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Energy Modeling and Chillers Sizing of HVAC System for a Hotel Building

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Abstract

With energy shortage issue rises, value of energy conservation grows. The energy consumption of HVAC system reaches about 50% of the building especially for the hot and humid ambient condition in Taiwan. Energy modeling code eQUEST was applied to evaluate the energy consumption of a hotel building. Through the validation of simulation data and field measurement data, the energy-efficient chiller sizing approach can be obtained. The results revealed that the energy saving of 10.5% can be achieved by optimizing the chiller capacity sizing. The approach by energy modelling in this study will identify the best practice under limited budget as well as to reduce the trial-and-error effort while chiller sizing decision for energy saving have to be carried out.

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Keywords: chiller, energy modelling, field measurement

1. Introduction

Energy consumption in buildings is always the main concern and retains a lot of research attention. However, due to the complexity of the facilities, it is quite challenging to approach the optimization of energy usage of all facilities. Energy modelling through commercial available computer code is widely accepted to evaluate energy consumption for whole building simulation. Yezioro et al. [1] conducted the research to evaluate different simulation tools for building performance. More detail simulation presented better results for energy consumption data. The building energy simulation using typical meteorological year data in different climate zone was conducted extensively [2].

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A case study using computer simulation code was conducted to assess different energy-saving approaches to determine the best solution for facility engineer [3]. Another case study for energy simulation to reduce energy consumption of building by using the control optimization strategy was investigated comprehensively [4]. The energy simulation code eQuest [5] was applied to envelope design of residential building in different climate zone of China. The best energy saving strategy for HVAC system could be developed through energy modelling to evaluate the effects of envelope design on energy consumption of air conditioners [6].

The strategy for designing energy-efficient chillers in building is essential in subtropical regions. Yu et al. [7] demonstrated the energy saving of 10.1 % in a hotel could be achieved by energy efficient operation of chillers. Besides, the part load performance of chillers with variable speed control was displayed [8]. The criteria for implementing energy-saving strategy for chillers could be develop accordingly to satisfy the cooling load profile of a given building. Furthermore, Li and Wu [9] also investigated the energy simulation and analysis on the cooling and heating for the building simultaneously.

2. System Description and Energy Modeling

The investigated hotel building is located in central Taiwan under subtropical weather condition. Its floorage is about 23,021 m2 from B2 floor to 13F. Public areas including lobby, reception, conference rooms and restaurants are located from 1st floor to 3F. There are 200 hotel rooms with almost the same layout from 4F to 13F. The HVAC facilities including chillers, pumps and cooling towers are located on roof top. Overall cooling capacity of 720 refrigeration tons (RT) are supplied by three screw-type chillers of 240RT and one 100RT heat pump to meet cooling or/and water heating options. The specifications of HVAC facilities are demonstrated in Table 1. Chiller 1 (CH1) and Chiller 3 (CH3) are constant speed driven chiller operated alternatively for base cooing load demand, while Chiller 2 (CH2) is variable speed driven chiller with inverter for peak cooing load variation. Cooling capacity of chiller and cooling tower along with the specification of cooling water pumps and chilled water pumps are listed in Table 1 for typical input parameters to facilitate the energy modeling of the building.

The energy modeling by eQuest was conducted based on all of the existing building information from building survey, documentations and drawings. The geometrical model for simulation of investigated building is shown in Fig. 1. Typical meteorological year (TMY) data were adopted to conduct energy modelling. The schematic diagram of the HVAC system is displayed in Fig. 2. To improve the accuracy of simulation results, the actual performance curves of the chillers and pumps were input by curve fitting. Furthermore, all of the air handling units for public areas and fan-coil units for the guest rooms along with primary air handling units for fresh air cooling for the HVAC system were input according to the specification of the facilities. Validation of the simulation model with actual on-site measurement electricity data has been conducted as well. Besides, the model was assessed based on 2013 electricity bill data. Validation simulation has been conducted and compared to actual field measurement data and actual electricity bills to assess the variation of energy consumption.

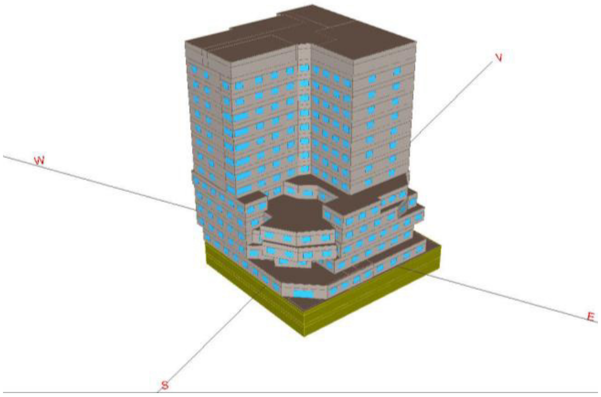
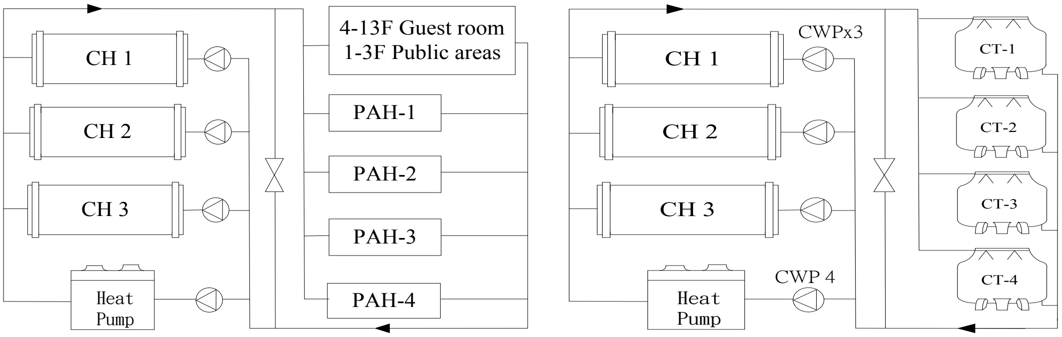


Fig. 1. geometrical model for simulation of the investigated building



(a) Chilled water loop (b) Cooling water loop

Fig. 2. schematic diagram of HVAC system

Table 1. Specification of HVAC equipment

Symbol	Capacity(RT)	Power(kW)	Type
CH-1	240	170	Screw
CH-2	240	170	Screw
CH-3	240	170	Screw
HP	100	120	Screw
	Flow (l/min)	Head (m)	Power (kW)
CHP-1	2420	37.7	30.0
CHP-2	2420	37.7	30.0
CHP-3	2420	37.7	30.0
CHP-4	1525	35.7	18.5
CWP-1	2908	21.4	18.5
CWP-2	2908	21.4	18.5
CWP-3	2908	21.4	18.5
CWP-4	1375	19.4	11
	Flow (l/min)	Power (kW)	Type
CT-1	13000	7.5	Open Tower
CT-2	13000	7.5	Open Tower
CT-3	13000	7.5	Open Tower
CT-4	13000	7.5	Open Tower

3. Results and Discussion

To evaluate the energy modeling data by eQuest software, the field measurement data from building energy management system (BEMS) as well as from field measurement were recorded and compared for one year. Calibration and verification of energy consumption data were modified to fit the actual energy consumption data from BEMS. As shown in Fig. 3, the energy simulation data present good agreement with field measurement data. The acceptable average error percentage is about 6% (ranging from 2.87% to 11.2%) between simulation and measurement for every month in one year. After applying the building energy modelling, the monthly load profile of HVAC system for the hotel building can be obtained accordingly. January presents the highest error percentage of 11.2% due to the minimum cooling load might be covered by heat pump chilled water without using chiller in January (winter).

By examining the operation hours with partial load ratio profile of each chiller for one year, different options for chiller sizing should be evaluated and compared extensively for energy saving concern (see Fig. 4). CH1 chiller operates with more operation hours at high partial load ratio 70-80% and 90-100% which reveals higher performance for chiller in terms of energy saving. CH3 chiller operates with similar operation hours with CH1 chiller at high partial load ratio 90-100% and 80-90%. However, CH2 chiller operates more frequently at the lowest partial load ratio at 0-

10%, 10-20% and 20-30% which cannot meet the design requirement for energy saving concern. Besides, the utilization rate (under operation) of each chiller can be obtained from BEMS system. The utilization rate for CH1, CH2, CH3 chiller presents at 29.9%, 29.4% and 41.3% respectively, which reveals very low utilization rate at the average of 33.5% for chillers operation. It reveals that improvement should be enhanced for chiller operation strategy.

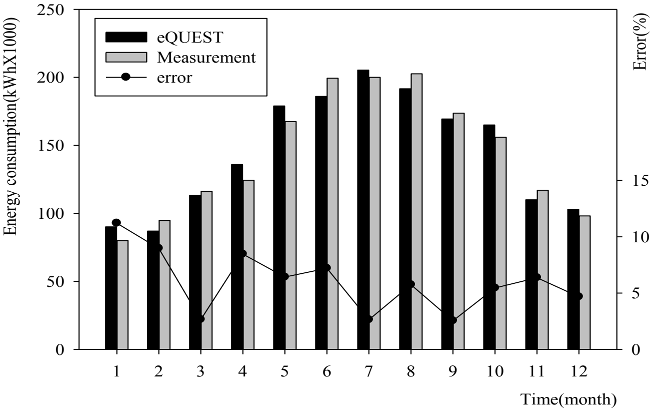


Fig. 3. comparison of simulation and field measurement data

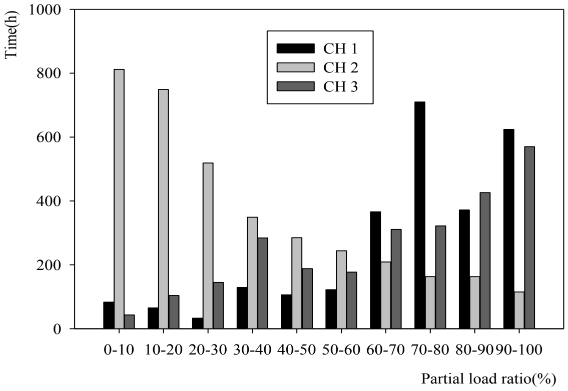


Fig. 4. partial load ratios for chillers

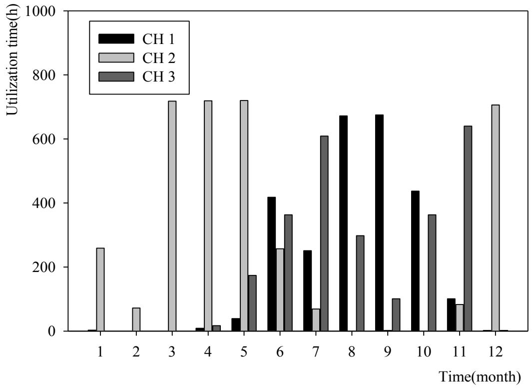


Fig. 5. operating hours by month for chillers

Fig. 5 depicts the operating hours by month for chillers in the hotel building for one year. Obviously, the CH1 chiller operates frequently during June to October to meet the cooling load demand of summer season. CH3 chiller operates similarly during summer season due to CH1 and CH3 operated alternatively to avoid chiller operation fatigue. CH2 chiller operates frequently only during off peak winter season. However, by examining from operating hours in terms of cooling capacity for chillers shown in Fig. 6, the peak cooling load demand for the hotel building is about 461 RT. It also presents most of cooling load demand is lower than chiller capacity. The operation hours for cooling load over 360 RT last for only 153 hours, which is less than one week. It reveals that partial load operations for chillers are frequent and downsizing for chiller is feasible for energy saving concern. Energy modeling tool is quite suitable to provide the reliable solution for chiller sizing based on cooling load profile and calculation.

Different case for chiller sizing option for energy modelling is possible. The base case is the original case with screw chiller CH1 (or CH3) and CH2 (240RT each) and one heat pump chiller/heater (100RT). There exists different option for chiller sizing to improve energy consumption. Different cases of chiller sizing option for energy modelling will be compared accordingly to optimize the energy consumption. Fig. 7 shows the energy consumption annually for one chiller sizing options. This case based on the same CH1 (or CH3) but along with small chiller capacity for CH2 (180RT). It demonstrated better energy performance than the original base case at the average of 10.5% energy saving per month. It presented substantial energy-saving of 12.2 MWh in July during summer season, while overall energy consumption reduction of 191.4 MWh year round. It revealed the energy saving for HVAC system can be obtained substantially by optimizing the chiller sizing through energy modelling.

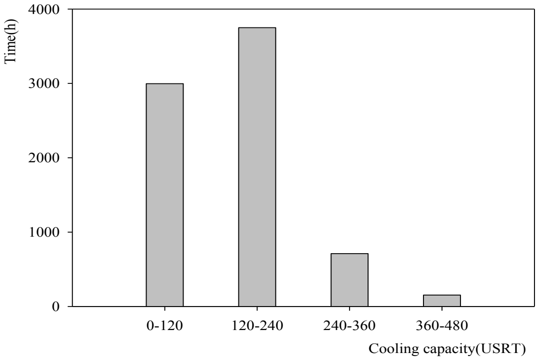


Fig. 6. operating hours vs cooling capacity for chillers

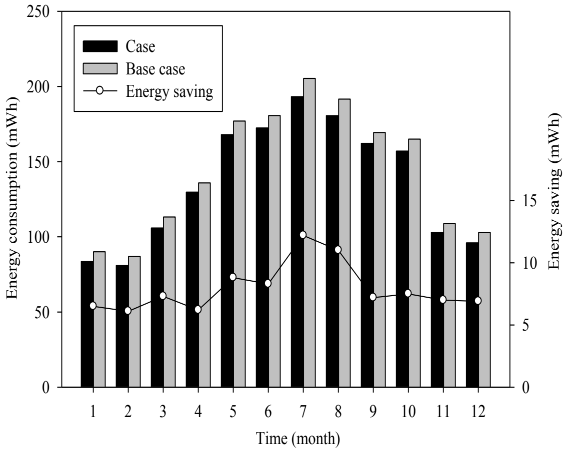


Fig. 7. energy consumption and saving for chillers

4. Conclusions

This study presents the strategic approach on energy saving analysis of a hotel building by applying energy modeling through chiller sizing. With the cost of energy rises, the value of conservation grows. Energy modeling tool eQuest has been applied to verify and predict the energy consumption satisfactorily based on actual performance data of HVAC facilities such as chillers and pumps. The energy modelling data revealed good agreement with energy consumption data from BEMS data. Through the optimizing of chiller sizing for different cases, substantial energy consumption reduction can be obtained in a feasible way. Besides, the load profile of a specific building can be achieved hourly, daily and monthly. It will provide valuable information to the facility engineers facing the energy cost rising. The approach by energy modelling in this study will identify the best practice under limited budget as well as to reduce the trial-and-error effort while chiller sizing decision for energy saving have to be carried out.

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