DESIGNING A THERMAL ENERGY STORAGE PROGRAM FOR ELECTRIC UTILITIES

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ABSTRACT

Electric utilities are looking at thermal energy storage technology as a viable demand side management (DSM) option. In order for this DSM measure to be effective, it must be incorporated into a workable, well-structured utility program. This paper describes a methodology to design a successful thermal energy storage program for electric utilities.

The design process is addressed beginning with the market research phase. The research includes information obtained from utilities having successful thermal storage programs. In addition, information is gathered from interviews with local architects and engineers, air conditioning contractors and potential thermal energy storage customers.

From this information a marketing plan is developed that addresses the target market, market penetration, promotional methods, incentive types and levels, internal and external training requirements and optimal organizational structure. The marketing plan also includes various rate structures, program procedures and evaluation techniques. In addition to the marketing plan, several case histories are addressed.

OVERVIEW

Utilities across the country are now taking a second look at thermal energy storage as a viable demand side management (DSM) option. Over sixty utilities currently have a thermal energy storage program in place. The Electric Power Research Institute (EPRI) estimates that by 1995, 2,300 thermal energy storage systems will have been installed in the United States. These energy storage systems have the capability to shift over 650 MW of demand from on-peak to off-peak periods. The bottom line is that fewer power plants need to be constructed to meet the peak-demand.

HOW IT WORKS

Thermal Energy Storage or cool storage is simple in concept. Ice or chilled water is produced by chillers or industrial grade ice making units and stored in tanks during utility off-peak hours. During peak hours, cooling is provided by circulating a chilled liquid (usually water) through the building's air handling units. The larger the storage system, the smaller the air conditioning system's electrical demand during peak hours.

NOT A NEW TECHNOLOGY

Thermal energy storage or cool storage is not a new technology, but one that has been around for some period of time. Thermal energy storage, or cool storage as it is sometimes called, was first used in the 1930's and 1940's on a commercial basis in theaters, churches, dairies and other applications where the building only required cooling for a specific portion of day. The thermal storage systems were used in these applications to downsize the expensive air conditioning or refrigeration installations.

As the cost of air conditioning systems became less expensive and chiller technologies and efficiencies improved, these ice storage systems were phased out in most of the original applications. Some of the older churches, however, still use their original ice storage systems, although they are few and far between.

STRONG COMEBACK IN THE COMMERCIAL SECTOR

Thermal energy storage is now making a strong comeback in the commercial sector primarily due to utility support, promotion and incentives. Today, thousands of cool storage systems are successfully operating in a variety of businesses. Thermal storage energy systems are applicable in both new construction and retrofit situations.

UTILITY GOALS AND BENEFITS

The utility's goal in these programs is to shift a portion of the large air conditioning load from periods of high demand, which usually occur during the hottest part of the day, to periods of low demand , which occur in the evening and early morning hours. This shifting of electrical demand has the effect of "flattening" the load

Proceedings of the Ninth Symposium on Improving Building Systems in Hot and Humid Climates, Arlington, TX, May 19-20, 1994

curve which is beneficial to the utility and ultimately to the customer, a true win-win situation (refer to Figure 1).

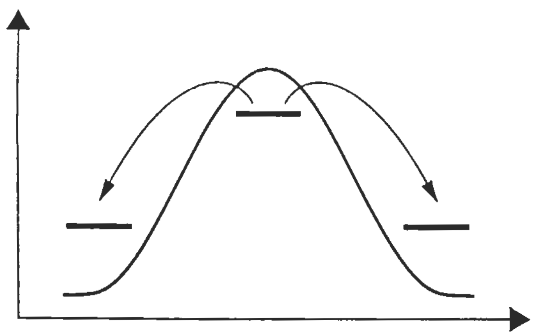

Figure 1 Thermal energy storage can "flatten" the utility load curve without eroding base kWh sales.

The load shift accomplished by the thermal energy storage installations benefits the utility by:

- Deferring the construction of new power plants
- Improving the system load shape
- Better utilization of existing facilities
- Improving customer relationships

In addition, thermal energy storage has an advantage over most other DSM programs in that it shifts the load rather than reduces it. This shifting of load does not erode base sales, and depending on the system, can actually increase KWH usage.

CUSTOMER BENEFITS

The customer benefits from thermal energy storage by:

- Lower installation cost through utility incentives
- Lower utility bills through off-peak pricing
- Increased flexibility of cooling system operation
- Reduced costs on new construction air conditioning systems as compared to conventional systems

TYPES OF TECHNOLOGIES

There are three basic technologies used for thermal energy storage: chilled water, ice, and phase change materials:

Chilled Water Storage

In the chilled water systems, reciprocating or centrifugal chiller compressors are used to make chilled water which is stored in prefabricated steel tanks, or in the case of larger systems, reinforced concrete tanks. The water is chilled during off-peak hours down to temperatures in the range of 40 to 42 degrees F. There is no efficiency degradation in the compressor when producing water in this design temperature range.

Chilled water storage tanks generally are designed to use the stratification effect to keep the warm return water separate from the chilled supply water. This tank design is relatively simple, and eliminates the need for diaphragms and multiple tank separation systems. Chilled water systems typically require about 25 cubic feet per ton-hour of storage for a 10 degree F temperature differential.

Ice Storage

Ice storage systems take advantage of the properties of phase change to store more cooling than chilled water systems in a given area. Ice systems are approximately seven to eight times smaller than chilled water systems for the same amount of storage capacity. For example, a typical ice storage system requires about 3.0 cubic feet per ton-hour of storage. Ice storage systems use less space than a chilled water system, but on a ton-hour basis, they consume more energy. This increased energy usage is caused by the chiller compressor operating out of its design range to produce ice. These ice systems require a suction temperature in the range of 18 to 25 degrees F, averaging 10 to 12 degrees F lower than the chilled water systems. Using a rule of thumb average of 2% increase in energy usage per degree F of suction temperature drop, the ice system will have an energy consumption 20% to 24% greater than comparable chilled water systems.

Eutectic Storage

Substances called salt hydrates or eutectic salts exhibit phase change properties like water, but at a higher temperature than 32 degrees F. This means that the eutectic system can benefit from the heat absorption associated with a phase change, but at a higher temperature. Eutectic salt solutions are designed to freeze at a temperature of around 47 degrees F. Since this freeze temperature is within the design range of the compressor, the operating efficiency is not reduced. Eutectic salts are usually encased in plastic containers for ease of storage. Chilled water from a conventional chiller is circulated through a tank filled with these containers in order to freeze them. Return water from the building HVAC system is then circulated through the tank to meet the cooling requirements of the building. Eutectic salt storage requires less space than chilled water, but more than for ice. Typical storage space requirements for these salt hydrate systems is 5.5 to 6.0 cubic feet per ton-hour.

MARKETING PLAN

The first step in designing an effective thermal energy storage program that meets the needs of both the customer and the utility, is to perform comprehensive market research. The first phase of this research should be a thorough search of technical literature. EPRI literature is highly recommended as well as the International Thermal Storage Advisory Council (ITSAC) bulletins. This literature is very helpful in showing the latest technological advances in thermal energy storage, and the pros and cons of operating systems. Manufacturers of the different types of thermal energy storage systems should also be contacted for details concerning pricing, equipment availability, and even utility incentive programs. The manufacturers of this equipment have a good feel for how well the various utility incentive programs work or don't work.

The second phase of research is to poll a large sample of utilities with existing thermal storage programs. This survey should be done by phone for maximum effectiveness. The following questions should be asked:

- What are the goals and objectives of your Program?
- Are you on target for meeting these goals?
- What would you do differently in the design?
- What do you like about your program?
- Any concerns with systems or manufacturers?
- What are your customer concerns?
- In your experience, who are the best candidates for thermal storage?
- What incentives do you offer?
- How do you calculate Kw shifted and energy usage?
- Describe your promotional methods.
- Describe your best success story.

Using the results of the first two phases of research, a list is compiled of the primary potential candidates for thermal energy storage projects. The list will vary according to the region of the country the utility serves, but will typically include:

- Schools
- Hospitals
- Large office buildings with chiller systems
- Places of Worship
- Hotels with convention centers
- Sport complexes

The next phase of the research process is to interview key utility accounts that meet these profiles. The consultant with the assistance of the Marketing Representatives should ask potential commercial customers questions as to their attitudes and concerns about thermal energy storage, their interest level, and their payback criteria. At least fifteen customers should be interviewed throughout the utility service territory.

Local A/Es and contractors should also be interviewed to determine if they would support and promote a thermal energy storage program. A&C Enercom has learned from previous program design and development that the support of local A/Es is critical for program success.

The final phase of research should be to interview the utility field Marketing Representatives and Staff to determine their wants and needs for this program, and what tools they required to effectively sell it to their commercial customers. Different training options can also be discussed at this time.

Based on the results of this research, a comprehensive marketing plan can be designed and developed which addresses:

- Target market
- Estimated market penetration
- Methods to reach and sell to this market
- Barriers to participation
- Training required
- Optimal organizational structure
- Incentives to ensure program participation
- Rate structures and rate rider recommendations
- Program flow and procedures
- Program evaluation

CASE HISTORIES - THERMAL ENERGY STORAGE PARTICIPANTS

Case History 1 - South Texas High School

Central Power and Light Company has an operating ice thermal storage account located at the South Texas High School in Mercedes, Texas. CPL estimates that the school has saved approximately $ 30,000 in the last nine months attributable to shifting 300 Kw of load to off-peak using thermal energy storage. The system is made up of a 28,000 gallon insulated ice storage tank connected to three existing 100 ton reciprocating chillers. The tank has a capacity of 2,132 ton hours, which provides full storage cooling during the day. The system cost approximately $118,000 which resulted in a simple payback of about four years. Metering has shown that the actual load shifted is very close to the 300 Kw projected.

Case History 2 - Texas State Technical College

The system at Texas State Technical College in Harlingen, Texas was designed to use existing concrete potable water tanks for the chilled water storage, thus reducing the initial cost of the system. The tanks were reconditioned and insulated for chilled water storage. The storage tank holds 400,000 gallons of water which equates to 4,015 ton-hours of thermal storage. This system was designed to shift approximately 1,000 Kw to off-peak resulting in an estimated cost savings of $ 145,000 annually. The system became operational in October, 1993. CPL has metered the installation and found that the actual shift is in the 500 to 700 Kw range.

Case History 3 - Delmar College

The installation at Delmar College in Corpus Christi, Texas is a chilled water system which uses a one million gallon storage tank to store 6000 ton-hours of cooling. The system was initially estimated to shift 850 Kw to off-peak. The system was projected to save Delmar $ 54,000 per year. The system was placed into operation in October, 1993. CPL metering revealed that the actual shift was closer to 1,000 Kw, with the savings increased proportionally.

THERMAL ENERGY STORAGE EVALUATION

In order to determine the "real world" performance of thermal energy storage installations, CPL contracted A&C Enercom to install end-use metering at the three locations previously mentioned. The parameters monitored included: total account kW and kWh usage, chiller and associated equipment kW and kWh, tank temperatures, supply and return water temperatures, flow rates and ambient conditions. As illustrated in the previous case histories, this evaluation phase provided valuable documentation for determining overall program impact and effectiveness.

In summary, a well designed thermal energy storage program can be used by utilities to shift their peak kW while maintaining or even increasing kWh sales. It is a proven technology that benefits both the utility and the customer, thus providing a "win-win" situation overall.