ACMV Energy Analysis for Academic Building: A Case Study

R Hywel1, B T Tee1*, M Y Arifin1, C F Tan1, C K Gan2 and CT Chong3
1Centre for Advanced Research on Energy (CARe)
Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

2Centre for Robotic and Industrial Automation (CeRIA)
Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

3Faculty of Mechanical Engineering, Universiti Teknologi Malaysia,
81310 Skudai, Johor.
E-mail: tee@utem.edu.my

Abstract. Building energy audit examines the ways actual energy consumption is currently used in the facility, in the case of a completed and occupied building and identifies some alternatives to reduce current energy usage. Implementation of energy audit are practically used to analyze energy consumption pattern, monitoring on how the energy used varies with time in the building, how the system element interrelate, and study the effect of external environment towards building. In this case study, a preliminary energy audit is focusing on Air-Conditioning & Mechanical Ventilation (ACMV) system which reportedly consumed 40% of the total energy consumption in typical building. It is also the main system that provides comfortable and healthy environment for the occupants. The main purpose of this study is to evaluate the current ACMV system performance, energy optimization and identifying the energy waste on UTeM’s academic building. To attain this, the preliminary data is collected and then analyzed. Based on the data, economic analysis will be determined before cost-saving methods are being proposed.

1. Introduction

Building energy auditing comprises of evaluating and indicating actual energy consumption, at site, which completed and occupied of particular building and essentially for the purposes to reduce and minimize current energy usage. It is useful for analyzing patterns of energy consumption, monitoring on how the energy used varies with time in the building, how the system elements interrelate and study the effect of external environment towards building[1]. Nowadays, high demands for efficient ways of building operation such as better energy conservation and optimization usage in purpose to cut off energy cost. Many studies has been made about the building energy audit for this particular purpose such Yu & Chow [2] [3], Ramli et. al.[4]. Even for the previous studies, there are

* To whom any correspondence should be addressed.
several researches have been conducted in the other academic buildings regarding the energy and ACMV system analysis such as Rosli [5], Tee et. al. [1], Ismail [6], and Roslan [7]. The authors are therefore interested to further conduct a building energy audit and analysis focusing on the ACMV system at FKM’s academic building located in UTeM’s Technology Campus.

2. Methodology

The building comprises of seven-storey with central air-conditioning system and the case study covered the ground and first floor as shown in Figure 1 and Figure 2 respectively. The operating hours of the ACMV system is from 8.00 am to 6.00 pm on Monday to Friday. This is the preliminary audit and energy analysis which consists of 5 aspects described as following:

(a) Walk – Through Audit
An initial facility tour was conducted to observe the major operational and equipment features of the facility. This can assist in identifying areas where have potential energy saving so that a simple and inexpensive action can provide immediate energy use and/or operating cost savings. The main purpose of the tour is to obtain general information and understanding on the ACMV system of the building. In fact, more specific data or information about ACMV system, equipment and occupancy should be obtained from the maintenance and operational officer during the second visit with detailed data collection tour [8]. In addition, it was also conducted to obtain electricity power and cooling load capacity (tones refrigerant-TR) for the water-cooled chiller, water pump, cooling tower and air-conditioning system units.

(b) Utility Cost Analysis
The main purpose is to analyze and evaluate the operating cost of the facility. This is important for several reason: the bills show the proportionate use of each different energy source when compared to the total energy bill; an examination of where energy use can point out previously unknown energy wastes; and, the total amount spent on energy puts an obvious upper limit on the amount can be saved [8]. Besides that, the electricity bills are evaluated to identify the pattern of energy use, peak demand, and potential energy savings.
(c) Physical Parameters Measurement
To obtain the best information for successful energy cost control program, some measurement must be conducted during the audit. In this case study, the physical parameters involved in the measurement are air temperature, air velocity and relative humidity. The purpose of this measurement is to determine whether ACMV system performance compromise the comfort level as outlined in MS1525 [9]. Air velocity meter was used to measure those parameters. The time and height of measurement are based on the previous works [1][10]. The air velocity meter is set at the height of 1.1 meter for both pilot and actual measurements. At any typical point of measurement, the time to record the readings is every 1 minute for one hour. The case study of measurement areas is located in lecture rooms and main lobby of the ground and first floor.

(d) Cooling Load
Cooling load calculation is calculated for each of case study floor of the building in order to identify the overall load that to removed for the building. The overall results are shown in Table 1.

(e) Economic Analysis
Economic analysis is provided the costing estimation for the energy usage of the building. Suitable measures are proposed based on the analysis and data for energy saving purpose.

3. Result & Discussions

(a) Cooling Load
The total cooling load can be estimated based on the information obtained through the walk-in survey and data measurement. Table 1 shows the total cooling load for ground and first floor based on the specific time taken. The total load minimum and maximum total load for ground floor are 76.9 TR and 109 TR respectively while the first floor are 62.4 TR and 91 TR.

| Level     | Time (hours) | Total Load (kW) | Total Load/Unit (TR) |
|-----------|--------------|-----------------|----------------------|
| Ground    | 0700         | 270.4           | 76.9                 |
|           | 1000         | 326.5           | 92.8                 |
|           | 1300         | 378.7           | 107.7                |
|           | 1600         | 383.4           | 109                  |
|           | 1800         | 327.2           | 93                   |
| First Floor| 0700         | 219.3           | 62.4                 |
|           | 1000         | 261.1           | 74.24                |
|           | 1300         | 306.4           | 87.1                 |
|           | 1600         | 319.3           | 91                   |
|           | 1800         | 261.7           | 74.4                 |

(b) Physical Parameter Measurement
All the data are shown in Table 2. The data then are compared with recommended indoor design conditions of an air condition space for cooling comfort as stated in the Malaysian Standard MS1525:2007 (Air velocity: 0.15-0.50 m/s, Air temperature: 23° C – 26° C and Relative Humidity: 55-70%) to indicate whether the current ACMV system is operating within the recommended comfort level or compromise.
Table 2. Physical Parameters Measurement Data for Ground and First floor.

| Location | Measurement Area | Average Flow (cfm) | Average Operating Temperature (°C) | Average Relative Humidity (%) | Average Air Velocity (m/s) |
|----------|------------------|--------------------|-----------------------------------|-------------------------------|---------------------------|
| Ground   | Lecture Room 3    | 17.82              | 23.1                              | 73.8                          | 0.09                      |
| Floor    | Lecture Room 5    | 12.74              | 22.1                              | 74                            | 0.06                      |
| Lobby    |                   | 16.04              | 27.8                              | 62.7                          | 0.08                      |
| First    | Lecture Room 10   | 32.27              | 22.1                              | 72.9                          | 0.16                      |
| Floor    | Lecture Room 11   | 2.61               | 24                                | 72.9                          | 0.01                      |
| Corridor |                   | 17.74              | 29.9                              | 60.7                          | 0.09                      |

Based on Table 2, most of the areas in ground and first floor are operating not within the recommended standard. As indicated in the table, air velocities were lower than the requirement by MS1525 except for the lobby area. Relative humidity seems to be slightly higher than the standard except for lobby and corridor area. Therefore, it is shown that the current ACMV systems for the ground and first floor are not operating within the expected comfort requirement.

(c) Energy Data Analysis

Electricity is the main sources of energy that generated in the case study building. All the electricity consumption of the building is charged directly by the local electricity utility company. An electricity meter or energy meter is a device that measures the amount of electric energy consumed and supposed to be installed in every building for billing purposes. Unfortunately, detail billing data in this case study is unavailable for the area. Specific assumption and consideration has to be made for determine cooling load and economic analysis based on the building section. The analysis of the overall monthly energy used pattern is based on the electricity consumption as shown in Figure 3.

![Figure 3. Energy consumption for one year.](image-url)
(d) Retrofit Analysis
The aim of conducting retrofit analysis is to reduce energy consumption in the study case building. Retrofit installations sometimes could be more expensive but it is better to know the long term benefits of energy efficient technologies from cost-benefit perspective. The result from inspection and after measurement work indicates that the current ACMV system is not working efficiently within the standard requirement probably due to lack of system maintenance and less control equipments. Retrofit installations can be considered include control setback thermostat temperature, off hour control timer, heat recovery system and variable air volume. Table 3, 4 and 5 summarize the total cost and savings estimation based on the retrofit implementation.

| Location | Total Cost of Electricity per monthly | Total Cost of Electricity per year |
|----------|--------------------------------------|-----------------------------------|
| Ground Floor | Maximum: RM 18771.26, Minimum: RM 13238.78 | Maximum: RM 225255.17, Minimum: RM 158865.41 |
| First Floor | Maximum: RM 15632.93, Minimum: RM 10736.93 | Maximum: RM 187595.136, Minimum: RM 128843.14 |

| Location | Total Energy Saving after Retrofit per monthly | Total Energy Saving after Retrofit per year |
|----------|-----------------------------------------------|-------------------------------------------|
| Ground Floor | Maximum: 115.02 kW, Minimum: 81.12 kW | Maximum: 1380.24 kW, Minimum: 973.44 kW |
| First Floor | Maximum: 95.79 kW, Minimum: 65.79 kW | Maximum: 1149.48 kW, Minimum: 789.48 kW |
| Total | 210.81 kW, 146.91 kW | 2529.72 kW, 1762.92 kW |

| Location | Total Cost of Electricity after Retrofit per monthly | Total Cost of Electricity after Retrofit per year |
|----------|-----------------------------------------------------|-----------------------------------------------|
| Ground Floor | Maximum: RM 13139.88, Minimum: RM 9267.15 | Maximum: RM 157678.62, Minimum: RM 111205.80 |
| First Floor | Maximum: RM 10943.05, Minimum: RM 7515.84 | Maximum: RM 131316.59, Minimum: RM 90190.19 |
4. Conclusions

Building energy audit is the suitable approach method or tool that used to measure and obtains information regarding actual energy consumption in site or the buildings by purposes to purposes of reducing and minimizing energy usage in order to improve the energy performance. Based on the preliminary building energy audits on ACMV system installed in study case areas, it was found that that the ground and first floor of the FKM’s building are contributed about 13 % - 18% of the total energy costs. Based on the retrofit saving analysis, it is estimated about 30% can be saved from the actual amount of the electricity and energy cost.

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