COOL STORAGE ECONOMIC FEASIBILITY ANALYSIS FOR A LARGE INDUSTRIAL FACILITY

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ABSTRACT

The analysis of economic feasibility for adding a cool storage facility to shift electric demand to off-peak hours for a large industrial facility is presented. DOE-2 is used to generate the necessary cooling load profiles for the analysis. The aggregation of building information for predicting central plant behavior at the site is discussed. The dollar benefits and costs for the project are favorable, providing a payback in the neighborhood of 4 to 5 years.

INTRODUCTION

The rationale for cold storage is primarily for electric load leveling by shifting the air-conditioning power requirements from the peak time hours to off-peak hours, normally at night. The utility--in this case Salt River Project (SRP)--has an interest in electric load leveling because it postpones or reduces the need for adding additional power plants. The utility can provide incentives to its customers to install thermal storage by contributing to the capital costs and by means of time-of-day electric rates which offer cheaper electric charges during the off-peak hours.

This paper describes the plant modeling and analysis procedures for determining the economic feasibility of using thermal storage at McDonnell Douglas Helicopter Co. (MDH) in

and distribution system.

COMPUTER MODEL OF THE FACILITIES

In order to assess the potential benefits of thermal storage, it was desirable to have representative hourly electric demand profiles for the central chiller plant operations throughout the year. Historical measured data for the chillers of the central plant were not available. A computer energy use model of the facilities was constructed with a microcomputer version of DOE-2 (v.2.1c) [2].

The program, however, is designed to handle a single-building model; it was not specifically designed to handle a multi-building complex. Some creative manipulation of the input data was required in order to reduce the computational time of doing eleven separate buildings on an IBM AT personal computer.

Thus, a simplified model of the site consisting of four buildings was proposed given the limitations of both the DOE-2 program and our hardware. The methodology used to construct these representative buildings was as follows. An informational data base on each building was generated using design information and as-built plans for the recently constructed facility. The buildings were classified by the following categories:

a) VAV buildings, single story
b) VAV buildings, multi-story
c) Constant-volume buildings, single story
d) Constant-volume buildings, multi-story.

The data fields describing each building category (i.e. walls, windows, roofs, people, etc.) were then aggregated into the four representative building models for DOE-2. The models preserved the exterior surface exposures and the interior volumes. The internal energy use schedules in terms of time and intensity of the activities are important to the load profile construction--especially for industrial operations.

The only available data to validate this model were some recent monthly electric profiles recorded by SRP. Specifically, the electric profile for June was used to calibrate the computer model. We obtained very good agreement for all of the other months choosing random days without making any adjustments to the data. Figure 1 shows comparison of a real and computed profile for a typical day of March and June. Since the electric profile from month to month reflect the impact of the varying weather conditions on the chiller plant operation, we were satisfied that DOE-2 was satisfactorily indicating the site cooling loads and electricity demands; Figures 2 and 3 shows the cooling load for same days of March and June.

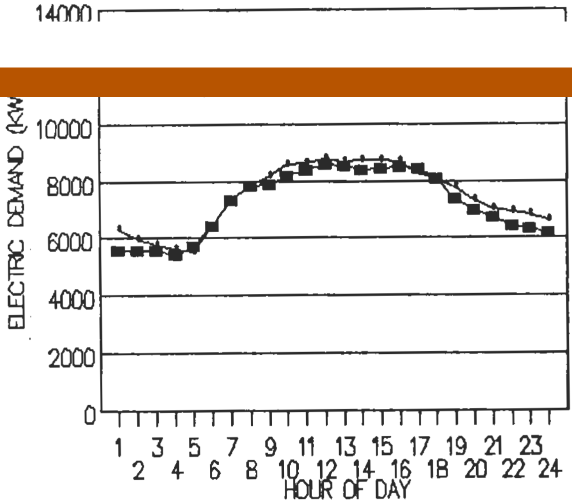

Fig. 1 ELECTRIC DEMAND PROFILE FOR TYPICAL DAY OF MARCH

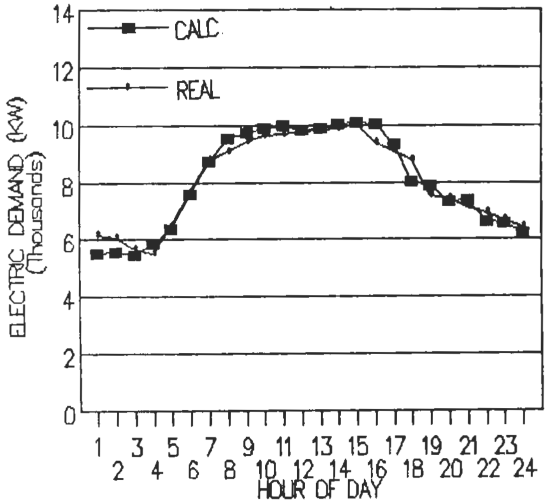

Fig. 2 ELECTRIC DEMAND PROFILE FOR TYPICAL DAY OF JUNE

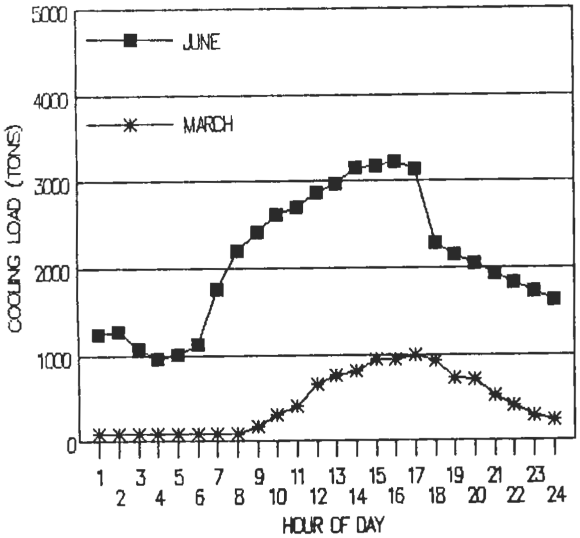

Fig. 3 COMPUTED CHILLERS LOADS PROFILES FOR TYPICAL MARCH & JUNE DAYS

FINANCIAL FEASIBILITY STUDIES

Although DOE-2 includes a storage sub-model, we chose not to do complete simulation runs initially. Instead, typical monthly cooling profiles for one day were introduced into a spreadsheet and analyzed. This approach saved much computational time and allowed us more insights as to the impact of various system parameters and the rate schedule. One key parameter that impacts the economics of thermal storage is the chiller plant efficiency, which includes the chillers pumps and cooling tower. The storage capacity is an important cost driver and a key factor in establishing the monthly energy and demand shift from the peak hours.

Financial cost/benefit studies have been on-going for more than a year. The DOE-2 studies were expanded to include the calculation of the utility bills once the design parameters were fixed. The results of these more recent studies are presented here.

The following conditions apply to the final study:

Storage media - Eutectic salt
Storage capacity - 10000 ton-hrs
Chiller efficiency - 0.65 kW/ton
Primary pumps & cooling towers - 0.2 kW/ton
Secondary pumps - 0.04 kW/ton
Applicable SRP rates - E39

The analysis was based on hourly simulations for one week in each month. The electric profiles and utility bills were computed by the DOE-2 program with and without storage. A minimum of 16 simulation runs (two runs per building per season with and without storage tank) were required for this more comprehensive analysis in order to accommodate a summer and winter rate. The weekly basis reduces the uncertainties associated with weekend operations and improves the statistical accuracy. Using the plant model in DOE-2 simulates more realistic system efficiency behavior and the affects of night time chiller operation.

BENEFITS

The benefits to MDH of having the storage system are, financial in nature and due to the reduced energy and demand charges resulting from shifting the cooling load from the on and off peak hours. With storage, the chiller operations will be partially reduced or completely eliminated during the on peak hours. The anticipated savings vary from month to month because of climatic variations and because different winter and summer rates are applicable. Figures 4 and 5 show the monthly reduction in demand and energy charges as predicted by the simulations. The yearly benefits are estimated to be $152,000 for the connected load in 1987. Since both the connected load and the utility rates, however, are expected to increase in the future, the savings estimate are a conservative forecast.

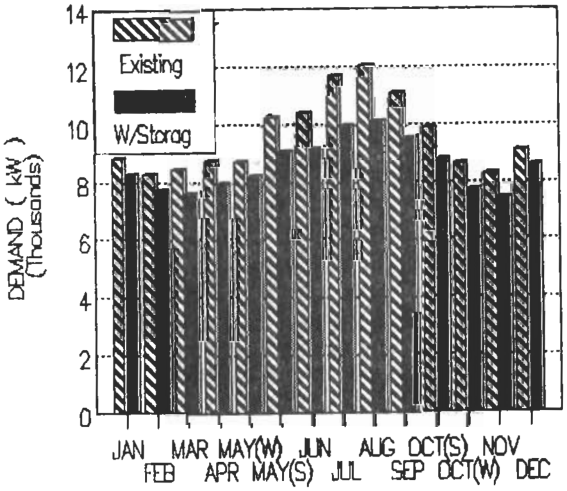

Fig. 4 ON-PEAK DEMAND COMPARISON FOR MDH - MESA SITE (DOE-2.1C)

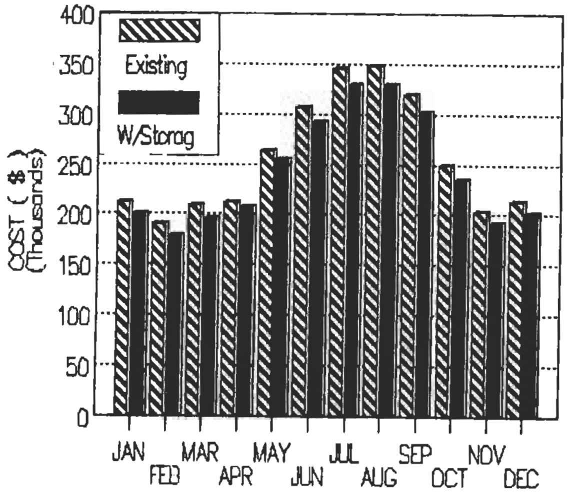

Fig. 5 ELECTRIC CHARGES COMPARISON FOR MDH - MESA SITE (DOE-2.1C)

COST

The installed cost of the eutectic salt tank, with a phase change at 47 F is expected to be approximately $92 per ton-hr. The pumps and associated piping are estimated to cost $62,000.

A financial incentive contribution is to be provided by SRP which depends on the magnitude of the demand shifted to the off peak hours. The current program allows $250/kw up to 300 kw and $115/kw thereafter.

The demand shift will be affected by the tank discharge rate during the 5 peak hours. Considering that the cooling load at MDH drops off after 4:00 p.m., the optimal discharge schedule, in terms of the rates, would be to base load the chillers during on peak hours to the lowest level permitted by the storage capacity i.e., the tank would be discharged according to the load. The optimum scheme is shown by Figures 6 and 7: a shift of 2200 kw is possible with this strategy.

At the other extreme, the tank would be unloaded uniformly at 2000 tons/hr which corresponds a 1700 kw shift. A constant shift may be more desirable for SRP's planning strategies of deferring new generation capacity; however, the motivating realities of the rates do not dictate this scheme operation to the customer. Furthermore, MDH is shifting load by its current schedule of the working hours at the plant.

CONCLUSIONS

The payback to MDH will be affected by a number of factors--the initial tank cost, the incentive provided by SRP, the chiller plant efficiency and the capacity of the storage. In addition free cooling (using cooling towers instead of chillers) can enhance the savings to MDH by providing additional night cooling hours. Free cooling can increase the yearly dollar benefits by as much as 10 percent [1]. The payback estimates for this project range between 4 and 5 years considering the benefits of free cooling.

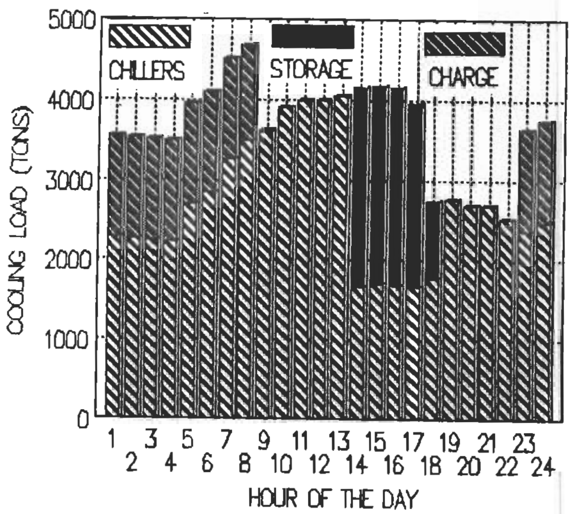

Fig. 6 COOLING LOAD FOR MDH - MESA JUL 17, 1988 (DOE-2.1C) - 2200 kW SHIFT

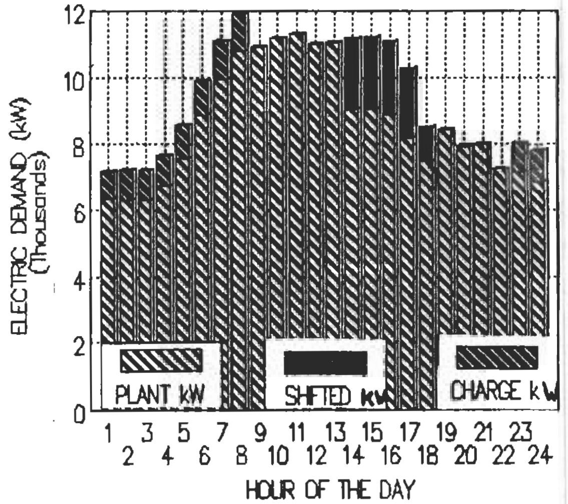

Fig. 7 ELECTRIC PROFILE FOR MDH - MESA JUL 17, 1988 (DOE-2.1C) - 2200 kW SHIFT

ACKNOWLEDGEMENTS

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REFERENCES

1. Fazzolari, R., Mascorro, J.A., "Cool Storage Feasibility Study," Nuclear & Energy Engineering Department, University of Arizona, November 1987.

2. "Micro-DOE2 Version 2.1C," ACROSOFT International, Inc., February, 1987.