Energy analysis on ACMV system for an academic building – Case study in UTeM

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ABSTRACT - Air-conditioning mechanical & ventilation system (ACMV) is one of the main contributors to the total building energy consumption. Thus, building energy audit is conducted in order to measure and analyse energy consumption patterns, monitoring of how the energy used, how the system element interrelate and record actual energy consumption. The study has been conducted at FKM's Building in UTeM's Technology Campus. Based on the collected data and information, the total of the building cooling load is being estimated. In addition, the Building Energy Index is also being determined. Finally, economic analysis is included with potential alternative measures to achieve optimum building energy usage.

1. INTRODUCTION

Air-conditioning & mechanical ventilation system (ACMV) is the main source of energy consumption for a non-residential building [1]. Any saving made on the energy consumption of this system will give significant impact on the building energy cost. Critical evaluation and advanced study is required in order to provide measures in achieving optimal building energy efficiency.

Globally, buildings consume about 40% of the total energy consumption and most of the energy is used for the purpose of heating, ventilation and air conditioning (HVAC) systems which are supported by Abdeen [2]. Yau has found in buildings, more than 50 % of the energy is consumed by the HVAC systems, especially in hot regions [3].The project is aimed to evaluate whether current energy usage is used efficiently or is being wasted, identify areas with potential for energy saving. This undertaking also aimed to look over the energy optimization stage in the building with compliance to a recommended comfort level.

2. METHODOLOGY

The energy audit process was started with the physical parameter measurement of the building, evaluation of historical electricity data and descriptive information about the building plant layout for each floor. The air velocity meter was used as shown in Figure 1 to conduct the physical parameters measurement. Before performing a physical data measurement, the following procedures are implemented:

(a) A selected rooms are cleaned and all the measurements were finished without the presence of occupants.
(b) All of the selected rooms are left to stabilize about one hour before conducting a measurement.
(c) The air velocity meter needs to be stabilized about 5 minutes before taking the real measurement.

Figure 1 Air velocity meter

The procedures mentioned above are based on the study by Lim et al [4]. The physical parameter measurement was conducted in the middle of the room. The objective of stabilizing as mentioned is to increase the accuracy of measurement data and also to make sure that the air-conditioning system in rooms selected are suitable for airflow measurement. The time and height while taking measurement by using an air velocity meter is following the standards as described in ASHRAE Standard 55-2014 [5]. The height of the air velocity meter probe is set at a height of 1.1 meters from a floor. Every one minute, air velocity meter measured and recorded the value.

3. RESULTS AND DISCUSSION

The results of physical parameter measurement are then compared with recommended indoor design conditions as outlined by Malaysian Standard MS1525:2014 [1]. The purpose is to evaluate the performance of the current ACMV system, whether it is still operating under comfort condition or not. The recommended indoor design condition of an air-conditioned space is 24^oC – 26^oC, 50 % - 70 % and 0.15 m/s – 0.50 m/s for design dry bulb temperature, design relative humidity and air movement respectively.

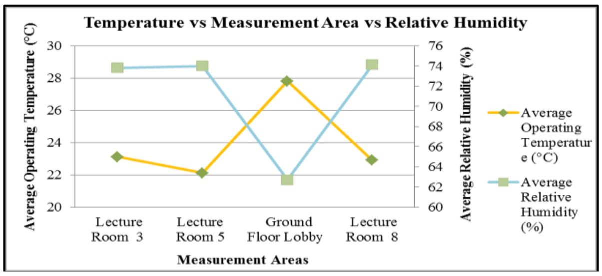

Figure 2 Temperature vs Measurement Area vs Relative Humidity at Ground Floor

Based on the result in Figure 2, the operating condition of Lecture Room 5 and Lecture Room 8 were operated below than the recommended range of design dry bulb temperature, meanwhile for the relative humidity, all the measured areas at ground floor are significantly over than the recommended value except in the Ground Floor Lobby. However, the temperature of the Ground Floor Lobby area is significantly higher than recommended standard. This is because of the Ground Floor Lobby is an open area with automatic gate that frequently close and open. This situation actually allows more heat to enter the lobby area.

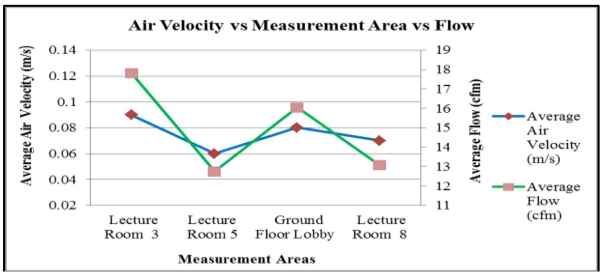

Figure 3 Air Velocity vs Measurement Area vs Flow at Ground Floor

In terms of air velocity, the measurement result for the ground floor are below than recommended standard (as shown in Figure 3). After an inspection was done on the ACMV system, it was identified that most of the the diffusers at the ground floor are not working in good condition and this is probably due to duct system leakage, dirty air filters and clogged from air particles.

Cooling load is the rate at which energy needs to evacuate from space. Based on the obtained information and measurement data, the total building cooling load can be estimated. According to Table 1, the ground floor gave the highest cooling load amount at 200.8794 kW. This is because the ground floor has more occupants compared to other floor and high exposure to the heat from the main entrance of the building. Meanwhile, the fifth floor of the building the lowest amount of cooling load 125.9162 kW.

Based on the annual electricity usage calculation, the Building Energy Index is being determined and the value of the Building Energy Index for whole of the building is 757.715 kWh/m²/year and for each level is 108.245 kWh/m²/year. Meanwhile, the value of the Building Energy Index based on the cooling load is 736.6 kWh/m²/year. Pusat Tenaga Malaysia has suggested the typical buildings in Malaysia have the BEI in the range of 200 to 300 kWh/m^2/year [6]. Both of the results shows that the consumption is higher than the recommended range for typical building.

Retrofit Analysis has been conducted in this study and two types of retrofit installations have been suggested which are variable frequency drive and 7-day programmable thermostat. The saving is estimated to be at 4% for installing variable frequency drive (VFD) and 2% for programmable thermostat which required RM 2204.56 and RM 1653.42 per month respectively. Based on the monthly cost saving at RM 3306.84 per month, the total of implementation cost will be recovered within 25 months.

Table 1 Cooling Load Summary for the Case Study Building

Level	Load (kW)	Load/Unit (TR)
Ground Floor	200.8794	57.11994
First Floor	162.1099	46.10635
Second Floor	157.1845	44.70552
Third Floor	130.2492	37.04471
Fourth Floor	161.6559	45.97723
Fifth Floor	125.9162	35.81228
Sixth Floor	126.6942	36.02489
Total	1064.689246	302.7909

4. CONCLUSIONS

According to the physical parameter measurement, most of the floors of the building do not achieve the acceptable air velocity recommended by Malaysian Standard. This is due to lack of maintenance of ACMV system and having equipment in ACMV system not functioning well. Overall, most of the temperatures at each level are below than the recommended comfort condition. Based on the calculation, an ACMV system was contributed about 49.4% of the total monthly energy usage.

5. REFERENCES

[1] Malaysian Standard 1525, *Code of practice on energy efficiency and use of renewable energy for non-residential buildings*; 2014.

[2] M. O. Abdeen, "Energy environment and sustainable development," Renewable and Sustainable Energy Reviews, vol. 12, pp. 2265–2300, 2008.

[3] Y. H. Yau, "The use of a double heat pipe heat exchanger system for reducing energy consumption of treating ventilation air in an operating theatre-A full year energy consumption model simulation," Energy and Buildings, vol. 40, pp. 917-925, 2008.

[4] J. S. C., Lim, A. Husain, B. T. Tee, " Simulation of Airflow in Lecture Rooms," Energy and Buildings, 2005.

[5] Ashrae Standard, *Handbook of thermal environmental conditions for human occupancy*, Atlanta:ASHRAE; 2004.

[6] H. Z. Xin, "The role of building active energy conserving strategies of the malaysia energy commission diamond building," Sustain, 2012.