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OPTIMUM STORAGE SIZE FOR THERMAL ENERGY STORAGE SYSTEM

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ABSTRACT

Thermal Energy Storage (TES) system has been established for quite some time and already being used in many places throughout the world. Generally, TES is good for a country because it will reduce the overall maximum demand by restructuring load distribution between peak and off-peak period. However, the electricity tariff such as Medium Voltage Peak/Off-Peak Commercial Tariff (C2) should be attractive so that the user would get the benefit from such system. For instance, the off-peak energy (kWh) rate must be low enough and maximum demand (kW) rate should be the same with the maximum demand for each kilowatt of Medium Voltage General Commercial Tariff (C1). This paper investigate the overall cost, using C1 tariff as a benchmark to compare with the C2 tariff based on the implementation of TES system in Engineering Complex UiTM Malaysia. Extra load, energy and cost as the result of the TES implementation were also evaluated in this study. The maximum cooling load required is 35,000 RTh with maximum cooling load demand is 3,500 RT. The results, showed that the TES system investigated in this study was best used with 100% storage capacity through the use of C2 tariff for optimum cost saving.

Keywords: TES system, C1 tariff, C2 tariff, maximum demand.

INTRODUCTION

Malaysian energy policy is to promote an efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption [1]. The need for the best energy management practice on Malaysian building, to achieve thermal comfort in the built environment, is the inspiration of this study. The need for the best energy management practice on Malaysian building, to achieve thermal comfort in the built environment, is the inspiration of this study.

The United Nations appointed an international commission in 1983, to propose strategies for "sustainable development"-way to improve human well-being in the short-term without threatening the local and global environment in the long term. The Commission was chaired by Norwegian Prime-Minister Gro Harlem Brundtland, and its report "Our Common Future", published in 1987 was widely known as "The Brundtland Report". The reports define sustainable development as "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2]. This energy management studies in building is in line with the spirit of the sustainable development agenda.

Nowadays, a lot of countries in the world use Thermal Energy Storage (TES) system as a cooling system to replace the conventional system. This is because the use of this system can shift the power consumption at peak hours normally during the day to the night time.

Theoretically, example of 600 kW of chiller can supply cooling to the building by 900 RT. If demand from building is less than 900 RT, the performance for chiller would an improvement drop. In Malaysia, the maximum kW/RT for chiller is 0.9 and minimum for coefficient of performance (COP) is 3.9 [3]. If value of kW/RT for chiller is more than one, therefore an increase in building cooling demand is warranted; to be more than 600 RT. Figure-1 shows the rating system for the chiller.

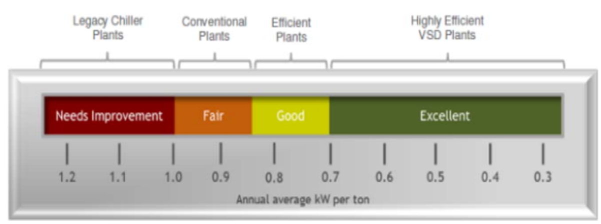

Figure-1. Rating systems for efficiency in kW/RT for chilled water plants [4].

Building chillers use more than 50% of its annual electricity use, thus makes the chiller an important equipment to handle. It should be put in the highest priority for any facility energy management system to be maintained. Consequences from lack of maintenance and proper operation would result in higher energy costs, lower system performance and reliability, and decrease equipment life. Factors contributed to the reduction in chiller efficiency are:

1. Poor operating practices
2. Ignored maintenance
3. Ignored cooling tower maintenance
4. Oversizing
5. Ignoring alternate-fuel chillers

Malaysia is a country located near the equator with an average temperature varied from 20°C to 32°C. Air-conditioning systems for countries near the equator normally would account to about 50% of electrical consumption [5]. The statistical data shows that 57% of offices building electricity bills in Malaysia are consumed by air-conditioning systems [6].

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In [7] stated that more than 30% of power consumption was used for air-conditioning system and it remains a major cause that increases the peak load in Taiwan. In [8] have indicated that the main contributor to the increase in energy consumption in buildings is the use of air-conditioning system. Usually, to achieve thermal comfort, significant amount of electricity bill will be for air-conditioning.

The main objective of this study is to determine the suitable tariff of either C1 or C2 for TES system that is already offered by the power utility. Size of ice storage which is 0% and 100% were used to optimize the usage of TES system, so the running cost of the system is lowest. All calculation is considered to determine energy, extra cost and total cost.

METHODOLOGY

Currently Engineering Complex use four chillers to supply cool to the building during peak period and build ice during off-peak period. However, in order to meet the demand of 3500 RT of building load using full storage, the Engineering Complex four chillers are not enough. In this section, overall cost will be calculated, using C1 tariff as a benchmark to compare with the C2 tariff.

Figure-2 and Figure-3 show the estimated electrical cooling load for 0% and 100% storage of ice. These figures can generally be used to describe the chillers and pumps kilowatt (kW) usage.

1. 0% storage, no process of ice making because the demand is totally supplied direct by chiller during peak period.
2. No chiller needed for 100% storage to supply cooling but it would still need pumps to distribute the cooling during peak period.

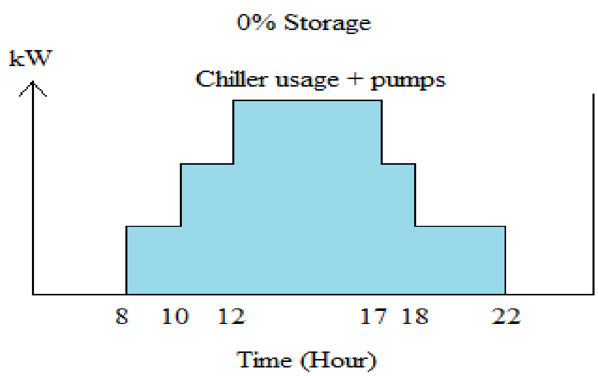

Figure-2. Estimated electrical load for 0% storage.

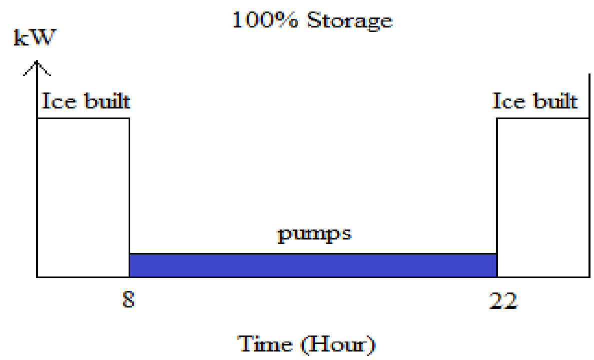

Figure-3. Estimated electrical load for 100% storage.

To calculate the overall cost, C1 tariff was used as a benchmark to compare with the C2 tariff. It is also used to determine the reference energy utilization to produce directly the amount of cooling requirement. The total cost cooling load (RTh) based on the requirement of a typical day will be determined using C1 tariff. Table-1shows the electricity rate of the C1 tariff from power utility.

Table-1. Electricity rate structure for C1 tariff.

Tariff	Description	
C1	For each kW of maximum demand per month	RM 30.3/kW
	For all kWh	RM 0.365/kWh

To calculate the electricity bill for TES system, the C2 tariff would be normally be used. The electricity rate for C2 tariff is higher than C1 tariff. Table-2 shows the electricity rate of C2 tariff from power utility.

Table-2. Electricity rate structure for C2 tariff.

Tariff	Description	
C2	For each kW of maximum demand per month during the peak period	RM 45.1/kW
	For all kW during the peak period	RM 0.365/kWh
	For all kW during the off-peak period	RM 0.224/kWh

Electrical load from chillers are needed to determine both periods, either during peak hour or off-peak hour. Each of the periods is at a different rate for C2 tariff. So the data from the calculation for peak hour and off-peak hour need to be separated. The power for one chiller is around 600 kW.

Calculation for electrical cost is based on the tariff from the power utility. The total kWh from the chiller will be considered in the calculation for electrical cost.

Power utility also charge user for maximum demand per day in a month during peak period. It means

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that the highest kW for each month used by chiller during peak period was taken and was charged RM 45.1/kW.

An example of extra electrical load in this system is pumps, cooling tower, etc. Each of these extra electrical loads has their own power (kW) that should be considered in this study. The calculation for cost (RM) of extra electrical load is no different from the electrical cost (RM) of the chiller.

Direct cooling or conventional system does not need storage to supply cooling. So, power for chiller during off-peak period was assumed to be zero. All of the calculation for kWh and RM only involved peak period. Calculation for extra cost is same as the calculation for electrical cost, which needs to be considered from the tariff of the power utility.

RESULTS AND DISCUSSIONS

It was assumed that six chillers are fully operational during off-peak period to make ice for the whole day. Calculation is based on the real power of the chillers and pumps. Latest tariff of C1 and C2 from the power utility were used. This system has been supported by the 4 most important sub-systems known as the chiller, ice cell, heat exchanger and cooling tower. The function of chiller is to chill the water and ethylene glycol solution for the heat exchange, and allow air conditioning of the building while cooling tower is to cool the warm water from the condenser water pump. Heat exchanger is the device that was design for efficient transfer of heat from one fluid to another fluid over a solid surface, and finally the ice cell storage which functions is to store the ice.

Table-3. Energy used by various percentages for C1 and C2 tariff.

Storage	Energy (kWh)			
Percentage (%)	Peak	Off-Peak	Total (C1 or C2)	Extra
0	33,000	0	33,000	0
100	11,200	42,000	53,200	20,200

Table-4. Percentage of extra cost.

Storage (%)	Off-peak		Cost	Peak		Cost	Maximum demand		Cost/day	Total cost	% extra cost
	Rate	kWh	(RM)	Rate	kWh	(RM)	Rate	kWh	(RM)	(RM)	(0% as a benchmark)
0	0	0	0	0.365	33000	12045	30.30	3000	3030	15075	–
100	0.224	42000	9408	0.365	11200	4088	45.10	800	1203	14699	2.50

Table-5. Total cost/day for C1 tariff.

Storage	RM		
Percentage (%)	**Peak**	**Off-Peak**	**Total/Day**
0	15,075	0	15,075
100	20,226	0	20,226

Table-6. Total cost/day for C2 tariff.

Storage	RM		
Percentage (%)	**Peak**	**Off-Peak**	**Total/Day**
0	16,555	0	16,555
100	5,291	9,408	14,699

Extra energy and cost

As shown in Table-3, energy being used would increase as the percentages increases. 0% storage used more energy during peak compared to 100%. However, during off-peak period, 100% storage is the highest energy used and that makes up to 20,200 kWh of total extra energy when compared to 0% storage.

From these two different scenarios of storage; 0% and 100% storage (see Table-4), a comparison study was conducted to look into the percentage of extra cost using 0% as a benchmark against 100% storage in terms of rate off peak, peak and maximum demand (MD).

It was found that the extra cost would increase if the total energy used increase. Additionally, 100% storage can save cost around 2.5% compare to 0% storage.

By using 0% storage or direct cooling from chiller, cost during peak and cost/day for maximum demand is very high compared to 100% storage because of full usage of chiller. 100% storage takes advantage of the off-peak rate by charging the ice.

Totalcost by using C1 and C2 tariff

Referring to the charge by power utility, calculation for peak hour (RM), off-peak hour (RM) and total (RM)/day can be obtain as shown in Table-5 and Table-6. Tariff C1 and C2 would then be used as a comparison in each percentage.

From Table-5, direct cooling from chiller to the building without any assistance from ice storage would result in the lowest RM if C1 tariff is applied to 0% storage. The highest RM/day however is by using 100% which is at RM 20,226. It is worth to note that for peak and off-peak rate for C1 tariff is the same which is RM0.365.

Result by using C2 tariff however, contradict with the C1 result. Most saving percentage by using C2 tariff is at 100% or full storage which is at RM 14,699. From the four results of C1 and C2 tariff, it can be concluded that the best result for total RM/day is 100% storage by using C2 tariff, followed by 0% storage (C1 tariff), 0% storage (C2 tariff) and lastly 100% storage (C1 tariff).

Owing to Malaysia climate factor, Malaysian buildings can save their energy and cost by using full storage (100%). Full storage system builds the ice during off-peak period from 10pm to 8am, thus taking the advantage of off-peak period rate. Six chillers are sufficient to produce ice in the tank for 100% storage, and then the stored ice would be used during peak hours to supply the building. So, there is no need for a chiller unit during peak hours which has been proven to be able to reduce the bills. Additionally, full storage is the best system for cost saving because it can reduce the total maximum demand for each kW per month.

CONCLUSIONS

The main purpose of using Thermal Energy Storage system is to take an advantage of the low off-peak rate, thus reducing the overall electricity cost. Nevertheless, TES system requires extra energy due to extra pumps and introduces more losses [9]. The tariff rate for maximum demand is also higher for C2 tariff compared to C1 tariff by 48.9%, thus increases the total cost. The high initial cost for the installation of TES must also be considered to determine the feasibility of the TES system.

The potential cost saving of TES system for the application in Malaysia is investigated in this study. The result can conclude that the best TES system is by using 100% storage with C2 tariff. So, the electricity tariff should be revised to be more attractive to the user. In Engineering Complex, UiTM Shah Alam, full storage (100% storage) is the best solution to reduce the electricity bill by using TES system. However, if user still want to use below 100% storage, it is better to apply 0% storage with C1 tariff. From calculation done in this study, the advantage by using 100% storage (C2 tariff) make it more applicable than other storage percentage. It can save about RM11, 280 per month. Nevertheless, the present system only has four chillers and the electrical system only support four chillers.

With maximum cooling load demand at 3500 RT and 10 hours charging period, six chillers are required to produce ice to use during peak period. The optimum result for this study is by using 100% storage where the cost is RM 14,699 per day by using C2 tariff. The percentage saving of using 100% storage compared with 0% storage is 11.21%. In a month, 100% storage can save around RM 56,000 by C2 tariff.

REFERENCES

[1] Ministry of Energy, Green Technology and Water (KeTTHA). 2005. National energy policy objectives. KeTTHA, Putrajaya, Malaysia.

[2] Boyle G., Everret B. and Ramage J. 2003. Energy systems and sustainability. Oxford University Press, England, UK.

[3] Department of Standards Malaysia. 2007. Malaysia Standard-MS 1525:2007-Code of practice on energy efficiency and use of renewable energy for non-residential building. http://www.msonline.gov.my/download_file.php?file=14239&source=production.

[4] T. Hartman. 2001. All-variable speed centrifugal chiller plants. American Society of Heating, Refrigerating and Air-Conditioning Engineers Journal. 43(9): 43-53.

[5] R. Saidur, H. H. Masjuki and M. Y. Jamaluddin. 2007. An application of energy and exergy analysis in residential sector of Malaysia. Journal of Energy Policy. 35(2): 1050-1063.

[6] R. Saidur. 2009. Energy consumption, energy savings, and emission analysis in Malaysian office buildings. Journal of Energy Policy. 37(10): 4104-4113.

[7] H. J. Chen, D. W. P. Wang and S. L. Chen. 2005. Optimization of an ice-storage air conditioning system using dynamic programming method. Applied Thermal Engineering. 25(2-3): 461-472.

[8] B. A. Habeebullah. 2007. Economic feasibility of thermal energy storage systems. Energy and Buildings. 39(3): 355-363.

[9] W. M. Dahalan, A. G. Othman,M. R. Zoolfakar, P. Z. M. Khalid and Z. I. Rizman. 2016. Optimum DNR and DG sizing for power loss reduction using improved meta-heuristic methods. ARPN Journal of Engineering and Applied Sciences. 11(20): 11925-11929.