CONSTRUCTION OF A DEMAND SIDE PLANT WITH THERMAL ENERGY STORAGE

MATT MICHEL
Division Manager, Marketing
Lennox Industries Inc.
Sacramento, California

ABSTRACT

Utility managements have two primary responsibilities. They must supply reliable electric service to meet the needs of their customers at the most efficient price possible while at the same time generating the maximum rate of return possible for their shareholders. Regulator hostility towards the addition of generating capacity has made it difficult for utilities to simultaneously satisfy both the needs of their ratepayers and the needs of their shareholders. Recent advances in thermal energy storage may solve the utilities' paradox. Residential thermal energy storage promises to provide the ratepayers significantly lower electricity rates and greater comfort levels. Utilities benefit from improved load factors, peak capacity additions at low cost, improved shareholder value (ie. a better return on assets), improved reliability, and a means of satisfying growing demand without the regulatory and litigious nightmares associated with current supply side solutions. This paper discusses thermal energy storage and its potential impact on the electric utilities and introduces the demand side plant concept.

Utility managements have two primary responsibilities. They must supply reliable electric service to meet the needs of their customers at the most efficient price possible while at the same time generating the maximum rate of return possible for their shareholders. In times past, it was easy to achieve both of these demands. Today, however, regulators are increasingly skeptical of any attempts to raise rates because of capacity additions.

The regulators, subjecting the utilities to increasingly intensive prudence reviews, have questioned every increase in capacity and disallowed many utilities' attempts to raise rates to pay for added capacity. The U.S. Department of Energy (DOE) described the situation stating that "regulators have shown a reluctance to pass through the costs of new plants to customers even if these same regulatory bodies had initially approved the plants' construction and the plants were prudently built" (1). For example, one electric utility located in the energy patch failed to forecast the region's oil recession and found itself with excess generating capacity when a nuclear plant they had invested in came on line. The utility is not being allowed to pass along part of their costs for the construction of the plant even though no one disputes that the utility made a prudent decision at the time they signed up for the plant. Actions like this have made the utilities wary of new construction. One by one, all of the options for adding large scale capacity are being eliminated.

Nuclear power is essentially out of the picture. The construction overruns have hurt many utilities. The current status of the Seabrook, Shoreham, and Rancho Seco plants speaks of the political/legislative fears the utilities exhibit. Despite increased interest in the wake of concern about the Greenhouse Effect, technophobic political antagonism against nuclear power remains too strong for any utility to consider this an option in the near term. With current U.S. nuclear plant construction lead times approaching 15 years, additional nuclear capacity (beyond current construction) is not likely before the second decade of the next century.

Coal is also coming under pressure. Tightened controls against acid rain are a major part of the new wave of environmental legislation sweeping through our nation's capitol; and the threat of even tighter controls remains strong. The scrubbers-versus-low sulfur coal debate is still unresolved. Clean-coal technologies hold promise, but only if the R&D financial resources needed to develop the technologies are not diverted to scrubber retrofits. In addition, coal contributes to the Greenhouse Effect. Although we have coal in abundance, coal based generation is being restricted as an option.

Oil based generation is another contributor to the Greenhouse Effect. Its application is still limited by the 1978 Fuel Use Act. Also, it is not the most secure natural resource with today's rising world (and domestic) consumption and declining exploration and development. America's oil imports are currently at the highest levels in our nation's history! Middle East OPEC oil, only 9% of our imported oil in 1985, was 25% last year. OPEC holds almost all of the world's excess capacity and soon OPEC's capacity will become strained, raising the possibility of a repeat of the 1973 and 1979 oil price shocks. Oil based generation is not a viable option.

Natural gas has been receiving a lot of praise and interest lately since it is a relatively clean burning fuel. However, the gas bubble is about to burst and current gas prices still do not support further drilling. Additional help from Canada will be limited. The

U.S. already consumes 34% of Canada's gas to satisfy 6% of our demand and pipeline capacity is strained with little relief in sight before 1992 at the earliest. Natural gas will help meet some of the peak demand requirements, but that is about all.

Hydroelectricity is the cleanest form of power. Yet most of the high potential large scale hydroelectric projects have already been built. Any remaining large scale project would almost inevitably result in the damming of a wild river, raising someone's ire (as witnessed recently in Colorado). The utilities are also worried about a repeat of the TVA's snail darter incident. Small scale hydro holds less promise than one might at first think. Gunnar Sarsten of the United Engineers and Constructors, while giving the keynote address of the Joint Power Generation Conference, pointed out that if small scale hydro alone were to meet our demand, we would need a couple of hundred thousand new dams flooding an area the size of New England. Hydro alone will not be able to add much capacity.

Other than hydroelectricity, most renewables are still not cost effective. We have had some successful applications of geothermal power, but the possible sites are few in number. Wind and solar power hold promise for some day in the future, but they are generally not cost effective today with the exception of remote, off-grid locations. They are also not the most reliable forms of electrical generation. One day these renewables may help, but that day has yet to arrive.

Recent breakthroughs with superconductivity and fusion power paint a bright portrait of tomorrow. But the canvas is still blank today.

Utilities, frustrated in their attempts to add capacity, are increasingly turning to cogenerators, independent power producers (IPPs), and plant refurbishing as alternatives. Gunnar Sarsten pointed out that if co-generation as a form of power was to meet our needs, we would need three times the number of sites currently available. IPPs might be able to help in an environment that deregulates. But currently they are a rather unreliable group. IPPs are under no obligation to provide service; utilities are. Plant life extensions, taking 30 year old plants and refurbishing them so they will reach 40 or 50 years, will remain a worthwhile effort until the plants built to tighter engineering tolerances become ready for retirement. These plants will be much more difficult to refurbish.

Utility managements are keenly aware of all of this. They are just as aware of their fiduciary responsibility to their shareholders. Thus, the characteristically *conservative* utilities have been making even more conservative forecasts. As a result, peak demand has consistently been outpacing forecasts while generation continues to be built to forecast. The sustained dynamic economic growth of the 1980s combined with an unusually hot summer strained North America's power grid to unprecedented levels in 1988.

The North American Electric Reliability Council's 1988 Annual Report was filled with citations of record demand. The East Central Area Reliability coordination Agreement's 1988 summer peak exceeded the 1994 forecast; it was 10.5% over forecast and 10.3% higher than the record. Net energy load grew by 5.9%. The Mid-Atlantic Area Council (MAAC) recorded a winter peak 9.8% above the year before and 7.4% above record. The summer peak was 6.4% above record. MAAC forced a system-wide 5.0% voltage reduction. Net energy load grew by 5.3%. The Mid-America Interconnected Network's summer peak was 9.0% above record. The Mid-Continent Area Power Pool's summer peak was 9.0% over forecast and 7.5% higher than 1987. Electricity use was 8.2% higher than 1987. The Southeastern Electric Reliability Council's summer peak was 4.2% over forecast. The Western States Coordinating Council demand increased 8.5% in 1988; the peak was 5.0% over forecast (2).

Left unchecked, the current slow growth in generating capacity combined with the greater than expected growth in demand will eventually lead to an electric generating capacity gap. In fact, the DOE has projected that "in the year 2000 the Nation will need approximately 100 gigawatts of new electric generating capacity (beyond plants now under construction) to maintain adequate electricity supplies (1). And that projection was based on assumptions of a 2% average annual demand growth and a 50 year average plant life!

DEMAND SIDE OPTIONS

Eventually the capacity problems the utilities face will have to be addressed. However, these are complicated issues involving many parties. The utilities can do little by themselves. The utilities can, however, work on the demand side of the equation.

Through the use of incentives, promotions, and innovative rate structures, the utilities can dramatically reduce their summer and winter peaks. While interaction with regulators is needed to implement some demand side management programs, there is every indication that cooperation will be forthcoming. Demand side management slows the need for capacity additions and allows the electricity end user to realize reduced prices through the application of new technologies and/or changes in behavior. This is generally acceptable to regulators and provides a means for the utilities to meet their requirement to provide reliable service to their customer base.

At the same time, demand side management can help the utilities fill in the valleys of a demand profile, improving load factors and revenues. The utilities realize greater revenue per kilowatt of generating capacity, satisfying the utilities' requirement to maximize shareholder value. Demand side management is consistent with the fiduciary obligations of utility managements to their shareholders.

The need for further demand side management has more urgency than is suggested by a mere revenue enhancement. In broad terms (with variations existing for individual utilities), utility load factors have been declining since the advent of air conditioning. If this decline continues, some utilities may be faced with the unpleasant circumstances where base load generating facilities must be cycled or throttled down. In terms of maintenance costs, plant reliability, and lost revenue, cycling base load plants is a grim scenario indeed. This gives utilities added incentive to improve load factors by whatever means are available.

Residential thermal energy storage (TES), a new, developing technology from the heating, ventilating, and air conditioning (HVAC) industry is close to fruition and marketplace introduction. TES represents an awesome potential for utilities. Close to 1/5th of our nation's aggregate energy is consumed for HVAC in the country's residential and commercial buildings. Daily variations in temperatures combined with end user behavior patterns result in tremendous peaks and valleys for the HVAC load profile. Lopping off the peaks and filling in the valleys of the HVAC demand profile will achieve much of the possible gains from demand side management.

IMPACT OF TES

A significant innovation in residential TES is currently in advanced development at Lennox Industries. This system stands to revolutionize the HVAC industry. It represents *the most significant innovative concept for residential and small commercial unitary air conditioning since air-cooled condensing units with hermetic compressors were introduced during the 1950s!*

Utilities will soon have a TES system available that will allow them to dramatically improve load factors and significantly increase their shareholders' returns while reducing peak demand and the need for new plant construction. This system will reduce condensing capacity of a given system to 50% of what is required for a conventional system. Total electric load is 60% of a conventional system. The aggressive utility can construct a *demand side plant* using the system that dramatically improves the revenue per kilowatt. Additional capacity is gained at very low cost. *And there is no prudence review!*

The best way to understand the demand side plant concept is through an example. The following hypothetical case will help explain the concept.

<u>Base Scenario</u>

Assume that a that a utility's average residential customer has a base load usage of 13,200 kWh per year with a peak demand of 6.00 kW. Of this base, 3,600 kWh and 3.60 kW is for air conditioning (assuming a 3 ton system with a 10 SEER and 1,000 hours of use). The utility charges $0.090 per kWh and has marginal generation cost of $0.025 per kWh (ie. the cost of generating an extra kWh is $0.025). The utility's revenue per customer breaks down as follows:

9,600 base kWh + 3,600 a/c kWh =
13,200 total kWh

13,200 kWh X $0.090/kWh =
$1,188.00 gross revenue

13,200 kWh X $0.025/kWh =
$330.00 generation cost

$1,188.00 - $330.00 =
$858.00 gross profit

$1,188/6.00 kW =
$198.00 revenue/kW

$858.00/6.00 kW =
$143.00 gross profit/kW

This represents the "marginal" revenue and gross profit per kilowatt and is thus effective only up to the point where new generating capacity is needed. The capital costs of new capacity are not addressed. In this sense, gross profit might also be stated in terms of the "difference" between the cost of adding one household and the added cost of supplying that one household with electric service, provided that the household does not require any additional fixed or semivariable overhead (ie. no additional manpower to connect power to the household, service the household, bill the household, and so on; no additional equipment to connect service to the household, provide power to the household, and so on). The "gross profit" would all be contributing to the pure variable costs of providing service.

<u>TES Scenario</u>

Using TES and a demand metered time-of-use (TOU) rate, the *average* cost of electricity to the homeowner is lowered, in this example, from $0.090/kWh to $0.072/kWh. With TES, the homeowner is using more electricity to cool the house. The air conditioning electricity usage jumps from 3,600 kWh to 4,500 kWh. Total consumption is now 14,100 kWh. The peak demand of the air conditioning, however, is cut 40% and falls to 2.16 kW from 3.60 kW. Total demand is now 4.56 kW. The utility's revenue per customer in this scenario breaks down as follows:

9,600 base kWh + 4,500 a/c kWh =
14,100 total kWh

14,100 kWh X $0.072/kWh =
$1,015.20 gross revenue

14,100 kWh X $0.025/kWh =
$352.50 cost

$1,015.20 - $352.50 =
$662.70 gross profit

$1,015.20/4.56 kW =
$222.63 revenue/kW

$662.70/4.56 kW =
$145.33 gross profit/kW

By encouraging the use of TES with a TOU rate, the utility, in this example, was able to raise revenue/kW for the average customer by 12% and gross profit/kW by 2%. All of this occurred without the addition of a single kW of capacity. In fact, the peak capacity required by this customer was cut by 24%. The residential customer comes out a winner; he saves $172.80 a year on his electric bills. The utility wins since its return on assets improves and there is now additional capacity to use elsewhere.

DEMAND SIDE PLANT CONCEPT

The utility can expand upon this concept to construct a demand side plant. Using the average residential customer described above, the utility could construct a 50 MW demand side plant with less than 35,000 customers at an annual opportunity cost of $135.63 per kW and a net present value (NPV) of $94.25 per kW (assuming a 15 year life and a 6% discount rate). The demand side plant is constructed as follows:

6.00 kW - 4.56 kW =
1.44 kW offset from TES/site

50,000 kW/1.44 kW =
34,722 sites

34,722 sites X $858.00 gross profit =
$29,791,667 gross profit before TES

34,722 sites X $662.70 gross profit =
$23,010,417 gross profit with TES

$29,791,667 - $23,010,417 =
$6,781,250 cost

$6,781,250/50,000 kW =
$135.63/kW opportunity cost

$145.33 gross profit/kW
- $135.63/kW opportunity cost =
$9.70/kW current value

$NPV_{15\ YRS\ @\ 6\%}$($9.70) =
$94.25/kW

With a positive NPV of $94.25 per kilowatt, the utility can construct a demand side plant. And throughout the construction period, the return per kilowatt of capacity increases one customer at a time, all without a prudence review.

IMPACT OF CONSUMER BEHAVIOR

Of course, the above examples completely ignored the potential for behavioral changes on the part of the residential customer once TOU rates are in place. The refrigerator is the only major appliance not affected by the homeowner's behavior. The range, dishwasher, washer, and dryer are all affected by behavior. If behavioral changes from the TOU rates are assumed to affect demand for the average customer by 1.56 kW, cutting total demand from 6.0 kW to 3.0 kW, the following example applies (note that the average price paid per kWh with TOU rates falls from $0.072 to $0.067 with the behavioral change assumption, as more activities are performed off-peak utilizing the lower rates).

9,600 base kWh + 4,500 a/c kWh =
14,100 total kWh

14,100 kWh X $0.067/kWh =
$944.70 gross revenue

14,100 kWh X $0.025/kWh =
$352.50 cost

$944.70 - $352.50 =
$592.20 gross profit

$944.70/3.0 kW =
$314.90 revenue/kW

$592.20/3.0 kW =
$197.40 gross profit/kW

In this case, the utility raised the revenue/kW for the average customer by 59% and gross profit/kW by 38%. Again, all of this occurred without the addition of a single kW of capacity. Peak capacity required by this customer was cut by 50%. The customer saved $243.30 per year.

The behavioral change assumption will also dramatically alter the construction of the demand side plant. The following illustrates:

6.0 kW - 3.0 kW =
3.0 kW offset from TES/site

50,000 kW/3.0 kW =
16,667 sites

16,667 sites X $858.00 gross profit =
$14,300,000 gross profit before TES

16,667 sites X $592.20 gross profit =
$9,870,000 gross profit with TES

$14,300,000 - $9,870,000 =
$4,430,000 cost

$4,430,000/50,000 kW =
$88.60/kW opportunity cost

$197.40 gross profit/kW
- $88.60/kW opportunity cost =
$108.80/kW current value

$NPV_{15\ yrs\ @\ 6\%}$($108.80) =
$1,056.69/kW

The utility has now constructed a demand side plant with a NPV of $1,056.69 per kilowatt! In demand side plant construction, there is no prudence review, revenue is realized during the entire construction period, and additional financing is not needed. It is a pay-as-you-go proposition. Figure 1 compares return per kilowatt from the scenarios above and Figure 2 summarizes the demand side plant construction.

LENNOX TES

The Lennox TES system makes demand side plant construction possible. This system fundamentally differs from the TES systems which are typically applied to large commercial structures today. These differences are worth noting.

To start, the system is a refrigerant based system and does not use a secondary fluid (such as brine or a glycol solution). The system thus avoids heat exchange losses associated with a secondary fluid circulating system. All pumping power is supplied solely by the compressor.

The system requires only liquid and suction line connections to the storage module, simplifying installation. Today's HVAC contractor already has the skills needed to install this system.

The design of the system results in less cycling by the condensing unit during periods of partial load. For light loads, below design conditions, the system will operate as a capacity reduced unit. Thus, better comfort conditions are provided.

The system is capable of supplying a total indoor evaporator capacity equal to as much as three times the condensing unit capacity. The system lends itself readily to residential and light commercial structures. The system is applicable to new construction, the replacement market, and to retrofitting homes currently without central air conditioning (through ductless systems). It will be applicable to air conditioning only or to heat pumps.

One of the principle differences between this system and the type of TES typically applied to large commercial buildings today is that it is load leveling rather than load shifting. This is illustrated by Figure 3. The load leveling feature of the system results in cost effective application for the homeowner.

A load leveling system operates continuously on the peak design cooling day, making ice with available excess capacity at night and using the ice the next day during the peak period. A load shifting system must be of sufficient capacity to meet night time cooling demand *and* build sufficient stored cooling to meet *all* of the peak load the next day. The load shifting system typically requires a condensing unit with the same capacity and electric demand as a conventional system. The load leveling system only requires 50% of the capacity.

The load leveling system, therefore, has a smaller condensing unit with smaller electric demand. Thus, it has a *finite* electric demand equal to the maximum electric demand of the condensing unit. With a peak shifting system, the possibility exists that an owner of the system could inadvertently or intentionally operate the condensing unit during periods of peak demand creating a *very expensive* demand charge the following year. This type of demand charge could result in a customer and public relations nightmare for a utility, especially if the demand charge comes following the sale of the home. This problem is eliminated with a load leveling system.

Since the load leveling system uses a smaller condensing unit, the cost of the system is lowered relative to load shifting TES. In addition, the load leveling system's storage module is only 30% of the size of a storage module for a load shifting system. And new construction applications will require less electric wiring capacity. All of this results in a TES system that only costs slightly more than a conventional high efficiency system.

Two-speed compressor heat pumps will be suitable to this system. High speed will pro-

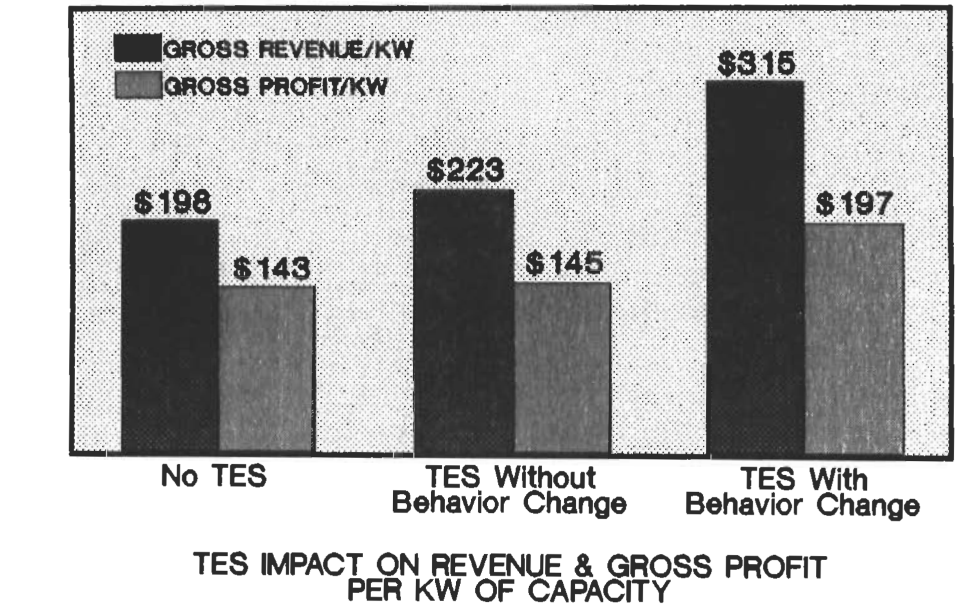

FIGURE 1: TES UTILITY IMPACT

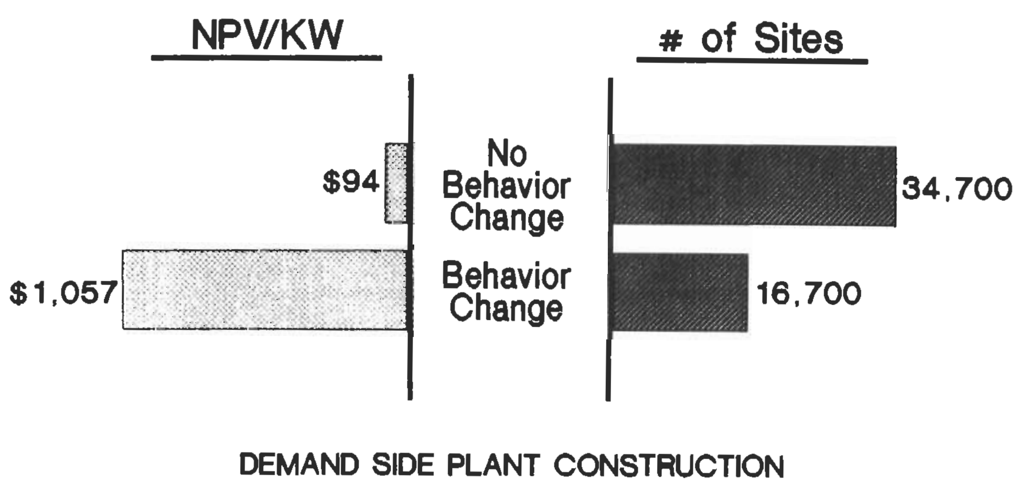

FIGURE 2: DEMAND SIDE PLANT UTILITY IMPACT

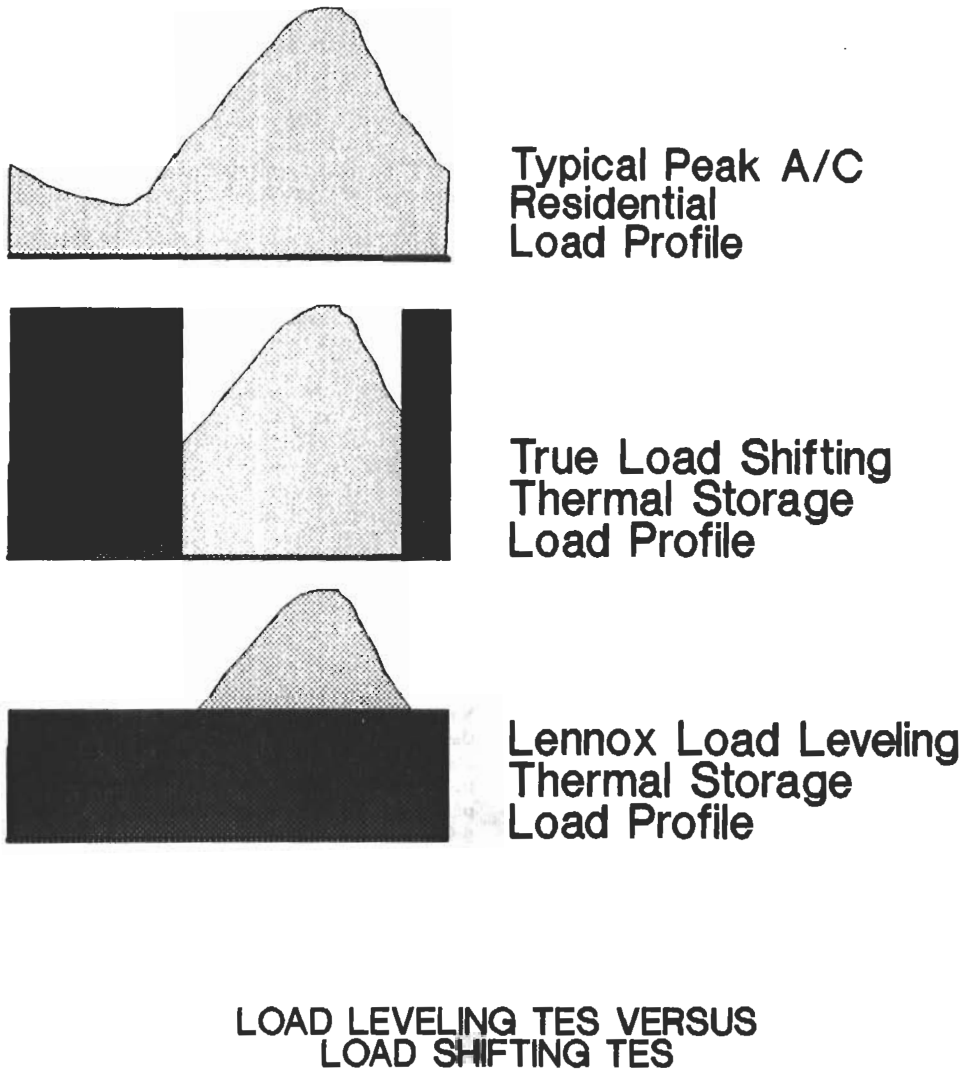

FIGURE 3: TES LOAD PROFILES

vide full capacity heating output and off-peak ice formation. Low speed will be used during on-peak cooling operation.

Utilities benefit from this system through improved load factors, low cost additions to peak capacity, improved shareholder value, improved reliability, and a way to meet growing demand requirements without the regulatory headaches accompanying capacity additions. Consumers benefit from the system through the realization of reduced electric bills and greater comfort levels. It is a truly unique HVAC product concept that satisfies utilities, regulators, and consumers. TES is a triple win!

The system can have a significant impact on a utility's financial performance, but only if the proper rate structure is designed. What is important is the difference between the average rate paid without TOU and the average with TOU. *The difference between the on-peak charge and the off-peak charge for TOU is insignificant if it doesn't lower the end user's average charge far enough below the regular rate.* This is critical! Rates must be designed with the average cost to the consumer in mind or TES will never get off of the ground.

There is much the electric utilities can do to encourage TES. When the product is launched, the public will have to be educated on its benefits. Since TES sounds exotic, some initial resistance may be encountered. The benefits of TES (ie. significantly lowered electric bills, greater comfort, and so on) must be promoted rather than the technical aspects. Monetary incentives will help to encourage rapid implementation. Nothing, however, is as important as the right TOU rate. Utilities interested in TES must begin developing the right TOU rates today and start pushing them through their arduous regulatory journey so they will be in place when TES is ready for the marketplace. It will be soon. If the utility industry wants to avoid the forecast 100 GW capacity gap, time cannot be wasted.

SUMMARY

Electric utility managements have two primary tasks. They must provide reliable electric service to their rate bases and they must maximize shareholder value. The current regulatory environment is making the satisfaction of both of these objectives difficult if not impossible using current means of providing additional capacity. The record sustained economic growth of the 1980s has helped to push electricity consumption past all projections. As a result, capacity is not being added fast enough to satisfy growing demand, leading to dire predictions of our nation's electric reliability. Demand side management solutions using TES can address part of the dilemma faced by the utilities.

Homeowner Benefits From TES

With TES, *homeowners should see significant savings in their electric bills.* Application of TES under the right TOU rate can easily reduce a consumer's electric bill by 15% in a moderate climate. In a sunbelt climate the savings significantly improve. Even greater savings are possible from the behavioral changes in the use of electricity.

With TES, *homeowners should enjoy greater levels of conditioned comfort.* The operating characteristics of a level loading TES result in more consistent and constant comfort levels than conventional cooling provides.

Utility Benefits From TES

With TES, *utilities have a means of improving load factors.* With the off-peak kicker the level loading system provides, base load plants are helped to run at capacity.

With TES, *utilities have a low cost means of adding peak capacity.* The demand side plant concept illustrated in the example above for the most climatically average Mid-America home one could imagine yielded a net present value to the utility of $1,056.69 per kilowatt.

With TES, *utilities are provided with a means of improving shareholder value.* Wide-scale use of TES in a given utility's service area will increase the utility's return on assets.

With TES, *utilities are given a means for improving reliability.* Redundancy is inherent in the demand side plant concept. A 50 megawatt generating plant always has the potential of failure and must be shut down for maintenance sooner or later. In addition, the transmission lines and connections for a generating plant are also subject to failure. The 50 megawatt demand side plant consists of thousands of small TES modules. Down time at the generator does not affect the demand side "addition" to peak capacity. Transmission line failure is not a possibility with the demand side plant.

With TES, *utilities have a means of satisfying growing demand without the regulatory and litigious nightmares associated with current supply side solutions.* The demand side plant satisfies all of the regulators' agendas. If it is to work at all, electricity rates will be lowered. The need for regulatory hindsight is eliminated since it is implemented as it is built and as it is planned.

Utility Support

Without the appropriate electric utility support, TES will not be successful in the marketplace. To be effective in addressing utility needs an marketplace needs, this technology must have correct and appropriate utility involvement and assistance.

CONCLUSION

Supply side solutions may not solve the utilities' growing capacity problems by themselves. Demand side solutions should play a supporting role. TES, a significant HVAC technology about to be launched, can help to meet capacity needs while simultaneously lending dramatic improvement to utility financial performance over time. This technology will help the electric utility industry maintain reliable electric service while improving shareholder value and satisfying regulatory requirements. Utility involvement and assistance, however, is critical to the success of TES in the marketplace. All told, support for this technology is an exercise in fiduciary responsibility for utility managements.

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