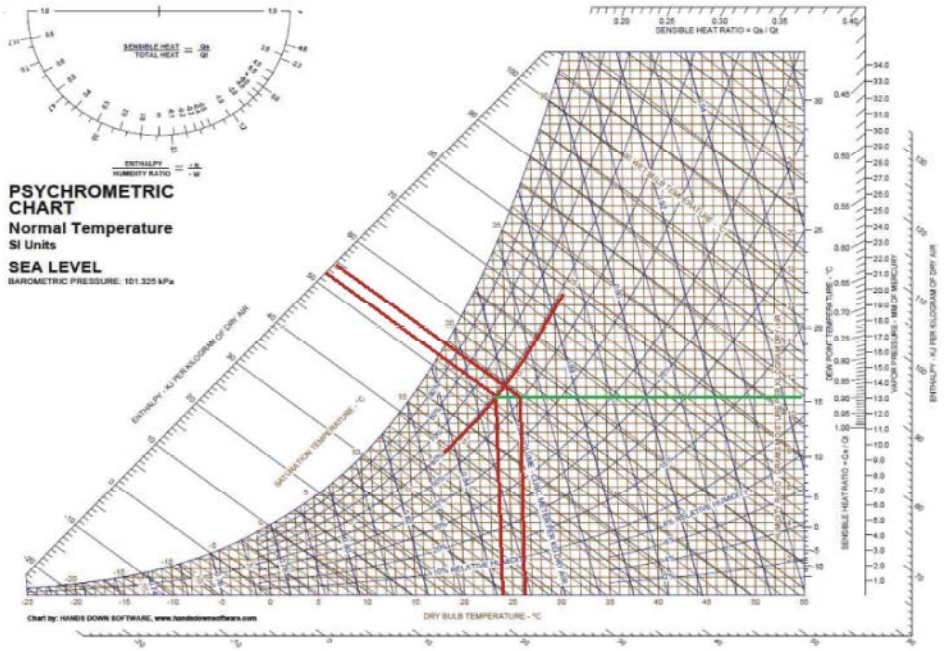

Fig. 2: Using Psychrometric chart to find out the enthalpies of air in different dry bulb temperature when humidity ratio is constant(11gr/Kg)

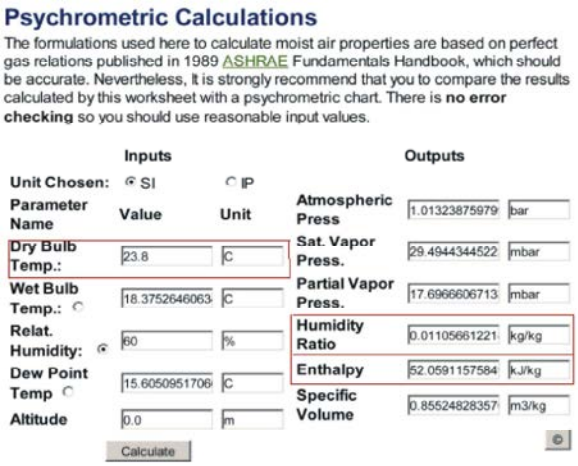

Fig. 3: Enthalpy calculation for Dry bulb temperature 23.8°C and and humidity ratio 11 Grams Moisture per Kg dry air (Psychrometric calculation website)

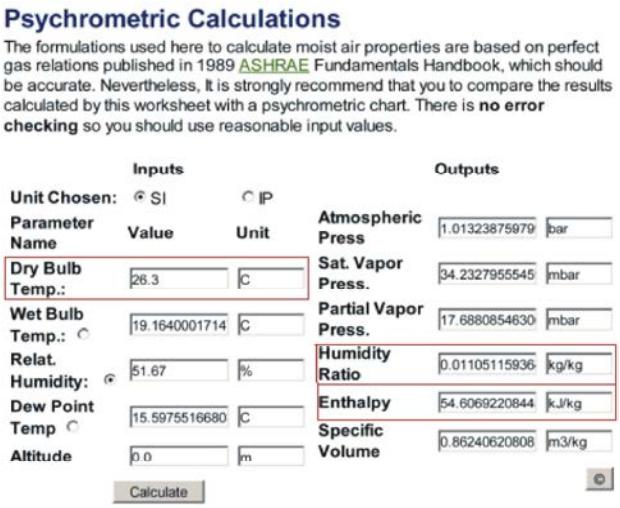

Fig. 4: Enthalpy calculation for Dry bulb temperature 26.3°C and humidity ratio 11 Grams Moisture per Kg dry air (Psychrometric calculation website)

When humidity ratio is considered constant with 11 grams moisture per kilogram dry air and dry bulb temperature is considered 26.3°C, the enthalpy of air is 54.60 KJ/Kg (Figure 4). Therefore the differences between enthalpies in two conditions with different dry bulb Temperature is 2.55 KJ/Kg. The internal volume of room No.1 is 135 m^3 and equal to air volume; In addition density of air is 1.2 Kg/m^3. Therefore the total heat gain can be calculated.

$$Q= \rho_{\alpha} V_d (h_2-h_1)/dt$$

$\rho_{\alpha} = 1.2\ Kg/m^3$
$V_d = 135\ m^3$
$h_1 = 52.05\ KJ/Kg$ based on Psychrometric chart when dry temperature=23.8°C and humidity ratio 11 g/kg
$h_2 = 54.60\ KJ/Kg$ based on Psychrometric chart when dry temperature=26.3°C and humidity ratio 11 g/kg
$dt = 300\ S$
$Q = 1377\ W$

Therefore the amount of heat gain is 1377 W in the office room in Energy Commission Diamond building at 12 p.m on 11th October.

Heat Gain Process in IES<VE>: Heat Gain in IES program performs based on heat gain calculations in CIBSE Guide A (1995, 1999, 2001, 2006). Apache Simulation is a dynamic thermal simulation program based on principles of mathematical modeling of the heat transfer processes taking place within and around a building. Apache Sim qualifies as a Dynamic Model in the CIBSE system.

Conduction, convection and radiation heat transfer processes for each element of the building elements are modeled in Apache Sim. The simulation results is based on real weather data and cover any times over a year.

The office room was modelled under Model It option as similar as actual room then the office room simulated with Apach option under Energy section of IES (VE) software. Then ApacheSim (Dynamic Simulation) was selected. Before running the simulation for a model weather data for Kuala Lumpure was selected. The specific time (12 p.m on 11th Octobor) should be selected, (Figure 5 and 6). The simulation result shows that the total heat gain through solar radiation and conduction is 1470 W at the exact time of simulation in the office room. The difference between heat gains is 93 W. This difference is less than 10% and is not significant. Therefore IES<VE> has enough validity for calculating the amount of heat gain in self shading room under climate condition of Malaysia.

Boevor (2010) proposed that IES<VE> have enough accuracy in result through comparison between experimental measurement and virtual environment. Furthermore Jan Hensen (2009) revealed the validation of IES<VE> with BESTTEST. Azhar (2008) indicated IES (VE) is a better tool for performance analysis compare to Green Building Simulation tools.

Chinnayeluka (2011) statistical methods for validation of IES such as normality test and variance. Chinnayeluka (2011) indicated the difference between IES result and measuring data is not significant.

IES (VE) has been tested and verified by both ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) and CIBSE [16].

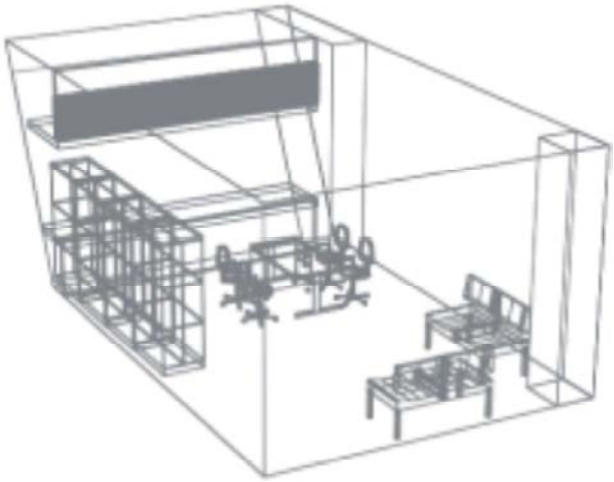

Fig. 5: Simulated room in Integrated Environmental Solution<Virtual Environment> (IES<VE>)

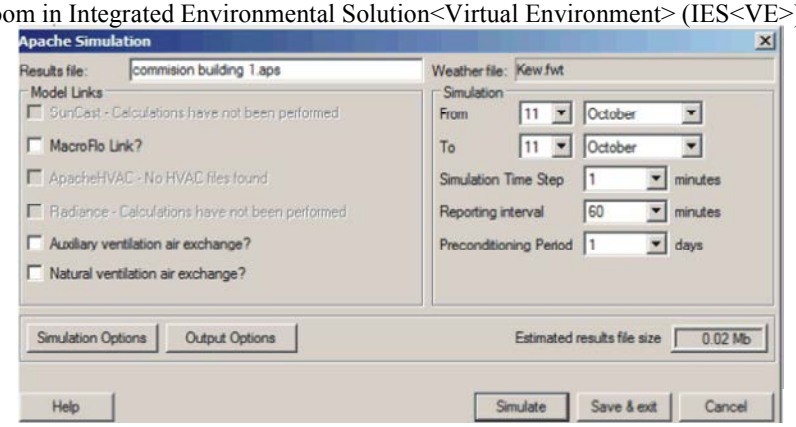

Fig. 6: Process of Heat gain analysis in simulation software

It has been demonstrated that the IES (VE) model is capable of making estimates and predictions to a reasonable level of accuracy for the purpose of examining design changes. It is unreasonable to expect any model to provide perfect predictions, but through the comparison of model predictions against real measurements, a reasonable level of confidence in the IES (VE) model estimates has been achieved [16].

The IES (VE) ASHRAE Loads method performs heat gain calculations according to the Heat Balance Method for one design day per month based on ASHRAE weather data [17].

Leng *et al*., (2012) proposed that IES has enough validity for analyzing thermal performance and relative humidity in buildings. Leng *et al*., (2012) stated the differences between simulation result in IES and experimental measurement is not more than 10% to 20% in term of air temperature and relative humidity. Finding of this research support strongly the result of current study that stated that the differences of IES simulation result and experimental measurement is not more than 10% in term of heat gain. Furthermore Attia and De Herde (2011) stated that IES APACHE Thermal Analysis has high accuracy and it has been validated by ASHRAE. Consequently finding of this study has been justified by the other researches and validation of IES can be approved for self shading office building in term of heat gain as well.

CONCLUSION

The amount of heat gain was calculated for an individual office room using experimental and simulation methods at the same date and time. Result of simulation shows the amount of heat gain is *1470 W* while the amount of heat gain derived from experimental measurement was 1377 W. Difference between simulation result and experimental result is not more than 10% and this differences can be ignored. Therefore it can be concluded that IES (VE) has enough validity for

determining the amount of heat gain in self shading rooms. Therefore IES<VE> can be used for developing self shading buildings especially in pre-design stage of office buildings.

REFERENCES

1. Clarke, J., M. Janak and P. Ruyssevelt, 1998. Assessing the overall performance of advanced glazing systems. Solar Energy, 63(4): 231-241.
2. Crawley, D.B., L.K. Lawrie, C.O. Pedersen, R.K. Strand, F.C. Winkelman, W.F. Buhl, Y.J. Huang, M.J. Witte, R.J. Henninger, D.E. Fisher, D. Shiery, Energy Plus: new, capable and linked, in Proceedings of eSim Building Simulation Conference: Montreal, Canada, pp: 244-251.
3. Morbitzer, C.A., 2003. Towards the integration of simulation into the building design process, University of Strathclyde.
4. Jan Hensen, I.R., M.L. Dipl, Ing. Marija Trcka, Daniel Costola and I.R. Pieter-Jan Hoes, Mohammad Mirsadeghi, Raha Sulaiman and Ing Wiebe Zoon, 2009. State of the art in Building Performance Simulation for Integrated Solution, Eindhoven University of Technolog: Eindhoven.
5. Lomas, K., *et al*., 1997. Empirical validation of building energy simulation programs. Energy and Buildings, 26(3): 253-275.
6. Clarke, J., 2001. Domain integration in building simulation. Energy and Buildings, 33(4): 303-308.
7. Clarke, J., 2012. Energy simulation in building design. Routledge.
8. Beevor, M., 2010. Smart Building Envelopes, University of Cambridge: london.
9. Bland, B., 1992. Conduction in dynamic thermal models: Analytical tests for validation. Building Services Engineering Research and Technology, 13(4): 197-208.
10. Rees, S.J., J. Spitler and D. Xiao, 2002. An analytical verification test suite for building fabric models in Whole Building Energy Simulation Programs.
11. Chinnayeluka, S.R., 2011. Performance Assessment of Innovative Framing Systems Through Building Information Modeling Based Energy Simulation, in The Department of Construction Management and Industrial Engineering. Osmania University: India.
12. Azhar, S., A. Nadeem, Y.N.K. Mok and H.Y.B. Leung, 2008. BIM: A new Paradigm for Visual Interactive Modeling and Simulation for Construction Projects, in First International conference on Construction in Developing Countries, Karachi.
13. Doyle, M.D., 2008. Investigation of dynamic and steady state calculation methodologies for determination of building energy performance in the context of the EPBD. Dublin Institute of Technology: Dublin.
14. Crawley, D.B., *et al*., 2008. Contrasting the capabilities of building energy performance simulation programs. Building and Environment, 43(4): 661-673.
15. Corrado, V. and E. Fabrizio, 2007. Assessment of building cooling energy need through a quasi-steady state model: Simplified correlation for gain-loss mismatch. Energy and Buildings, 39(5): 569-579.
16. Booth, A., 2009. Modelling and Simulation of Building Physics. Fourth-year undergraduate project in Group D.
17. Waddell, C., S. Kaserekar and A. Ten, 2010. Solar Gain and Cooling Load Comparison Using Energy Modeling Software.
18. Leng, P., *et al*., 2012. Investigation of Integrated Environmental Solutions-Virtual Environment Software Accuracy for Air Temperature and Relative Humidity of the Test Room Simulations, in International Annual Symposium on Sustainability Science and Management Terengganu, Malaysia.
19. Nikpour, M., *et al*., 2012. Heat Transfer Reduction Using Self Shading Strategy in Energy Commission Building in Malaysia. Journal of Applied Sciences, 12: 897-901.