Impact of Thermal Energy Storage Application in the Commercial Sector on Power Generation in Thailand: A Scenario-Based Assessment

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ABSTRACT

Thermal energy storage (TES) for air conditioning has been included as a load management tool in the fledgling Demand-Side-Management Plans of the utilities of ASEAN countries. With a number of assumed penetration rates of TES application in commercial buildings in Thailand, we show that there are quantitative benefits in the improvement of the Thai utility's system operation, although TES is already attractive to the utility's customers under the present situation.

INTRODUCTION

Thailand has achieved sustained high economic growth for three decades and has experienced a high growth in the rate of electricity consumption as a consequence. Traditionally, the economy has been agriculture-based with the residential electric load dominating and causing a peak in the system load in the evening. The country is served by a single generation utility. Though the (Electric) Power Development Plan (PDP) puts an emphasis on system expansion to meet the load forecasted by the Load Forecast Working Group (LFWG) [2], the electric utility has adopted a Demand-Side-Management (DSM) Plan [3] to improve the system's load factor and increase efficiency in the use of electricity. The DSM Plan includes a program to encourage the use of thermal energy storage (TES) for air conditioning in the commercial sector, with the aim to influence the system load shape and increase the load factor. However, the DSM Plan has not been considered in the PDP. This paper attempts to provide a preliminary assessment of the impact of TES application in the commercial sector on the forecasted system load, and the consequential improvements in the system parameters. The assessment is based on three assumed penetration scenarios.

LOAD FORECAST AND THE POWER DEVELOPMENT PLAN

Load Forecast

The early electric load development was traditionally dominated by the increase in residential consumption, particularly due to accelerated rural electrification programs. The resultant load shape shown in Fig. 1, with a load factor of around 0.68, has not changed for two decades up to 1992, by which year over 95% of the country was electrified. The rapid change in the economy in recent years has however seen rapid growth in electricity consumption in the industrial and commercial sectors. This has lead to an increasingly significant second peak in the load shape in the afternoon, with an expected slight improvement in the load factor. Table 1 shows some pertinent figures of the recent past and forecasted system load. The shares of commercial customers, in the small and large commercial categories are also shown in the table. Small commercial customers are those whose demands are estimated to be below 30 kW, and not subject to demand charge, while large commercial customers are those whose demands exceed 30 kW, and are subject to demand charge.

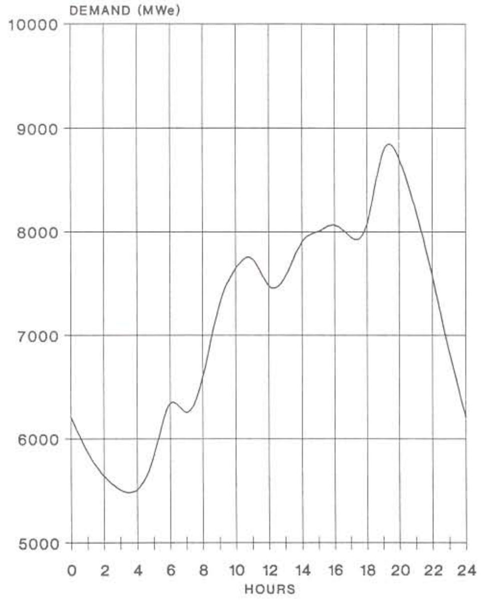

Fig. 1. System load shape for a typical day (1992).

Table 1. Recent past and forecasted system load.

Fiscal Year	Peak Demand (MW)	Energy (GWh) Commercial Small	Energy (GWh) Commercial Large	Energy (GWh) Total	Load Factor
Historical					
1987	4,734	2,980	2,068	28,193	0.68
1992	8,877	5,552	5,942	56,006	0.72
Forecast					
1996	13,103	8,150	10,339	83,896	0.73
2001	19,029	11,530	16,520	124,158	0.75
2006	25,371	15,381	22,887	169,545	0.76

The Power Development Plan

This plan identified the required long-term investment in system generation capacity to meet the demand load forecasted. The plan calls for a phasing in of facilities based on the use of imported coal after 1996, and the use of nuclear facilities towards the end of 2006, as against facilities relying on indigenous lignite and other sources, and imported oil in 1991. Table 2 provides details on the capacity mix according to the PDP.

TES APPLICATION IN COMMERCIAL BUILDINGS AND THE DSM PLAN

TES Application in Commercial Buildings

In tropical Thailand, comfort air-conditioning has reached saturation point for large commercial buildings, and almost reached saturation point for small commercial buildings. A thermal energy storage (TES) system produces ice or chilled water during the off-peak period, and the ice or chilled water is used as a supplement to air-conditioning during the peak period. Generally, TES costs more than a conventional air-conditioning system, but can become viable for commercial buildings if the

Table 2. Power generation facilities according to the PDP.

Type		Year			
		1991	1996	2001	2006
Lignite	(MW)	2069	2626	3226	5776
	(%)	21	18	14	19
Combined cycle	(MW)	2036	4326	4325	3666
	(%)	21	29	19	12
Gas/oil	(MW)	2580	3760	3750	3780
	(%)	27	25	16	12
Oil	(MW)	267	267	237	–
	(%)	3	2	1	–
Gas turbine & diesel	(MW)	266	1140	1440	1300
	(%)	3	8	6	4
Hydro	(MW)	2428	2665	3631	4431
	(%)	25	18	16	14
Coal/oil	(MW)	–	–	4200	4200
	(%)	–	–	18	13
Coal	(MW)	–	–	2000	6000
	(%)	–	–	9	19
Nuclear	(MW)	–	–	–	2000
	(%)	–	–	–	6

electric tariff possesses a high charge for electric power demand, or a high differential tariff charge for the peak period. A number of studies [4, 5] have indicated that under the present tariff, TES is viable for new buildings, and for those retrofitting air-conditioning systems. A few large commercial buildings are already reported to have installed TES systems. The electric load shapes for a typical day for large commercial buildings including offices, hospitals, and retail store buildings, appear in Fig. 2. Each of these already includes the electric load due to air-conditioning. The predominant types of large commercial buildings are offices, hotels, department stores, and hospitals. For small commercial buildings, the office type is predominant. Because of a large differential tariff charge on the peak evening period, the TES application in the demand-limited mode, where the chiller operates to store ice or chilled water during the non-peak period and stops operation entirely during the peak period, is the most feasible mode assumed here. The resulting load shapes are shown in Fig. 3 and Fig. 4 for the office and the hotel buildings, respectively.

The DSM Plan

A five-year Demand-Side-Management Plan with a total expenditure of US$ 180 millions has been adopted by the utility since 1992. The plan contains several programs on load management, including thermal energy storage application, which is expected to lead to the development of a new tariff to support TES systems for load management. So far as known, no attempts have been made to start the program.

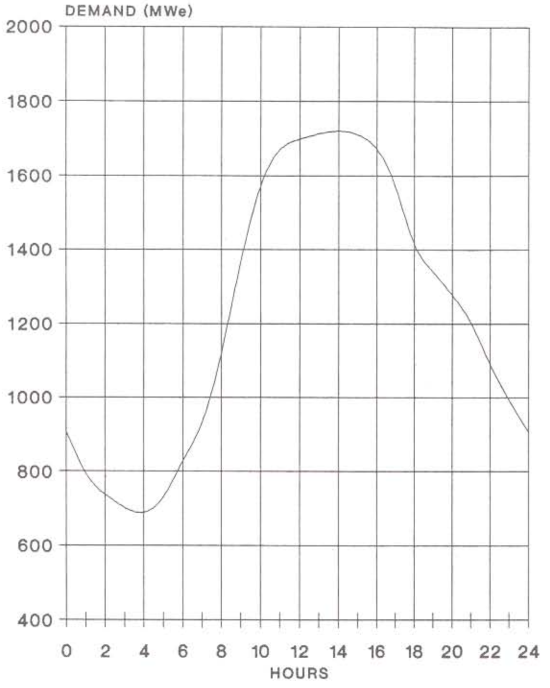

Fig. 2. Load shapes of large commercial buildings.

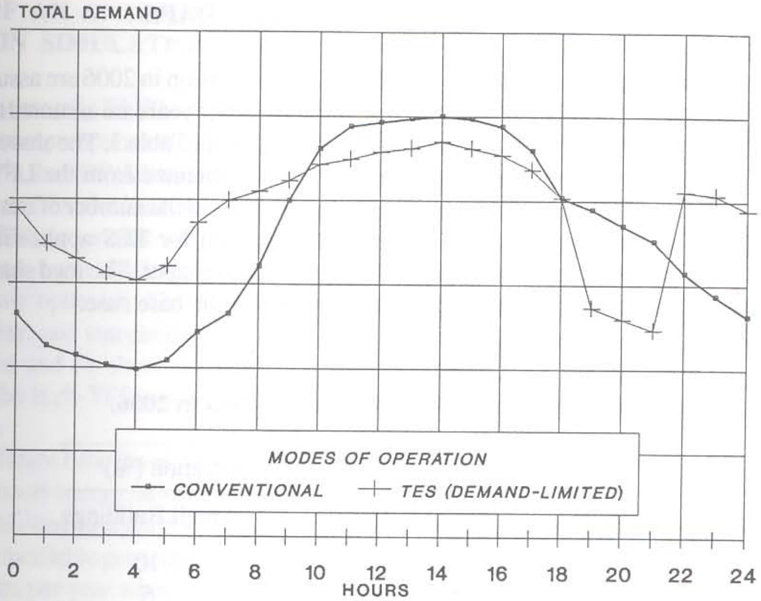

Fig. 3. Load shapes of large office buildings with TES in demand-limited mode.

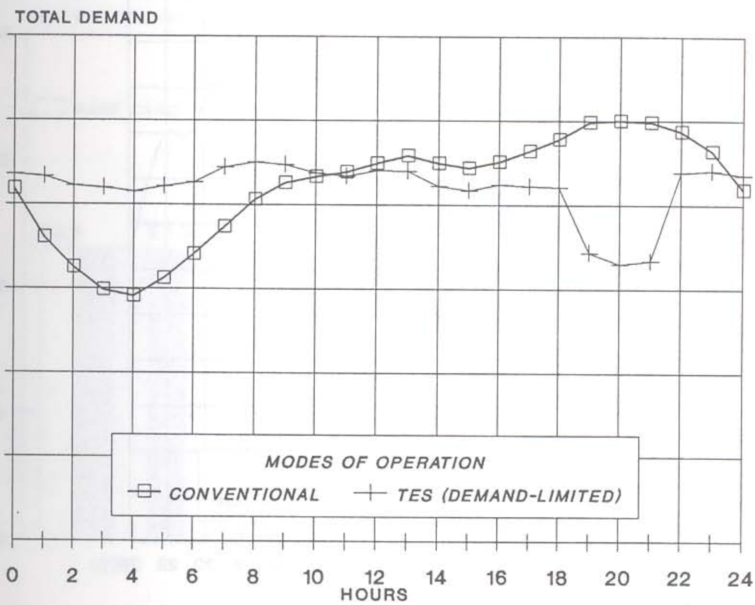

Fig. 4. Load shapes of large hotel buildings with TES in demand-limited mode.

SCENARIOS OF TES IMPACT ON SYSTEM LOAD SHAPE

In this assessment study, three scenarios of final TES penetration in 2006 are assumed as shown in Table 3. In each scenario, the penetration rates for the intermediate years are assumed to vary linearly with zero penetration in 1992, the starting year, to the final values in Table 3. The shares of electricity consumption for four types of large commercial buildings are obtained from the LFWG and MEA report [6]. The LFWG and MEA group the customer types and report the number of customers in each type. These figures are used with the penetration rates assumed for TES application in the four commercial buildings to reconstruct the TES-applied system load shapes. The load shape for the high penetration case is shown in Fig. 5, in comparison with that for the base case.

Table 3. Final rate of TES penetration in 2006.

Scenario	Final Rate of Penetration (%)	
	Large Buildings	Small Buildings
High	75	10
Medium	50	5
Low	25	2

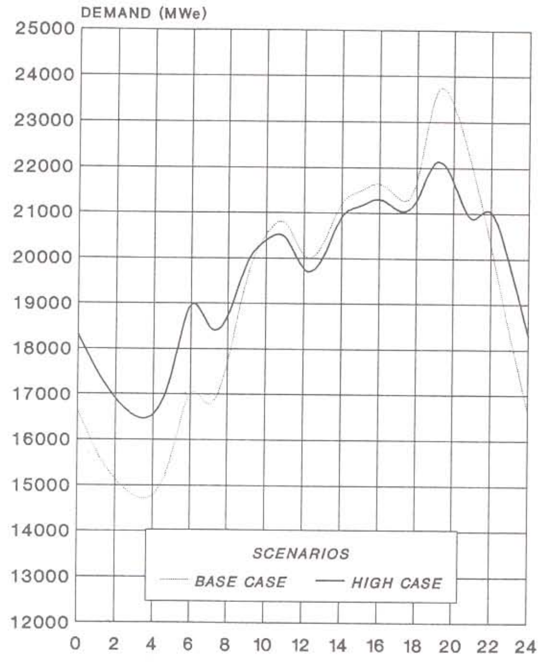

Fig. 5. System load shapes for high TES penetration scenario vs base case for 2006.

RESULTS OF AN ANALYSIS BASED ON A POWER PRODUCTION SIMULATION MODEL

This study uses the ELFIN (Electric Utility Financial and Production Simulation Model, version 1.97) to perform a comparative analysis of the power system production, using the system configuration reported in the PDP, for the system load requirements corresponding to the base-case load shape of the LFWG, and for the load shapes corresponding to the TES scenarios.

The ELFIN's generation submodel is used to simulate the energy production to meet the loads, under the given system configuration and generation costs of the different facilities, to arrive at the overall economic optimum. The report includes annual generation summary, annual plant factors, system reliability, and marginal cost of production for each specified period of the day.

Figures 6a and 6b show the relative marginal energy costs, for peak and off-peak periods, respectively. The high-TES penetration scenario features reduced peak-time cost and increased off-peak-time cost.

The significant benefits of TES are obtained in terms of the decrease in loss-of-load probability, decreased unserved energy, and an improved reserve margin shown in Figs. 7, 8 and 9, respectively. First, the loss-of-load probability indicates the probability that some portion of the load will not be satisfied by the available generating capacity. More specifically, it is defined as the proportion of days per year or hours per year when insufficient generating capacity is available to serve all the daily or hourly loads. The unserved energy measures the expected amount of energy which will not be supplied per year owing to generating capacity deficiencies and/or shortages in basic energy supplies, and finally, the reserve margin is a measure of the generating capacity available over and above the amount required to meet system load requirements. It is the excess of installed generating capacity over annual peak load expressed as a fraction or percentage of annual peak load.

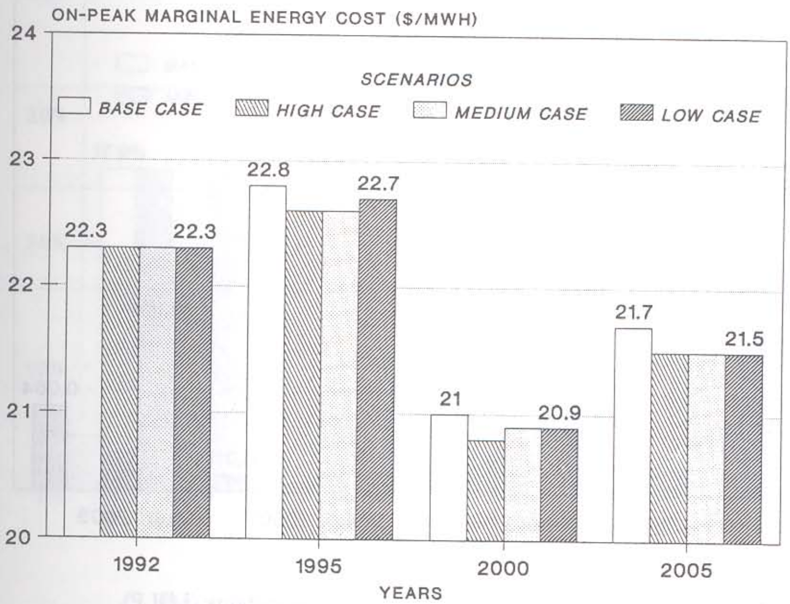

Fig. 6a. Changes in peak marginal generation cost.

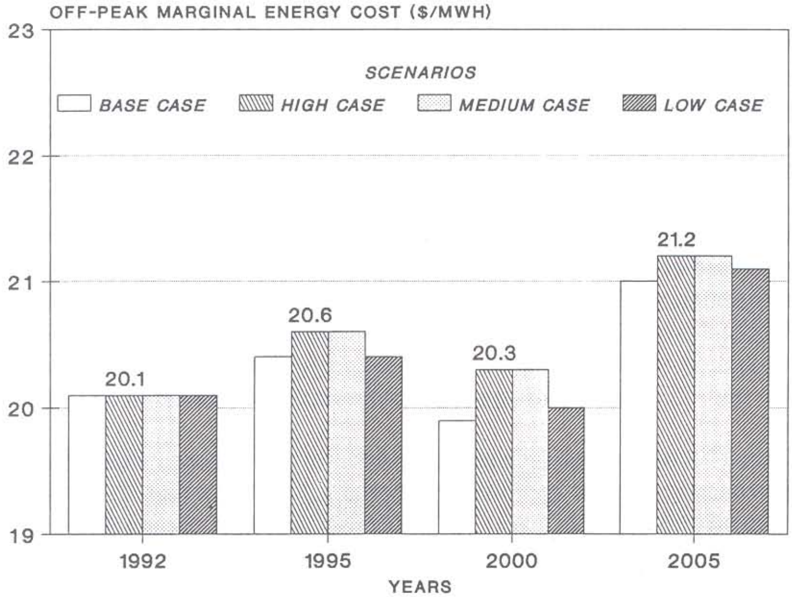

Fig. 6b. Changes in off-peak marginal generation cost.

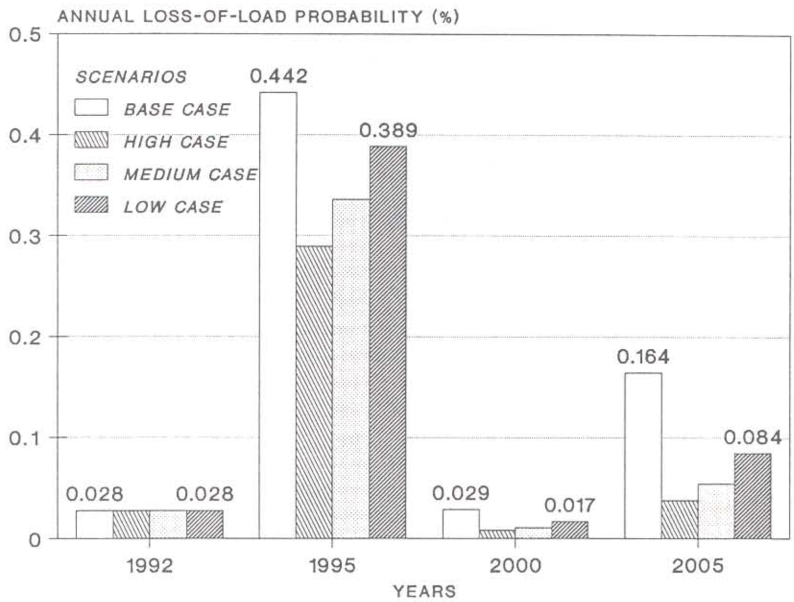

Fig. 7. Changes in annual loss-of-load probability (LOLP).

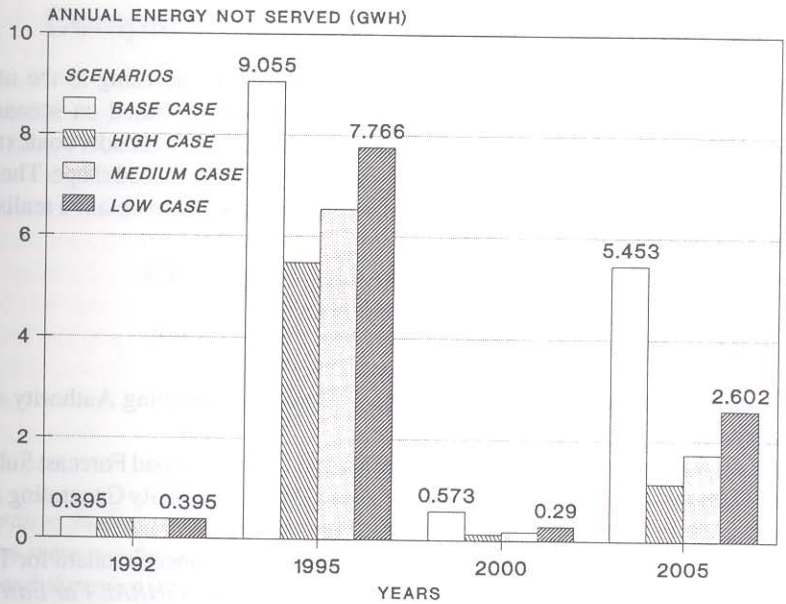

Fig. 8. Changes in annual energy not served (ENS).

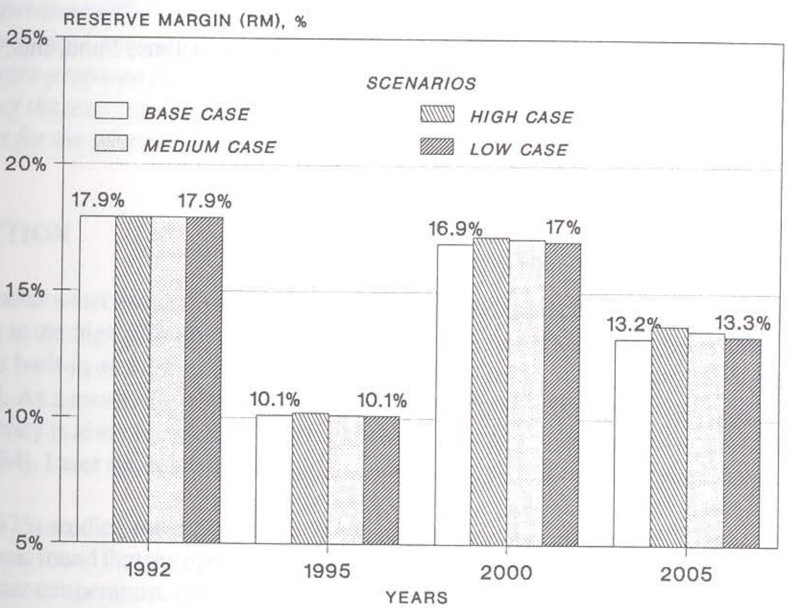

Fig. 9. Changes in operating reserve margin (RM).

CONCLUSION

This paper illustrates how to assess the system-wide benefits, accruing to the utility, of the application of TES (a load management program of the DSM plan) based on scenarios of TES penetration and available system information including the PDP. But in a broader context, the system configuration should be altered to reap the additional benefit of a change in load shape. The PDP should also then be adjusted to reap such a benefit. Further research is needed to obtain a realistic estimate of the extent of TES penetration.

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