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Relation between Room Temperature and WCPU Control Temperature for Office Building

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Abstract: The HVAC system uses the most energy in a building in Malaysia. An HVAC system takes into consideration the price at the time of use. Load shifting can only be anticipated immediately before usage since the interior temperature varies with time. As a result, the objective of this case study is to minimize operating time by changing the interior temperature limit during the expected peak period. One of the ancient office buildings in Pantai Timur, Malaysia, has been chosen for this study since it is fitted with an outdated HVAC system. The building does not have a mechanism in place to monitor the condition of the components or the supply rate of ventilation from the outset. In this research, the building, consists of 5 floors. Each floor is equipped with 2 WCPU except 1 WCPU for the 4th floor. Each floor has been supplied with a different horsepower compressor based on the area, number of departments and number of occupants for each floor. The relationship between indoor room temperature and WCPU temperature is influenced by a few factors. The climate change in Terengganu building has the greatest impact on indoor temperature. To find the best setting of thermal comfort for each department in this building, this paper aims to investigate the relation between room temperature and WCPU room temperature. This thermal comfort follows to the Department of Standards Malaysia (DOSM) in tropical climate condition.

Keywords: Climate change, HVAC system, Temperature setting

1. Introduction

This study establishes a conceptual foundation for the study's objectives by generating questions. It requires reviewing a wide range of publications, as well as referred academic journals, all of which are organized around significant themes. Malaysia is located at latitude 3.12°N and longitude 101.55°E, hence its climate is classified as equatorial, which means it is hot and humid throughout the year. People spend nearly 80% of their time indoors, in addition to the severe environmental challenge of global warming [1-3]. The indoor building environment contributes to the performance of the occupants in terms of health, comfort, and productivity [3]. The operation of heating, ventilation, and air conditioning (HVAC) is critical to indoor thermal comfort [4].

HVAC systems account for over 60% of a typical commercial building's total energy consumption. The HVAC system's energy-efficient design and optimization helped to drastically reduce energy usage and save money. Buildings in Malaysia consume 15% of total energy, and this figure is expected to rise at a rate of around 6% each year. Buildings in tropical areas, such as Malaysia, are exposed to sun radiation all year, increasing their cooling load [4-5]. The predicted mean vote (PMV) is a thermal comfort model developed by to predict occupants' thermal sensation in an indoor environment by accounting for the heat balance between actual heat flow from the human body in each environment and heat flow required to achieve optimum comfort during a specific activity [6-16].

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Understanding the history and current state of thermal comfort, as well as the implications for building energy use, is crucial. The purpose is not to conduct a comprehensive analysis or comparison of various thermal comfort models and research (such an analysis and comparison can be found in references [16]. The HVAC system does not usually come with an automated system in older buildings. A novel alteration to the HVAC system in buildings is the addition or upgrade of automation systems for old HVAC systems.

To assure the system's success regarding innovations, extensive study is required. As a result, the focus of this research is on the relationship between temperature data for WCPU and interior systems after the automation system is implemented to determine the appropriate temperature limit for the automation system. To discover the best recommended setting for the automation system, it's also necessary to identify the parameters that affect the indoor temperature. Most previous research efforts concentrated on locating physical defects in AHUs. VAV terminal unit faults and soft-faults in VAV-AHU systems are the subject of only a small percentage of studies. In fact, one AHU supports numerous VAV thermal zones, and more than 90% of building sensors and actuators are distributed to separate zones. This circumstance presents a significant potential for us to save energy and money by designing indoor climates that are tailored to each zone's occupancy and comfort preferences [17].

1.1 Malaysia Climate

Malaysian states have similar climate conditions. Subang Jaya was chosen to study the climate in Malaysia because it is situated at a latitude of n 3° 7° and a longitude of E 101° 33°, making it the geographic Centre of Peninsula Malaysia as well as the country's economic, social, and administrative hub. The climate in this country is hot and humid, with a diurnal temperature of around 16°C that varies from month to month [18]. March is the warmest month, with a high of 27.8°C, while December is the coldest, with a low of 25.9°C. Malaysia has an average of 6.2 hours of sunshine per year, ranging from 4.7 to 7.2 hours per day.

One of the most important concerns affecting humanity today is climate change. Climate change is now recognized as a societal and economic challenge, notably in the energy sector [18]. The six key drivers of renewable energy expansion around the world, particularly in Europe, are climate change and the need to cut greenhouse gas emissions. Despite being one of the most crucial systems for social and economic growth, energy systems typically fail to account for climate change consequences in their planning and operation [19]. Climate impact assessments on energy planning and operation must consider a larger range of scenarios and investigate the implications for individual energy sectors.

As a result of the significant increase in power demand for building air-conditioning because of global warming, primary energy demand for building cooling would rise, necessitating the usage of passive cooling technologies [20]. These systems rely on natural heat sinks that are inextricably related to local meteorological variables like temperature and humidity. Direct night ventilation, subsurface pipe systems, controlled thermal phase-shifting, and evaporative cooling are just a few of the methods used to activate and distribute available cooling resources through the building's ventilation system. Direct ventilation and evaporative cooling are the most employed of these systems due to their simplicity. Because they utilize natural heat sources and sinks, passive cooling systems can be considered renewable energy resources. Direct ventilation and evaporative cooling systems are the subject of this research.

2. Thermal Comfort in Building

Thermal comfort is a state of mind that transfers satisfaction to the thermal environment. According to this notion, thermal comfort pleasure is linked to the thermal environment around us. According to ASHRAE 55, thermal comfort is defined as the range of conditions in which 90% of sedentary or lightly active people find the environment thermally acceptable. ASHRAE 55 uses two theories of thermal comfort to analyses thermal conditions: the analytical model and the adaptive model. In most scenarios with air conditioning PPD, the PMV and PPD analytical models of thermal comfort should be used. Adaptive thermal comfort can be measured using outside climate conditions, ethnic characteristics, and people's adaptive behavior. These difficulties are described in length in several building regulations.

Thermal comfort field studies utilize objective and subjective questionnaires to evaluate thermal comfort levels. In past surveys, this research was carried out in accordance with ISO 7730 or ASHRAE 55 standard criteria. The investigations range in length from a few days to a year. Current comfort standards include provide design parameters for operative temperatures and comfort equations based on logical and adaptive thermal comfort models.

3. Temperature Setpoint in Building

According to a rising number of studies, how people use and operate building systems has a significant impact on energy use. Even in new or reconstructed energy efficient buildings, inefficient working practices by users or facility managers can contribute to excessive energy consumption levels. While the conventional approach to energy conservation has primarily concentrated on improving building design, there is an increasing trend to concentrate on and enhance how occupants and facility managers interact with various systems.

Adjusting thermostat setpoints to save on cooling or heating loads has been demonstrated to have the most potential among the several initiatives that tenants can take to conserve energy. Furthermore, such an intervention has a minimal to no direct financial cost and is not limited by architectural constraints in its execution. As a nudging strategy, intra-building occupant behavior and energy efficiency awareness are gaining traction. Several programmers have been put in place around the world to reduce energy use by changing thermostat settings. In 2005, the Japanese government began the "CoolBiz" campaign, urging public buildings to have a minimum cooling setpoint of 28 degrees Celsius. Other research questioned the policy's negative impact on thermal comfort and productivity, while supporters claimed it worked.

Several studies have looked at the effect of setpoints and dead band widening (i.e., the range of thermo-stat setpoints) on energy end consumption in HVAC systems. In the United Kingdom, researchers did field research to examine if a 2°C increase in office buildings (from 22 to 24 °C) influenced thermal comfort. According to the findings, the research group does not appear to be bothered by the increase. Despite the positive outcomes of such investigations, the scenarios examined are pre-determined and do not cover a broad search area. As a result, the proposed setpoints can be considered good, but not optimal, in terms of maximizing energy savings while maintaining thermal comfort, two objectives that may conflict.

MOO is a strategy for dealing with a circumstance like this. Because of the competitive nature of the objectives, no single solution can frequently achieve the best results for all of them at the same time, necessitating the adoption of a group of non-dominated (Pareto optimal) solutions. The solution is called Pareto optimal when none of the objective functions can be improved without affecting some of the other objective functions. MOO algorithms have been used in building energy assessments to discover the best mix of energy conservation measures, considering factors such as energy usage, installation cost, and life-cycle cost. Ref. was one of the first to use MOO in the renovation of existing structures. Their discoveries paved the way for more in-depth research on the problem, including the proposal of a retrofit optimization framework based on an artificial neural network and a genetic algorithm by one of the researchers. To demonstrate the usefulness of their technique, they looked at the interaction between energy usage, retrofit capital cost, and thermal discomfort hours in an existing school building. Even though technical retrofits are increasingly being studied through optimization issues, human-based interventions are less regularly researched.

3.1 ASHRAE Standard 55-2013

When persons are exposed to moderate temperatures, this international standard defines methods for estimating their general thermal experience and degree of discomfort (thermal dissatisfaction). By PMV and PPD calculations, it enables for the analytical measurement and interpretation of thermal comfort. It can be used by healthy men and women who are exposed to interior settings that require thermal comfort but have minor changes. When it comes to establishing new settings or analyzing those that already exist. Although it was created with the workplace in mind, it can be used in a variety of situations.

Table 1 depicts the three different types of thermal environments. It confirms that the PMV corresponds to the class A category (-0,2 PMV+0,2), category B (-0,5 PMV+0,5), and category C (-0,7 PMV +0,7). As a result, Table 2 depicts radiant temperature asymmetry in three categories. Warm ceiling, cool wall, cold ceiling, and warm wall are the conditions for radiant temperature asymmetry.

Table 1 – Category of thermal environment

Category	Thermal state of the body as a whole	
	PPD (%)	PMV
A	< 6	-0.2 < PMV <+0.2
B	< 10	-0.5 < PMV < +0.5
C	< 15	-0.7 < PMV <+0.7

Table 2 – Radiant temperature asymmetry

Category	Thermal state of the body as a whole			
	Warm ceiling	Cool wall	Cool ceiling	Warm ceiling
A	< 5	< 10	< 14	< 23
B	< 5	< 10	< 14	< 23
C	< 7	< 13	< 18	< 35

3.2 Solar Heat on HVAC System

Buildings require a lot of energy to cool, heat, and illuminate themselves all over the world. Lighting in office buildings consumes 20–40% of the total energy used in the buildings. Well-designed buildings must incorporate multiple variables such as orientation, shading devices, and building form to reduce energy usage across a structure. Furthermore, windows, glazed facades, and apertures have a significant impact on building energy usage, whether for heating, cooling, or lighting. To provide access to natural light, solar gain, and an outdoor perspective, new buildings are increasingly adopting glass facades and large windows. Increased glass area demands careful attention in building design in terms of cooling, heating, and lighting requirements. While correct shade design can help boost interior sunlight lighting, thermal comfort, restrict solar heat gains, and reduce glare, it also blocks the view out and detracts from the building's aesthetic.

The thermal performance of a building is influenced by the solar absorptance of its roof. During clear sky conditions, up to 1 kW/m2 of solar energy can be incident on a roof surface, and between 20% and 95% of this radiation is typically absorbed. The color of the roof, as perceived by reflected visible1 solar radiation, usually represents the solar absorptance value (e.g., a black surface with low visible reflectance suggests a high solar absorptance).

Buildings near the equator (tropical zones with a latitude angle of 23.58° or less) do not require active heating even during the winter since ambient temperatures and solar radiation levels are high enough. Daytime heat flow from a sun-exposed roof surface is mostly downward, which is normally undesirable since it overheats the structure or puts more load on the air conditioning system.

Thermal radiation is responsible for most of the heat transmission between the roof and the ceiling for downward heat flow. In upward heat flow, where the air in the roof area is heated from below, heat is carried by both convection and radiation.

4. Conclusion

In conclusion, the suitable application of innovative control strategies in Heating, Ventilation, and Air-conditioning systems is important to improving the energy efficiency and maintenance of temperature set point to improve thermal comfort in buildings. The increased focus on energy savings and appropriate thermal comfort has resulted in the necessity for more dynamic approach to the use of these controllers.

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References

[1] B. Crook, N.C. Burton, Fungal Biol Rev, Indoor moulds, sick building syndrome and building related illness, 24, 106-113, (2010).

[2] A. Norhidayah, C.K. Lee, M.K. Azhar, S. Nurulwahida, Procedia Eng, Indoor air quality and sick building syndrome in three selected buildings, 53, 93-98, (2013).

[3] H. Wang, S. Hu, Build and Environ, Experimental study on thermal sensation of people in moderate activities, 100, 127-134, (2016).

[4] Bin Razali Mohd Azahari, Masayuki Mori, Masataro Suzuki, Wataru Masuda. Effects of gas species on pressure dependence of thermophoretic velocity, (2012).

[5] Azwan Sapit, Mohd Azahari Razali, Mohd Faisal Hushim, Amir Khalid, Md Norrizam Mohmad Ja'at, Muhammad Fauzi Samsubaha, Tuan Mohamad Kamarul Hisyam Tuan A Talib. Effect of Acoustic Excitation towardJetFlame:An Experimental Design, (2018).

[6] Z. Gou, W. Gamage, S. Lau, S. Lau, Build, An investigation of thermal comfort and adaptive behaviors in naturally ventilated residential buildings in tropical climates: A pilot study, 8, (2018).

[7] P.H. Shaikh, N. Mohd, A.A. Sahito, P. Nallagownden, I. Elamvazuthi, M.S. Shaikh, Renew Sust Energ Rev, Building energy for sustainable development in Malaysia: A review, 75, 1392-1403, (2017).

[8] Taleghani M, Tenpierik M, Kurvers S, van den Dobbelsteen A. A review into thermal comfort in buildings. Renew Sustain Energy Rev 2013;26:201–15.

[9] Mohd Azahari Razal , Azwan Sapit, Akmal Nizam Mohammed, Md Nor Anuar Mohamad, Normayati Nordin1, Azmahani Sadikin, Mohd Faisal Hushim, Norrizam Jaat and Amir Khalid. Thread angle dependency on flame spread shape over kenaf/polyester combined fabric, (2017).

[10] Bin Razali Mohd Azahari, Masayuki Mori, Masataro Suzuki, Wataru Masuda. Effects of gas species on pressure dependence of thermophoretic velocity, (2012).

[11] Azwan Sapit, Mohd Azahari Razali, Mohd Faisal Hushim, Amir Khalid, Md Norrizam Mohmad Ja'at, Muhammad Fauzi Samsubaha, Tuan Mohamad Kamarul Hisyam Tuan A Talib. Effect of Acoustic Excitation towardJetFlame:An Experimental Design, (2018).

[12] Mohd Azahari Razali, Azwan Sapit, Akmal Nizam, Mohammed, Mohd Faisal Hushim, Azmahani Sadikin, Md Norrizam Mohmad Ja'at, Hazahir Peraman, Mirnah Suardi. Flame Spread Behavior over Kenaf Fabric, Polyester Fabric, and Kenaf/Polyester Combined Fabric, (2018).

[13] N. Djongyang, R. Tchinda, D. Njomo, Renew Sust Energ Rev, Thermal comfort: A review paper, 14, 2626-2640, (2010).

[14] T. Hoyt, S. Schiavon, A. Piccioli, T. Cheung, D. Moon, K. Steinfeld, CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley, http://comfort.cbe.berkeley.edu/, (2017).

[15] Brager GS, de Dear RJ. Thermal adaptation in the built environment: a literature review. Energy Build 1998;27:83–96.

[16] van Hoof J. Forty years of Fanger's model of thermal comfort: comfort for all? Indoor Air 2008;18:182–201.

[17] Burak Gunay, Weiming Shen, Chunsheng Yang, Characterization of a building's operation using automation data: A review and case study, (2017).

[18] Ahmed, S., Zain-Ahmed, A., Rahman, S. A., & Sharif, M. H. (n.d.-a). Predictive tools for evaluating daylighting performance of light pipes. In International Journal of Low Carbon Technologies (Vol. 1, Issue 4). https://academic.oup.com/ijlct/article/1/4/315/703751

[19] Schaeffer, R., Szklo, A. S., Pereira de Lucena, A. F., Moreira Cesar Borba, B. S., Pupo Nogueira, L. P., Fleming, F. P., Troccoli, A., Harrison, M., & Boulahya, M. S. (2012a). Energy sector vulnerability to climate change: A review. In Energy (Vol. 38, Issue 1, pp. 1–12). Elsevier Ltd. https://doi.org/10.1016/j.energy.2011.11.056

[20] Aebischer B., Jakob M., G. Henderson, M. Jakob, Catenazzi G., Impact of climate change on thermal comfort, heating and cooling energy demand in Europe. Proceedings ECEEE 2007 Summer Study.