

Cooling Load Investigation for Air-condition System in Faculty of Education and Technical Vocational, UTHM

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Abstract: When it comes to designing air conditioning system prior to installation, cooling load estimation is required. This is because proper design of air conditioning system can provide thermal comfort to occupants in the building, significantly affects the overall energy consumption and reduces maintenance costs of the air conditioning system. In FPTV (Block C & D), UTHM, the current air conditioning system has been operating for some time. It is not known whether the current air conditioning system in the studied buildings is still working efficiently as before. The objective of this study is to determine the efficiency of air conditioning system in FPTV (Block C & D), UTHM. The study is focused on non-residential building. In this study, cooling load estimation is carried out using Cooling Load Temperature/Cooling Load Factor/Solar Cooling Load Factor (CLTD/CLF/SCL) method. Prior to the cooling load estimation, the data of the studied buildings are gathered from physical measurements, calculations, floor plan drawings and many more. The total cooling load obtained is compared to the chiller's cooling capacity. From the comparison, it is observed that the calculated total cooling load of the studied buildings is within the chiller's cooling capacity. In conclusion, the efficiency of air conditioning system in FPTV (Block C & D), UTHM has been determined. It is proven to be still efficient and needs no replacement now. The scopes of research can be extended on the study of air circulation and heat distribution in conditioned spaces using simulation software, and on the study of indoor air quality.

Keywords: Air conditioning, cooling load, CLTD/CLF/SCL method

1. Introduction

Air conditioning systems have been widely used in all around the world. The purpose of most systems is to provide a comfortable indoor environment. People spend most of their time indoor, so it is important to have an efficient air conditioning system. Not only having an efficient air conditioning system can provide a comfortable indoor environment, but it also can reduce overall energy consumption as air conditioning system consumes the most energy in a building or facility [1]. Thus, efficient air conditioning system reduces electricity costs and most importantly, it emits lesser greenhouse gases to the environment.

For tropical climate countries like Malaysia, Singapore, Indonesia and many more, air conditioning system operates as a cooling system only unlike other countries which have cold climate will need to have both cooling and heating systems in their air conditioning system [2,3]. When it comes to designing air conditioning system prior to installation, cooling load estimation is required. This is because proper design of air conditioning system can provide thermal comfort to occupants in the building, significantly affects the overall energy consumption and reduces maintenance costs of the air conditioning system [4-6].

For this project, building for Fakulti Pendidikan dan Teknik Vokasional (FPTV) focusing on Block C & D were chosen because these two blocks have the highest electricity consumption among the FPTV blocks as most of the classes for FPTV students are held there. Besides that, these two blocks share the same chiller for their air conditioning system, thus both must be included in the cooling load estimation which will be shown in the later part. This study will be focusing on cooling load which is the amount of heat energy which is required to be removed from a space to maintain the temperature in an acceptable or comfortable range [7-8].

2. Methodology

In this project, the efficiency of air conditioning system in FPTV, UTHM will be determined by estimating the cooling load. Estimation of the total cooling load requires specific parameters such as ambient temperature, relative humidity, dimensions of studied buildings and many more [9-10]. These parameters can be obtained through physical measurement, floor plan drawings of studied buildings, topic-related reference books and websites, and so on. The estimation of total cooling load of FPTV, UTHM will be conducted using Cooling Load Temperature Difference/Cooling Load Factor/Solar Cooling Load Factor (CLTD/CLF/SCL) method [11-13]. The total cooling load obtained will then be compared to the chiller's cooling capacity to determine the efficiency of the air conditioning system in the studied buildings.

2.1 Location for Investigation

Two FPTV buildings, Block C and Block D, are chosen for this project because most of FPTV lectures are held in these two blocks. Besides that, these two blocks share the same chiller for their air conditioning system. Therefore, both must be included in the cooling load estimation. Block C consists of three floors. The facilities in this block are classified into laboratories and studios. Both types of facilities are used for conducting FPTV lectures. For this project, Block C will be divided into two wings, Wing A and Wing B as the whole building is not fully air-conditioned. Block D consists of two floors. However, only the ground floor of Block D will be included for the cooling load estimation because there are no facilities on the first floor of Block D. The facilities in this block are all laboratories which are used for conducting FPTV lectures. For this project, Block D will be divided into two wings, Wing A and Wing B as the whole building is not fully air-conditioned.

A digital temperature and humidity meter (Mastech MS6508), as in Fig. 1 was used to measure the ambient temperature and relative humidity of each facilities. MS6508 is a new type of digital temperature and humidity meter. It is designed to combine the functions of humidity meter, temperature meter, wet bulb temperature and dew point temperature. The function of the humidity meter is shown in Table 1.



Fig. 1 – Temperature humidity meter, MS6508

Table 1 – Functions of the labelled buttons

Button	Function
1	Freeze the current reading and stop the meter from displaying the measurements.
2	Save the reading (up to 99 groups reading).
3	Switch the temperature unit from °C to °F
4	Automatic power-off function (automatic closes the device if it is without operation in 30 minutes).
5	Switch on or off the device.
6	Display minimum and maximum reading of temperature and humidity.
7	Display wet bulb and dew point temperature.
8	Read saved reading.
9	Switch on the backlight (for reading in dark environment).

2.2 Method of Investigation

For the methodology of this project, the location will be selected first which is FPTV. Once the location has been confirmed, data collection will then be conducted. The data of the studied buildings will be gathered from floor plan drawings, topic-related reference books and websites. Physical measurement will be carried out to measure ambient temperature and relative humidity of each facility in Block C and Block D using a digital temperature and humidity meter (Mastech MS6508).

All the obtained data will be used in next step which is estimating total cooling load of the studied buildings using CLTD/CLF/SCL method. The obtained result from the cooling load estimation will proceed to discussion and conclusion if it is satisfying. However, if it is not satisfying, data collection will be conducted again followed by cooling load estimation using CLTD/CLF/SCL method. Once the obtained result is considered satisfied, the next step is the discussion and conclusion.

The total cooling load of the studied buildings will be compared with the chiller's cooling capacity. After the comparison is made, a discussion will be conducted based on it. From the discussion, the findings will be concluded, and the efficiency of air conditioning system in the studied buildings will then be determined. Summarize of the flow chart methodology are shown in the Fig. 2.

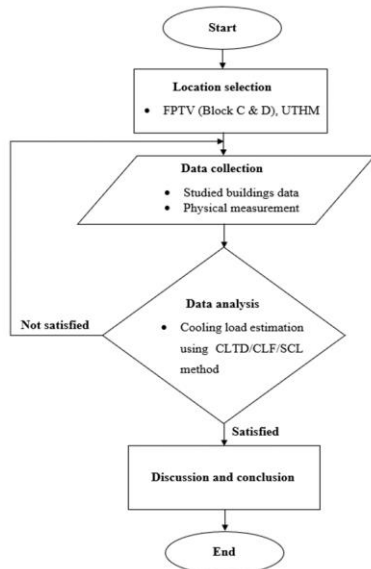


Fig. 2 – Flowchart of methodology of the project

2.3 Equations

Based on the cooling load estimation using CLTD/CLF/SCL method, the total cooling load of the studied buildings are contributed by heat conduction through exterior structures, heat conduction through interior structures, heat gain from solar radiation through window glasses, heat gain from lightings, heat gain from people, heat gain from equipment and appliances, heat gain from infiltration through windows and doors, and heat gain from ventilation. The equations are shown as below.

$$Q = U \times A \times CLTD_c \quad (1)$$

$$Q = U \times A \times TD \quad (2)$$

$$Q = SHGF \times A \times SC \times CLF \quad (3)$$

$$Q = 3.4 \times W \times BF \times CLF \quad (4)$$

Eqn. 1 is used to obtain the cooling load for roofs, walls, and window glasses of the studied buildings while Eqn. 2 used to obtain the cooling load for partitions, floors, and ceilings of the studied buildings. Cooling load from solar radiation through window glasses of the studied buildings and cooling load due to heat gain from lightings can be obtained by using Eqn. 3 and 4 respectively.

$$Q_s = q_s \times n \times CLF \quad (5)$$

$$Q_l = q_l \times n \quad (6)$$

Eqn. 5 and 6 are used to obtain the sensible and latent cooling loads due to heat gain from people in the studied buildings, respectively. The Eqn. 7 and 8 used to obtain the sensible and latent cooling loads from infiltration air in the studied buildings, respectively. These two equations are also used to obtain the sensible and latent cooling loads from ventilation air in the studied buildings, respectively.

$$Q_s = 1.1 \times CFM \times TC \quad (7)$$

$$Q_l = 0.68 \times CFM \times (W_o' - W_i') \quad (8)$$

3. Results and Discussion

This study is to investigate the cooling load of air conditioning system in FPTV, UTHM. Both blocks share the same chiller for their air conditioning system. All the data had been gathered from physical measurement, calculations, floor plan drawings and many more. The cooling load estimation was carried out using CLTD/CLF/SCL method. A comparison between the chiller's cooling capacity and the predicted cooling load was made to determine the efficiency of the air conditioning system.

Table 2 below shows data about summary of cooling load estimation of FPTV using CLTD/CLF/SCL method. From the comparison between the two blocks, three floors of Block C were included for cooling load estimation whereas only one floor of Block D was included. Thus, the total cooling load for exterior and interior structures of Block C is so much higher compared to Block D. Block C has more facilities compared to Block D. By having more facilities, the number of lightings, people, and equipment and appliances in Block C is higher. Besides that, Block C also has higher infiltration rate due to having more facilities compared to Block D. This is because by having more facilities, Block C has more windows and doors which then leads to having more outdoor air enters through the building openings.

Table 2 – Summary of cooling load estimation of FPTV using CLTD/CLF/SCL method

Heat Gain Components		Cooling Load Block C (BTU/hr)	Cooling Load of Block D (BTU/hr)
Exterior structures	Roofs	40,634.59	71,985.04
	Walls	324,858.46	314,401.38
	Windows	65,140.04	42,959.93
Interior structures	Partitions	92,186.24	57,966.58
	Floors	440,430.74	60,698.44
	Ceilings	435,916.38	336,876.41
Infiltration	Windows	75,434.58	6,743.72
	Doors	59,494.07	70,368.27
Solar radiation		102,446.96	4,429.70
Lightings		112,914.00	53,244.00
People		186,000.00	111,600.00
Equipment and appliances		46,512.40	23,256.20
Ventilation		139,781.00	187,815.13
Total		2,121,749.46	1,342,344.80

Moreover, block C has higher heat gain due to solar radiation through window glasses since it has more windows compared to block D. For ventilation, block D has higher heat gain compared to Block C. This is because all the facilities in block D is laboratories which have higher area outdoor air rate (0.18 CFM/ft²) compared block C whose facilities are mostly lecture halls with fixed seat having area outdoor air rate of (0.06 CFM/ft²). A chiller with cooling capacity of 350 RT is used to supply chilled water for air conditioning process for both blocks investigated.

The comparison between the chiller's cooling capacity and the calculated total cooling load of the studied buildings was made to determine whether the chiller was able to fulfil the load demand or otherwise. Table 3 below shows the chiller's cooling capacity at maximum/full load and 80% load and calculated total cooling load of the blocks. From the comparison, the calculated total cooling load (288.7 RT) is within the chiller's cooling capacity at maximum/full load 350 RT.

However, most chillers rarely operate at maximum/full load design. According to previous data from researchers, they normally operate at around 60% to 80 % load [14,15]. So, the chiller will be operating at most around 80% load which is still sufficient to fulfil the maximum load demand from the studied buildings. This is because the actual load demand will not be 100 % as not all classes will be carried out at the same time, the number of occupants in each facility will not always be maximum and so on. Thus, the actual load demand will be less than 280 RT.

The calculated total cooling load of the studied buildings has exceeded the cooling capacity of chiller at 80 % load. This is due to temperature rise from global warming which had affected the cooling load of the studied buildings. The air conditioning system of the studied buildings was designed in September 2009. The average ambient temperature for September 2009 was 27°C whereas the average ambient temperature for March 2020 was 29°C. The average ambient temperature had increased 2°C over the 10 years. So, the studied buildings in year 2020 will then receive more heat compared to in year 2009 due to global warming. Hence, the total cooling load of the studied buildings in year 2020 is higher compared to in year 2009. From the cooling load estimation, the efficiency of the air conditioning system in the studied buildings has been determined which is 82.5%.

4. Conclusion

To determine whether the chiller was able to fulfil the load demand or otherwise, a comparison between the chiller's cooling capacity and the calculated total cooling load of the studied buildings was made. From the comparison, it showed that the total cooling load of the studied buildings was within the chiller's cooling capacity. However, most chillers rarely operate at maximum/full load design. The normally operate at around 60% to 80% load. So, the chiller will be operating at most around 80% load which is still sufficient to fulfil the maximum load demand from the studied buildings as the actual load demand will not be 100 %. This is because not all classes will be carried out at the same time, the number of occupants in each facility will not always be maximum and so on. Thus, the actual load demand will be less than 280 RT. In conclusion, the efficiency of air conditioning system in both blocks investigated has been determined using CLTD/CLF/SCL method which is 82.5 %.

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