Benefits of Cool Thermal Storage in Thailand

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ABSTRACT

The use of thermal storage on a large scale to provide a cool reservoir for use in peak periods is an attractive financial option for large hotels, hospitals or office blocks. This enables the refrigeration plant to operate more effectively and to be completely or partially shut down during peak periods when the demand can be met in full or in part from the cool store. In this paper an overview is given of the power generation capacity and costing structure in Thailand and a typical load profile is presented to illustrate the advantages to be gained by shifting plant operation to off-peak periods. Specific load calculations have been utilized to demonstrate the cost savings possible by incorporation of such a cool thermal storage system into a traditional refrigeration and air conditioning plant for a major hotel complex.

1.   CURRENT ELECTRICITY GENERATION SITUATION

Thailand has approximately 17 500 MW of installed electricity generation capacity [1, 2]. In 1996, this plant generated roughly 82 billion kWh of electricity. The Electricity Generating Authority of Thailand (EGAT) has projected that the demand for electricity from 1997 to 2001 will increase on average 7.3% or 1200 MW per year. Note that the initial cost estimated by EGAT for a coal fired power generation plant in 1994 was about 18,000 to 29,000 Baht/kW [3].

Historically, the load shape of the Thailand system is like a bell that has one highest point. The peak of the curve is in the evening, during 18:30 to 21:00 hours. While the peak load for business buildings is in the afternoon. EGAT has in place many major Demand Side Management (DSM) programs and has also restructured its tariffs to ensure that peak loads are charged at a very high rate compared with those in non-peak periods [4].

The time of day (TOD) tariff is used to induce users not to use electricity during peak time. The principle is that the highest rate will be applied to ones that use electricity during the peak period and a very low rate is applied in the off-peak period. The tariff will be applied to medium-scale users whose electricity demands exceed 30 kW and to large-scale users whose electricity demands exceed 2000 kW. The tariff comprises of a flat energy charge of 1.07 Baht/kWh (or USc 3.06 at 35 Baht/US$) and TOD demand charge, which is shown in Fig. 1.

It is clear that if users can avoid using electricity in the peak time they will be able to save operating energy costs. This leads to the idea of load shifting to off-peak period.

2.   DEMAND SIDE MANAGEMENT PROGRAM

The Demand Side Management (DSM) program was invoked by EGAT in 1993 in order to control
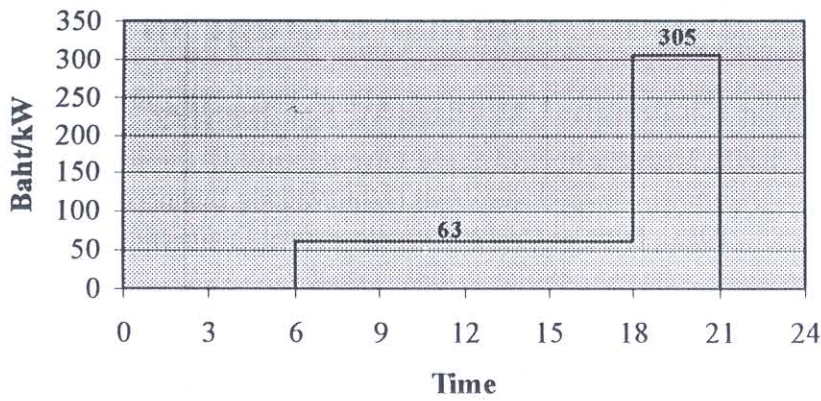
Fig. 1. TOD tariff for medium and large scale enterprises in Thailand.

and change the pattern of the increasing demand of electricity from users. The principal objective of this program is to modify the Thailand load shape. Many programs are involved in this activity such as Energy Efficient Fluorescent Programme, Energy Efficient Refrigerator Programme, Energy Efficient Air-Conditioners Programme, and Green Building Programme.

The main target of the DSM program is the shifting of the country electricity load for cooling. Report from the Thailand Environment Institute [3] shows that, in 1994, cooling applications in Thailand consumed approximately 16% of the country's total electricity consumption and the trend is increasing. This increasing electricity load can be overcome by applying cool thermal storage to conventional air-conditioning systems.

3.   COOL THERMAL STORAGE

Cool thermal storage is the storage of thermal energy at temperatures below the nominal temperature required by the space or process [5]. It is an economically attractive approach for cooling applications in Thailand. This technology is appropriate because the following conditions apply for air conditioning in Thailand:
- Cooling loads are cyclical in nature,
- Electricity costs are time-dependent, and
- Electricity supply from the utility is limited.

Coolness is produced by chillers during off-peak or partial peak periods and stored in some medium. During peak demand period, the coolness is extracted from the medium and used as required. It should be noted that the cool storage is a method mainly used for economic reasons associated with shifting peak load not for energy conservation.

4.   MEDIA USED FOR COOLING THERMAL STORAGE

The cool thermal storage can be classified by the medium that is used to store cooling. The most well known medium is water because of its high heat capacity compared to other common fluids. In addition, its chemical and economic properties are suitable for large-scale applications. Table 1 shows the comparison of the heat capacity of common media.

Table 1 Comparison of the Heat Capacity of Common Media

Liquid	Water	20% Brine	Methanol	Propylene Glycol
Cp (J/kg K)	4 180	3 110	2 470	2 504

Ice and Phase Change Material (PCM), such as polymers and hydrated salts, are other candidates for the storage medium. These two media provide greater storage capacity compared to water because they store energy in the form of latent heat. For example, one kilogram of ice stores 334 kJ of coolness at 0° C while one kilogram of water at 10° C temperature drop stores only 42 kJ of coolness.

5.   CHOICE OF STORAGE MEDIA

Storing coolness in the form of ice is the most appropriate for cooling applications in Thailand because of its desirable properties. It can store more coolness than other media can. Therefore, it requires the least floor area and volume. The ice is made from water, which is cheap and abundant in all zones. The chemical properties of water are also satisfactory to users. There is very low chance of corrosion if the water is purified.

Ice storage systems can be classified by their ice production process into five categories [5], which are:
- External Melt Ice-on-Coil Systems;
- Internal Melt Ice-on-Coil Systems;
- Encapsulated Ice Systems;
- Ice Harvester Systems; and
- Slurry Ice Systems.

6.   FULL OR PARTIAL SYSTEMS

There are two distinct designs of cool thermal storage: partial and full storage designs. Both of them are mainly used to shift peak load. The full storage designs are used to decouple the operation of the cooling generating equipment from the peak-cooling load. For example, the peak cooling is utilizing the storage while the refrigeration equipment is idle. The full storage designs are suitable for applications in which the cooling period is short and high peak demand charge is applied.

The partial storage designs provide the best economic choiçe. Although they do not shift the whole peak load as the full storage designs do, they often offer the prospect of using lower chiller sizes.

7.   QUANTITATIVE ANALYSIS

A hotel nominal system cooling capacity of 1000 kW is used to illustrate quantitative data. This hotel operates 24 hr a day and has 22 248 m² of floor area [6]. The Coefficient of Performance (COP) of the chiller used in this study is assumed at 2. The maximum cooling load of the hotel is in the peak period, as can be seen clearly in Fig. 2. A simple calculation has been carried out in order to examine benefits of applying cool thermal storage. There are three designs of the cool thermal storage that are investigated: no-storage, partial-load storage, and full-load storage.

7.1.   Reduced Chiller Size

A 1 000 kW chiller is required for the non-storage air conditioning system. If the partial load design is applied to this hotel the size of the chiller can be reduced considerably to about 630 kW. For the full-load design, a larger chiller of 750 kW will be required.

7.2.   Capital Cost Saving

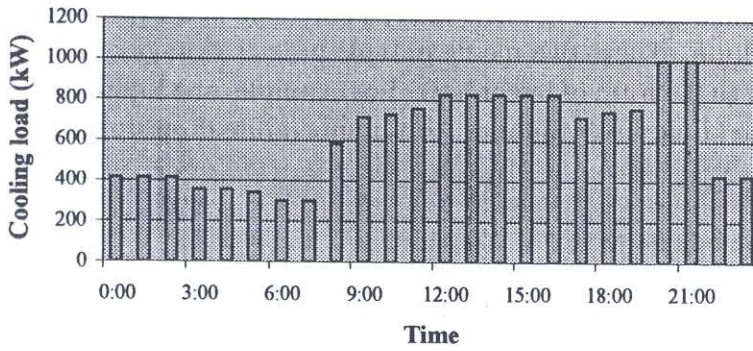The reduced equipment size, as discussed in the previous section, will lead to reduction in

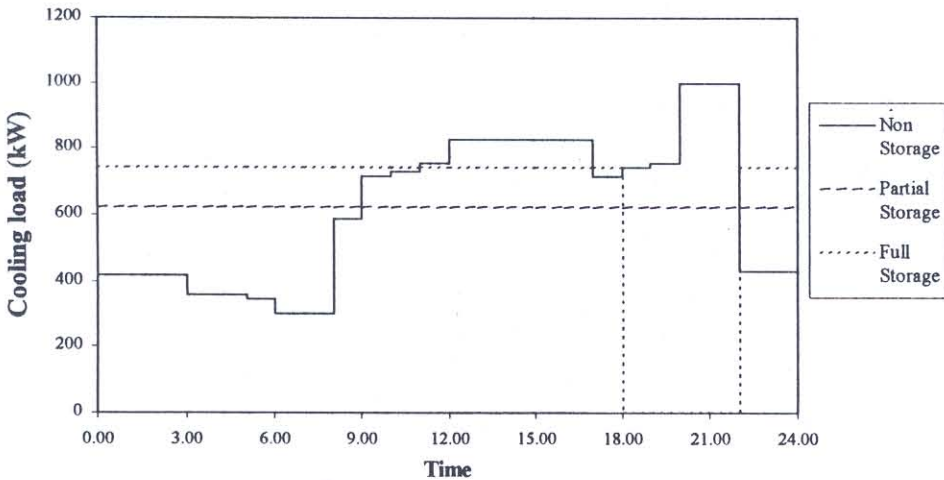Fig. 2. A typical hotel cooling load.

Fig. 3. Cooling load comparison: Non, Partial, and Full storage designs.

capital cost of the air conditioning system. This reduction includes saving due to reduced water and air piping systems. The cool thermal storage systems provide low temperature air and water, which contain higher cooling capacity. Moreover, other components such as pumps and fans also can be downsized.

7.3. Improved System Operation

Partial and full storage options allow de-coupling of load and operation of equipment. In these operations, the chiller is running at constant capacities: 620 kW for the partial storage and 745 kW for the full storage, while the cooling load requirement varies from 300 kW to 1000 kW. Steady operations minimise transient losses of the system.

7.4. Energy Cost Savings

It was found that the energy cost is decreased from 630,790 Baht/month (1.32 Baht/kWh$_c$) for the non-storage design to 572,967 Baht/month (1.20 Baht/kWh$_c$) for the partial storage design. The great cost decrease is in the full-storage design. Only 501,758 Baht/month (1.05 Baht/kWh$_c$) would need to be paid to an electricity provider. Approximately 22% (3500 kW) of the total cooling peak demand is shifted to the off-peak period by the full-storage option.

7.5. Estimated Investment Costs and Payback Periods

Installation and operating costs of ice thermal storage depends on a number of factors such as storage system, land and location of the building, and shape and size of the building. In this study, only

the costs of chiller and storage are compared. It was assumed that at the same site, the cost of chilled water distribution, and installation and maintenance costs are the same for every system. Therefore, these costs are not included in this report. In addition, it was assumed that the ice stored is depleted at 10 PM each day. Then the ice starts to accumulate after this hour. Maximum coolness capacity required by partial storage and full storage are 2490 kWh_c and 3900 kWh_c, respectively. The cost comparison of each system is shown in Table 2. The price estimates of refrigeration plant and storage systems in Thailand were provided by Leeyutthanont [7].

Table 2 Cost and Saving Comparisons of Different Cooling Options (Baht).

Option	Conventional	Partial storage	Full storage
Chiller cost[1]	4,700,000	2,961,000	3,525,000
Storage cost[2]	-	2,490,000	3,900,000
Total system cost	4,700,000	5,451,000	7,425,000
Additional cost	-	751,000	2,725,000
Monthly energy cost	630,790	572,967	501,758
Monthly saving	-	57,823	129,033
Payback period (month)	-	13.0	21.1

Note: 1. Chiller cost: 4,700 Baht/kW.
        2. Ice storage cost: 1,000 Baht/kWh of coolness.

8.   CONCLUSIONS

The cool thermal storage can provide economic advantages for businesses to avoid high electricity charges due to TOD rate. A substantial saving in demand charge and peak-load shifting are the most attractive aspects of this technology. In addition, system efficiencies are also improved. For the investigated case study, the full-storage option can reduce the operational energy cost from 1.32 Baht/kWh_c to 1.05 Baht/kWh_c. The cooling peak load of 3500 kW can be shifted to off-peak period. Seventy percent of the original chiller size is required.

The partial-storage option offers the minimum chiller size. Only 60% of the original chiller size is required to meet the load. Its additional equipment, such as water pipes, air ducts, pumps, and fans, can be downsized since lower operating temperature is applied. For the investigated case study, the partial-storage option can reduce the operational energy cost from 1.32 Baht/kWh to 1.20 Baht/kWh. The estimated payback periods for partial storage and full storage options are about one and two years, respectively. Leeyutthanont [7] compared ice harvesting and ice-on-coil coolness storage systems for a shopping mall which cooling load is about three times larger than that considered by the authors. In his analysis costs of the chiller, storage system, land and other miscellaneous items were included. The payback periods were found to be 6 and 13 years. It should be noted that costs of land and other miscellaneous items were not included in the authors analysis. If these costs were included the payback period would be a bit longer but believed to be in the same orders of magnitude.

9.   ACKNOWLEDGEMENTS

neering, University of Melbourne. The sponsorship for this study at the University of Melbourne from the Thai Government is gratefully acknowledged by the authors.

10. REFERENCES

1.   United States Energy Information Administration (US-EIA). 1998. *http://www.eia.dos.gov/ emeu/cabs/thailand.html* [accessed January 1999].
2.   Department of Energy Development and Promotion (DEDP). 1995. *Electric Power in Thailand.* Bangkok, Thailand.
3.   Thailand Environment Institute (TEI). 1995. Electricity: 'Meeting Needs with Least Environment Impacts', 1995 Annual Conference, Bangkok, Thailand.
4.   Electricity Generation Authority of Thailand (EGAT). 1997. *Demand Side Management.* 1997 Annual Report, *http://www.egat.or.th/annual_97/dsm.html* [accessed January 1999].
5.   ASHRAE. 1995. *ASHRAE Handbook, Heating, Ventilating, and Air-Conditioning Applications.* SI Edition. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
6.   Chirarattananon, S. and Limmeechokchai, B. 1993. A new building energy-efficiency law in Thailand: Impact on new building. *Energy* 19(2): 269-278.
7.   Leeyutthanont, S. 1996. Feasibility Study of Thermal Storage for Air-conditioning Building. M.Eng. Thesis. Department of Mechanical Engineering. Chiang Mai University, Thailand. In Thai.