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Evaluation of UTHM Administrative Office Block Cooling Load through Dynamic Simulation

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Abstract—**The energy requirements for a building have a direct impact on the cost of operating a building and an indirect impact on the environment. The energy estimation can be used as a guide in design, for standards compliance, and for economic optimization. Energy estimation can be done in several ways. The methods vary from steady state/static to dynamic estimation. Building energy simulation is an analysis of energy performance of building dynamically using computer modelling and simulation techniques. This study compares the building cooling load derives from audit report and through energy model with the dynamic simulation result. The building cooling loads were determined by extracting SIRIM energy audit report on the building and also by using energy model of Malaysia reference office building. The building cooling load was estimated using IES software, which simulates cooling load demand for the building dynamically. The study found that the simulated cooling load varies in the range of 6% from other methods cooling load values. The difference is considered small for estimation purposes.**

Keywords: cooling load, energy estimation, simulation, energy model

I. Introduction

Buildings are well known to be major energy consumers and so any reduction in their energy usage is welcome. The consequences of an energy inefficient building are great and cause not only high running costs, the depletion of natural fuel resources that are unsustainable, but to excessive global pollution. Based on the application and the level of detail required, different methods could be used to estimate building energy requirements. In general, the methods can be divided into three categories:

- Steady-state methods — they include degree-day method, variable-base degree-day method and bin method [1]. Based on steady-state assumptions, these methods only require simple inputs, but their accuracy and capability are also limited.
- Dynamic methods — the methods estimate and analyse the building energy consumption by modelling the dynamic behaviour of buildings. The most popular one is generally known as building energy simulation which models building energy performance over the time domain[2].
- Measurement-based methods — these methods focus on the actual building operation and behaviour rather than on a prediction based on physical properties and performance specifications [3].

This study is to compare cooling loads determined through various methods that are by simulation, extraction from energy audit report and using energy model developed from reference office building [4]. The selected building is located in the University Tun Hussein Onn Malaysia (UTHM) campus, Batu Pahat, Johor. The building for this study is an administrative office block.

II. Energy Audit Report

Energy audit from SIRIM [5] involved 49 buildings consisting of administrative office, lecture halls, lecture rooms and others. Not all the buildings are air-conditioned. The air conditioning used in some of the buildings are classified as; central air distribution system, central circulating water system and multiple unit system (split/window type). Certain buildings use a combination of centralised air conditioning system and multiple unit system where the multiple units act as standby and occasionally used in the evening when staffs work overtime. A timer control system is applied to the central air conditioning systems. The energy was audited for one-year period from September 2001 to October 2002. The report given by SIRIM was used to extract the cooling load of the administrative block.

The coefficient of performance (**COP**) of an air conditioning is the ratio of the energy removed to the energy supplied [6]. The annual average COP of the air-conditioning units given by the report varies from 1.1 to 2.6. Some of these are lower than some of the recommended values that range from 2.0 to 3.3 [7].

A The Building

The building in this study is parts of the buildings that were audited by SIRIM. It is an administrative and office building, which was been occupied since the year 2000. The

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total floor area for this building is 3,666 m^2. In term of construction, this building is considered as a lightweight building because the wall is made-up of half brick plastered both sides.

The building is fully enclosed and air-conditioned. Only the staircase and toilet are not air-conditioned. The indoor set point temperature of the building varies from room to room with the temperature range from 18 to 27 degree Celsius. The numbers and types of air-conditioning system used in this building are seven multiple unit (split) and five central air-cooled systems (packages). The capacities of the seven split type units are 2HPeach. The package types have two different capacities, two units with 20HP each and three units with 50HP each (HP denotes horse power of the compressor, which is the usual way of rating air conditioning system in Malaysia).

The audit report found that the electricity consumption of the building was more than it should have been. It argued that high consumption could be the faulty of air distribution system, operating the central and the split unit of air conditioning systems simultaneously and the uncontrollable infiltration of outside air.

B Extraction of Cooling Load

Two approaches were used to estimate cooling load adopted by the report are by meter logging on main switch board (MSB) and by rated power as specified on the nameplates of equipment.

Logging approach is where the meter was logged at the Main Switch Board (MSB) of the building. From the report the meter was logged for a day. The annual estimation was by multiplying numbers of days the equipment run. The cooling load index using this method is as in **table 4.0**. The logging for a day may not so accurate to present for the whole year. As the logging was done at MSB, cable energy losses were not considered in the report.

Rated power technique used the rated power of the system and equipment. This approach is subjected to errors because the actual usages of the electricity fluctuate along the time. The cooling load index from this technique is as in **table 5.0**.

III. Simulation

The energy consumption of the building was simulated using the IES software together with Malaysia typical weather year hourly data. The simulation on the building was based on APSim idealised room control. The idealised temperature and humidity control is modelled by APSim operating in standalone mode with an assumption that the HVAC system and HVAC plant performed as required in the input data of the simulation.

Weather data used in the simulation is important because it contributes to external heat gains to the building. Ideally, the weather data used should be at the location of the building to be simulated, but such data is not available. This simulation used the Malaysia typical weather year hourly data [8] generated from Subang weather station data. Since the weather data used are not from the actual site and period, we have to expect the discrepancy of the simulation result. The distance between the building location and Subang is quite far, but Malaysia which is located around the equator, experiences weather that does not vary much from place to place[9].

A Model Construction

Before a simulation can be carried out, the model of building has to be constructed or imported from other file. To construct the building model, we can use IES application tool known as Model IT. This tool uses a drag and pull-down menu bar to construct the building model. For this work, the author constructed the building model using the tool based on the available building plan.

B Input Data

Once the shape of the building has been constructed, the construction types of the building and the room thermal attributes data were then assigned. Each construction type consists of a layer-by-layer description of the element’s thermo-physical properties, together with other data such as surface solar absorptivity and emmissivity. The construction attributes of the building are as in **table 1.0**. The room thermal data is a set of attributes that describe conditions and events in the room. Room thermal attributes data assigned to the building are as in **table 2.0**.

C Simulated Cooling Load

The annual simulated cooling load of the building is 806,729kWh/yr as in **table 3.0**. This figure is converted into building cooling load index by dividing with the floor area. Thus, simulated building cooling load index becomes 220.0 kWh/m^2/yr. This value is compared with values generated from other methods as in **table 7.0**. From this table, the index generated from the simulation approach is lower either from the logged or the rated methods.

IV. Energy Model

Energy index is the consumption of energy for one metre square area for a period of one year. The simulated index is compared with the index generated from reference office energy model [4] below:

$$\textit{Cooling Load} = [464 + 57SC + 121WWR - 17AT + 2EQ + 2LL + 170OC]\ kWh / m^2 / yr$$

The values of the parameters of the model above are in **table 6.0**. The generated building cooling index of the building is **216.7kW/m²/yr.**

The percentage difference of this cooling load index with other is as in **table 7.0**. The difference is probably because the model is relatively rough as only six parameters were considered. The model would be much better if other parameters are considered for example the ventilation rate, building form, thermal insulation, HVAC system and others. However, this model is practical, quick and effective in estimating the building load of Malaysia office building.

V. Conclusion

Before a comparison can be made between the methods, it is better to consider the shortcomings each of the approach.

Logging approach gives the actual power usage of the equipment. If the logging is done at the MSB, then consideration should be given to the cable loss from the MSB to the equipment. Unfortunately, in for the report the logging was done for only one day and the cable loss was not considered.

Rated approach is a static method, which estimates the energy index in a rough way. This method refers to the rated power nameplate of the equipment. The rated power on equipment is usually based on design values with some safety factor. Therefore, using this method should gives higher energy index compare to other methods.

Model method is relatively rough as only six parameters were considered but is better than OTTV technique. The application of the developed energy equation on the actual building shows that the estimated cooling load is approximately to the simulated value. This means that the equation can be used as early energy estimation for the office building in Malaysia.

Simulation method gives reliable value if all the input data are similar to the actual case. Since in this case, the input data are not very definite especially the weather data used are not from the location, only one set-point temperature for the simulation but in actual case several set-point temperatures, using default values where the information is not available example few of the building features, operating hours and others.

Simulated value is lower either from the logged or the rated methods However, this value is higher than that by model method. The differences are shown as in **figure 1.0** and in **table 7.0**. Difference variations are not that significant, about 5%. The simulated value is much accepted as the report claimed that the building consumed more energy than expected and the model is still rough as it considered six parameters.

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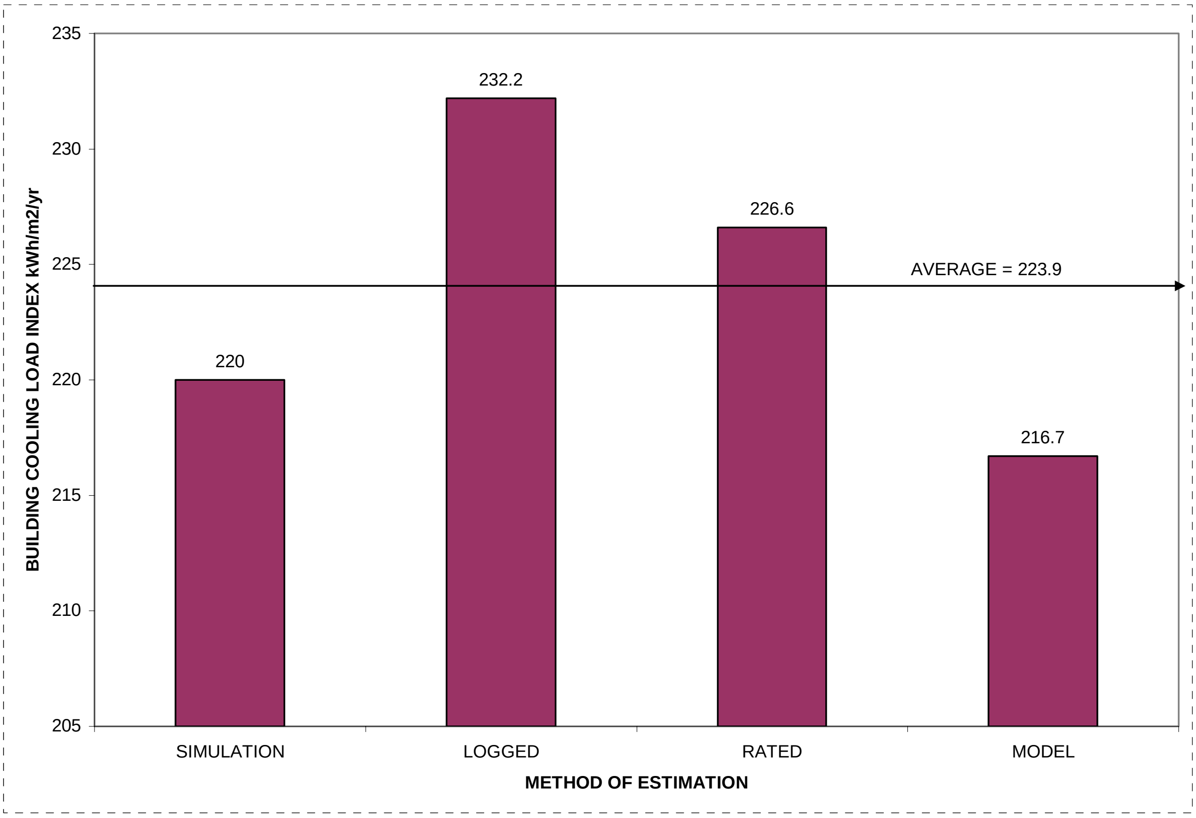

Figure 1.0 Estimated building cooling load index

Table 1.0 Construction attributes input to the building

Item	**Descriptions**	**U values W/m^2. K**
Roof	Sloped clay tiles and insulated with glass wool	0.45
Ceiling or intermediate floor	Concrete with ceiling and finishes	1.24
	Timber with ceiling and finishes	0.67
External Wall	115mm brickwork with 12mm dense cement render both faces	2.76
Internal Partition	115mm brickwork with 12mm dense cement render both faces	2.14
	2x12mm gypsum plaster board and 50mm air gap	1.77
Door	Wooden	2.07
	Single glazing 6 mm	5.65
External Glazing	Single glazing 6 mm	5.65
Internal Glazing	Single glazing 6 mm	4.27

Table 2.0 Room thermal attributes input to the building

Items	**Descriptions**	**Values**
Cooling Simulation set-point	Room	22^0C
	Corridor	26^0C
Relative Humidity	Maximum	65%
	Minimum	55%
Profile of working hours	Mon to Fri full working day	8am to 5.00pm
	Sat. half working day	Off
	Sun is not a working day	Off
Casual gains	Computers	$15w/m^2$
	People	0.1 persons/m^2
	Lighting	$16w/m^2$
Ventilation	Mechanical	3 ach
	Infiltration	0.5 ach

Table 3.0 Output of the simulation

Months	Simulated cooling load kWh
JAN	58,834
FEB	61,706
MAR	67,873
APR	75,344
MAY	68,338
JUN	73,941
JUL	71,071
AUG	68,066
SEP	66,495
OCT	62,361
NOV	67,102
DEC	65,600
Annual (kWh/yr)	806,729
Floor area (m^2)	3666
Building cooling load index kWh/m^2/yr	**220.0**

Table 4.0 Energy index based on MSB logged data from SIRIM report[5]

Item	Values
Electricity consumption (**logging**-kWh/day)	1548
Operating time (days/yr)	275
Total air conditioning electricity consumption (kWh/yr)	425,700
COP (assumed)	2.0
Building cooling load (kWh/yr)	851,400
Floor area (m^2)	3,666
Building cooling load index (kWh/m^2/yr)	**232.2**

Table 5.0 Energy index based on rated power from SIRIM report [5]

Item	Values
Electrical load (kW)	152.2
Operating Hours (hr/yr)	2730
Total air conditioning electricity consumption (kWh/yr)	415,506
COP (assumed)	2.0
Building cooling load (kWh/yr)	831,012
Floor area (m^2)	3,666
Building cooling load index (kWh/m^2/yr)	**226.6**

Table 6.0 Energy estimation using energy model

Item	Values
Shading coefficient(SC)	0.69
Window-wall-ratio(WWR)	0.40
Set-point temperature(AT)	22^0C
Equipment load(EQ)	15W/m^2
Lighting Load(LL)	16 W/m^2
Occupancy density(OC)	0.1 person/m^2
Estimated building cooling load index using this energy model: $Cooling\ Load = [464 + 57SC + 121WWR - 17AT + 2EQ + 2LL + 170OC] \quad kWh/m^2/yr$	216.7 kWh/m2/yr

Table 7.0 Energy index with different methods of estimation

Methods	Building cooling index ($kWh/m^2/yr$)	± percentage above or below simulated value
Simulation	220.0	-
MSB logged data	232.2	+5.5%
Rated power	226.6	+3.0%
Energy model	216.7	-1.5%