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DOE/ORNL DEMONSTRATIONS OF LOAD MANAGEMENT BY CONTROLLED CUSTOMER-SIDE THERMAL ENERGY STORAGE*

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ABSTRACT

The Division of Electric Energy Systems of the Department of Energy (DOE/EES) is funding a nationwide demonstration of electric load management through the use of utility-controlled customer-side thermal energy storage for residential space conditioning. These demonstration projects, which are being conducted by utilities under contract to Oak Ridge National Laboratory (ORNL), are designed to 1) collect reliable load research data for assessing the impact on the utility system, 2) delineate and solve installation problems, 3) establish maintainability, 4) illuminate customer and utility acceptance, and 5) generate cost data.

Ten demonstrations, 5 heat storage and 5 cool storage, are underway. The thermal energy storage systems being demonstrated include ceramic brick, pressurized water, and building structural heat storage systems, and ice cool storage systems. The demonstrations will cover two full conditioning seasons.

The results obtained from these demonstrations are expected to be useful to utilities in making local load management decisions, to assist DOE in establishing priorities for R&D efforts in load management, and to provide objective information related to electric system impact, energy conservation, and the cost effectiveness of this form of load management.

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INTRODUCTION

Load management has been proposed as a means whereby an electric utility can reduce its requirements for additional generation, transmission and distribution investments, make more efficient use of its existing facilities, and shift fuel dependency from limited oil and gas to more abundant resources such as coal or nuclear. In its broadest sense, load management refers to any method used to modify system load patterns to more closely match electric energy use with electric energy production. It is useful to distinguish between two different approaches to load management: use management and supply management. Use management refers to techniques which impact on the energy consumption patterns of individual consumers, (e.g. direct control or voluntary control either with or without customer energy storage), while supply management refers to the use of utility-owned facilities to improve the match between electric energy production and use by taking advantage of the natural diversity of power demand (e.g. expanded interconnection and operation of power systems) or by providing storage in the system (e.g. central or dispersed storage).

A careful analysis of any proposed load management program must be made because substantial costs can be incurred in initiating a load management program, and if the program is not carefully designed, the implementation costs can exceed the benefits that are realized. Assessing the desirability of various load management options can be a difficult task because of the significant differences in the shape and composition of load curves among utility systems, geographic variations in capacity types and fuel costs, and the unique set of

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benefits, costs, and social, technological, and environmental constraints associated with each load management option which must be considered in any analysis.

The DOE/ORNL demonstration program addresses one particular approach to load management; specifically the use of utility-controlled customer-side thermal energy storage (TES) for residential space conditioning. The demonstrations are part of a comprehensive load management program being conducted by the Division of Electric Energy Systems of the U.S. Department of Energy (DOE/EES)[1] which includes technical demonstrations of emerging technologies, the development and application of state-of-the-art analytic methods, and the development of advanced concepts and technologies for the future.

The objectives of the demonstrations is to employ promising near-commercial, customer-side TES devices in sufficient quantities to 1) collect reliable load research data for assessing the impact on the utility system, 2) delineate and solve installation problems, 3) establish maintainability, 4) illuminate customer and utility acceptance, and 5) generate cost data.

DEMONSTRATION DESIGN

The concept of using customer-side TES for load management is not a new concept, having been practiced widely in Europe with varying degrees of success.[2] While customer-side TES has not been widely applied in the United States, a recently completed survey of utility load management and energy conservation projects has identified 71 utility-sponsored TES projects.[3] These projects generally consist of one or two TES units installed in a given region and, although valuable for determining the applicability of a particular TES concept to a given region, the information collected from these projects is inadequate for estimating what widespread implementation might mean to that utility because of the small sample size. Information such as the diversified demand characteristics of the TES units and of the conventional equipment they are replacing can only be derived if sufficient data is collected to cover the range of applications and use characteristics experienced in the region. Consequently, each project consists of from 30 to 50 of the same manufacturers' storage units installed in a given region. A number of projects, involving both heat and cool storage, are being conducted so as to cover a range of geographic, climatic, demographic, utility, and storage system characteristics.

The projects are limited to near-commercial heat or cool storage for residential space conditioning with the optional addition of water heating. The candidate storage systems were selected by the responding utilities on the basis of high potential for economic effectiveness and customer acceptance in their service area. The units are located in both new construction, or retrofit applications selected to be representative of the utility's service area.

Project plans include provisions to handle the service problems involved with the test including such steps as providing a service warranty, spare parts and trained dealer and utility personnel. Plans also provide for removing the storage system at the conclusion of the test if desired by the customer in order to minimize any ill feeling or inconvenience to the customer during and after the demonstration.

All of the storage homes, and a control group each containing a conventional space conditioning system, are to be instrumented to collect the necessary load research data. In addition, several of the storage homes in each project will be more fully instrumented to obtain detailed information on the storage unit characteristics. Data on utility operations and weather conditions will also be collected for correlation with device performance. The data from all the demonstrations will be collected in a consistent manner so that the results from the various projects can be compared.

Remote utility control of the storage device was required as part of the project. This is because one of the outputs desired from the demonstrations was a measure of the effectiveness of various control strategies from the standpoint of system reliability and costs. The utilities will be investigating a number of control options such as active utility control to minimize production costs, and fixed time-of-day control.

The demonstrations will cover two full conditioning seasons. At the conclusion of the demonstration, each of the utilities will prepare a final report which includes an analysis of the market potential of the TES system and the impact of this mode of load management on their system. Such factors as operational integration, transmission and distribution reinforcement, production costs, generation expansion, and customer acceptance will be included in the impact analysis.

PROJECT DESCRIPTIONS

Ten storage demonstration projects, five heat and five cool, have been undertaken by the utility industry under contract to Oak Ridge National Laboratory (ORNL). Over 200 utilities received an outline of the demonstrations in a letter asking if they wished to receive a detailed Request for Proposal (RFP) to bid for participation. Sixty-four utilities asked for RFPs and seventeen proposals were received. Eight of these proposals resulted in contracts. (Two utilities are employing both heat and cool storage.) The work to be performed by each utility consists of (1) planning the demonstration; (2) selecting, purchasing, installing, and maintaining the storage space conditioning equipment and the instrumentation for load research and device-specific data; (3) providing a communication and control system and operating the storage system according to several control strategies; (4) collecting data; (5) performing data analysis and a preliminary assessment of the impact on the utility of TES load management; and (6) presenting results in a final report.

The locations of the heat and cool demonstrations projects are shown in Figures 1 and 2. As indicated in the figures, the storage projects cover quite a range of heating degree days and cooling degree days from some of the most severe in the country to more temperate regions. The projects also include quite a range of utility, geographic, and demographic characteristics.

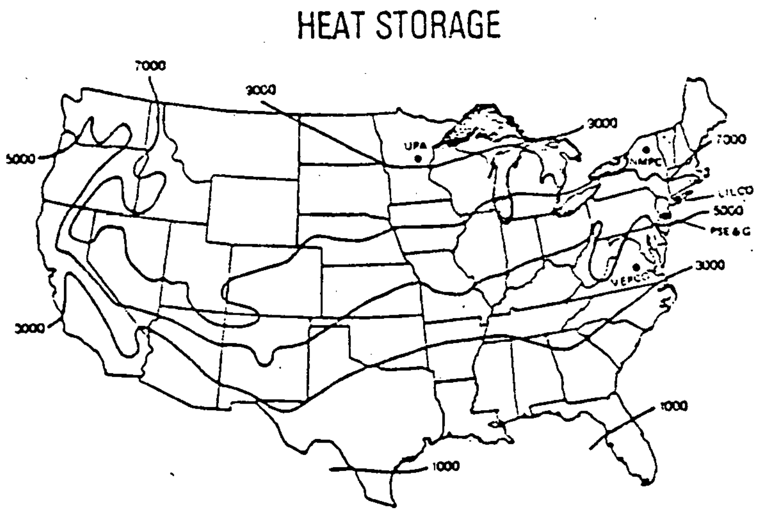

Fig. 1 Locations of heat storage projects.

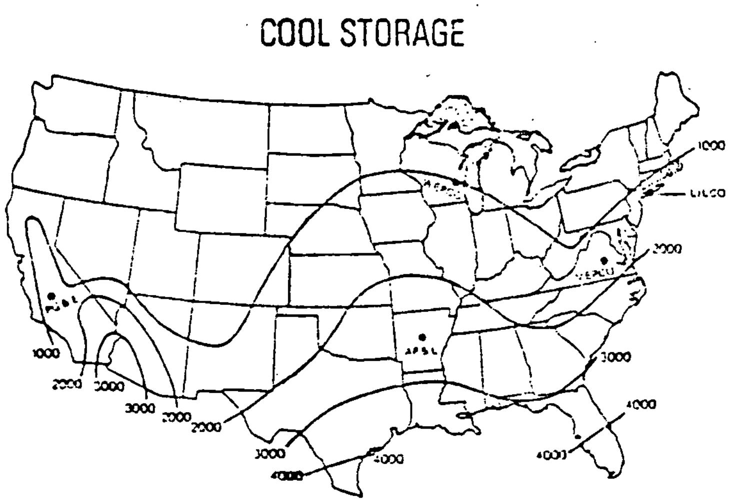

Fig. 2 Locations of cool storage projects.

All the demonstrations are to cover two space conditioning seasons and, except for the Niagara Mohawk project, are for single family residences only. The space conditioning systems in all cases respond to the local room thermostat, resulting in no life-style changes on the part of the occupants. The storage systems will be charged upon command from the utility. Several strategies will be employed, including simulation of the fixed periods of time clocks and time of day rates and the variable periods resulting from the most economic power production and anticipated weather conditions.

The data, except as noted below, will be collected on four-track magnetic tape. All homes in both the test and control groups will produce load research data including at least the total house energy, the normal space conditioning energy, the storage unit energy, and indoor temperature. Additional device-specific data such as state of charge of the storage unit and temperatures and flows for efficiency determinations will be collected on a limited number of the units for each project. This device-specific data will be similar to, but not as extensive as, the data being collected by EPRI projects RP1089-1 and RP1089-2 for cool and heat storage instrumentation and data verification. In these projects one or two installations in a number of utilities (15 to 25) are heavily instrumented to provide extensive data (approximately 20 points) on device operation, weather conditions, and comfort levels in the installation. The EPRI projects and this DOE project were planned together in order to promote effective utilization of the results of both programs.

Each utility will use the data for planning studies to determine the impact of several levels of saturation of thermal energy storage in their system. These studies will include an assessment of both costs and benefits.

The projects chosen for contract award are listed in Tables I and II. The participating utilities with their project descriptions are:

Wisconsin Electric Power Company (WEPCO) — Cool storage, 70 retrofit installations in two sizes. Full storage using two A. O. Smith ice tanks and a full-size compressor for off-peak operation only and half storage using one tank with a half-size compressor for nearly continuous operation. The control group of 25 residences will have conventional air conditioning. All residences will be fitted for load research instrumentation while five full-storage and

Table I. Heat storage

UTILITY	EQUIPMENT	NUMBER TEST/CONTROL	CONTROL
UPA	TPI	35/35	RADIO
PSE&G	TPI	30/30	TELEPHONE
LILCO	MEGATHERM	50/35	RADIO
VEPCO	MEGATHERM (CARRIER HP)	40/40	TELEPHONE
NMPC	AEG	8*	TELEPHONE
	MEGATHERM	8	
	CARRIER HP	4	
	PSC (SLAB)	4	

*A FIFTH DORMITORY WITH RESISTANCE HEATING SERVES AS THE CONTROL.

Table II. Cool storage

UTILITY	EQUIPMENT	NUMBER TEST/CONTROL	CONTROL
WEPCO	A. O. SMITH	35/35/25	PLC
LILCO	CALMAC	50/35	RADIO
VEPCO	CARRIER	40/40	TELEPHONE
AP&L	A. O. SMITH	35/35	RADIO
PG&E	CARRIER	30/30	RADIO

five half-storage residences will have additional instrumentation for device-specific data. Storage control and data acquisition will be through a two-way power line carrier communications system from a central control office.

Long Island Lighting Company (LILCO) — Heat and cool storage, 50 homes each. Heat storage using Megatherm pressurized water units retrofitted in existing oil-fired hydronic heating systems. Cool storage using Calmac ice tanks retrofitted in existing air conditioning systems. Control groups of 35 homes each will be established with conventional heating and air conditioning. All residences will be instrumented for load research data with ten each from each group instrumented for additional device-specific data. Storage control will be by Scientific Atlanta radio from the central load management project office.

Virginia Electric Power Company — (VEPCO)— Heat and cool storage in 40 new construction homes using a heat pump for space conditioning. Electric storage water heaters will also be installed. Megatherm pressurized water units will provide heat storage for supplemental heat, and Carrier (Girton) ice tanks will supply cool storage for air conditioning. Heat for domestic hot water will be reclaimed during the air conditioning season. Forty control homes will be new construction with conventional heat pumps only. All homes will be instrumented to collect load research data, and six test homes will be instrumented for additional device-specific data. Storage control will be through leased telephone lines to groups of five homes.

Arkansas Power and Light Company (AP&L) — Cool storage in 35 homes using A. O. Smith ice tanks retrofitted into existing 2-1/2 and 3-1/2 ton central air conditioning systems. A control group of 35 homes will have conventional air conditioning. A. O. Smith storage water heaters will be installed in 15 homes in place of existing electric water heaters. All homes will be instrumented for research data while six homes will have additional instrumentation for device-specific data. Storage control will be by existing Motorola radio control from the system dispatch center.

Pacific Gas and Electric Company (PG&E) — Cool storage in 30 homes using Carrier (Girton) ice tanks retrofitted into existing air conditioning systems. A control group of 30 homes will have conventional air conditioning. All homes will be instrumented for load research data with five homes instrumented for additional device-specific data. Storage control will be Scientific Atlanta radio from UPA's Elk River Energy Control Center.

Public Service Electric and Gas Company (PSE&G) — Heat storage in 30 homes using TPI ceramic brick storage furnaces retrofitted in existing central forced air systems. Each home will also have an electric storage domestic water heater. Thirty control homes will have conventional electric furnace central heat. All homes will be instrumented for load research data while five homes will be instrumented for additional device-specific data. Storage control will be by DARCOM telephone communication from the load management program office.

Niagara Mohawk Power Corporation (NMPC)— Heat storage in a dormitory complex for the 1980 Winter Olympics. Four of five dormitories will have multiple heat storage units of the same type, each unit being approximately the size for a single family residence. Each dormitory is a modified circular two-floor building with eight sleeping wings. The environmental aspect of all buildings is nearly uniform. The heat storage systems are: eight AEG ceramic brick units, eight Megatherm pressurized hot water units; four Carrier heat pumps with hot water supplemental heat storage, and four Peak Supervision Control (PSC) trellis (in-slab) heating systems. The fifth dormitory in the complex will have electric resistance forced air heat and will be the control sample. Storage control and data acquisition will be by leased telephone line from a central office.

STATUS OF PROJECTS

Some heat storage equipment was installed and tested under local control during the 1978-79 heating season, but the demonstrations will really commence with the 1979 cooling season. The installation of the cool storage units is underway and the first seasons operational results are expected in the fall of 1979. Equipment installation is also underway for the heat storage projects and first season results will be available in the summer of 1980.

The impact assessments will be performed at the conclusion of the second conditioning season after which final reports will be prepared and available.

CONCLUSIONS

The results of these demonstrations will include data on the use characteristics of residential customer-side TES space conditioning and water heating systems, and on the use characteristics of their conventional counterparts. These results will include the performance of the storage systems as a function of regional and weather characteristics suitable for forecasting what the widespread implementation of these systems might mean to the utility system.

These results can be used in a number of assessment areas such as forecasting, expansion planning, production costing, and reliability analyses. Work is also underway as part of the load management program to develop new tools for assessing the impacts of load management alternatives on such things as generation expansion plans, short-term operating procedures, distribution system operation and reinforcement, and consumer reliability.

In addition, much valuable information will have been gained from the demonstrations on the installation of customer-side TES systems, their maintainability, and consumer acceptance of this technology.

These results should be useful to utilities in determining the system savings that might be realized through the widespread implementation of customer-side TES in residences. This information is needed to design appropriate rates and, together with the cost data generated, will help utilities make decisions on the desirability of this load management alternative.

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