The Effect of Real Time Pricing (RTP) on Thermal Energy Storage (TES) Systems

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With the onset of deregulation of electrical utilities it is interesting to speculate on what the future will bring and how it will effect existing and potential new thermal energy storage projects. Let us be realistic, there is no reason to implement TES if there is not a rate structure that allows us to reduce energy cost. TES systems save money by reducing demand cost and utilizing lower energy charges during off peak periods.

Certain electric utility companies in anticipation of what may be coming have developed an experimental rate structure that charges energy in relation to what it actually costs the utility on an hourly basis. Many factors influence the cost of electricity during the day so that the cost per kWh can vary considerably on an hourly basis.

ELECTRIC RATE SCHEDULES

Time-of-Use Rate Schedule

Larger facilities usually purchase electricity from utilities under some form of time-of-use rate schedules. A time-of-use rate schedule basically divides the 24-hour workday into three periods for four to seven summer months: On-peak, partial peak (mid-peak) and off-peak. Some rate schedules have winter on-peak periods, some only have partial peak periods.

Different rates are charged for each time period. Also maximum demand charges are applied for the on-peak and partial peak periods on a monthly basis.

TES takes advantage of reducing demand charges by shifting electrical load from on-peak periods to off-peak periods. The expensive on-

Typical TOU Rates	Summer	Winter
Demand:	$/kW	$/kW
On-Peak	$15.00	$7.00
Mid-Peak	$4.00	$3.50
Maximum	$2.50	$2.20
Energy:	$/kWh	$/kWh
On-Peak	$0.09263	$0.08345
Mid-Peak	$0.06598	$0.06265
Off-Peak	$0.05512	$0.05367

peak demand charge is therefore reduced and the energy used to produce cooling is less expensive during the off-peak periods.

Time Pricing (RTP)

Program History

RTP is a unique program which began in 1985, and was designed to investigate customer responses to changing prices. The program completed a three-year Demonstration Phase in 1990 which focused on rate design and customer equipment. Since then, the California Public Utility Commission (CPUC) has approved the continuation and expansion of the RTP Program.

Daily Price Schedules

The utility calculates and transmits the energy prices for 24 hourly periods to each participating customer, usually by 1:00 pm every weekday. The prices are in effect for the following calendar day(s), midnight-to-midnight. Saturday, Sunday, and Monday prices are transmitted on the previous Friday. Holiday prices are transmitted on the last weekday preceding the holiday.

RTP prices are developed from daily system cost information and vary depending on such system conditions as weather and demand. For example, electricity is less expensive to produce when hydroelectric power is plentiful, or during times of low demand, such as late at night or on weekends.

Temperature Threshold T&D Price Signals

When forecasted temperatures meet certain temperature driven criteria, the RTP prices will include a price component designed to collect for the additional cost of Transmission and Distribution (T&D). These added costs will increase the daily prices by a significant amount. There can be up to 25 such days on summer weekdays and 25 on winter weekdays.

Load Management Price Signals

When forecasted total electrical generation reserves and afternoon temperatures meet certain predetermined conditions, PG&E will revise the prices for that day, giving at least one hour notice to the customer. This is the Load Management Price Signal (LMPS), the dispatchable load management component of the RTP Program. The LMPS prices are the highest RTP prices during the year.

These prices can be revised for the 7-hour period lasting from noon to 7 p.m. in order to induce load shifting or curtailment when system conditions are constrained and energy production costs are very high. These revisions to the RTP prices can occur up to 10 times during the year and will occur during the summer season.

DISCUSSION

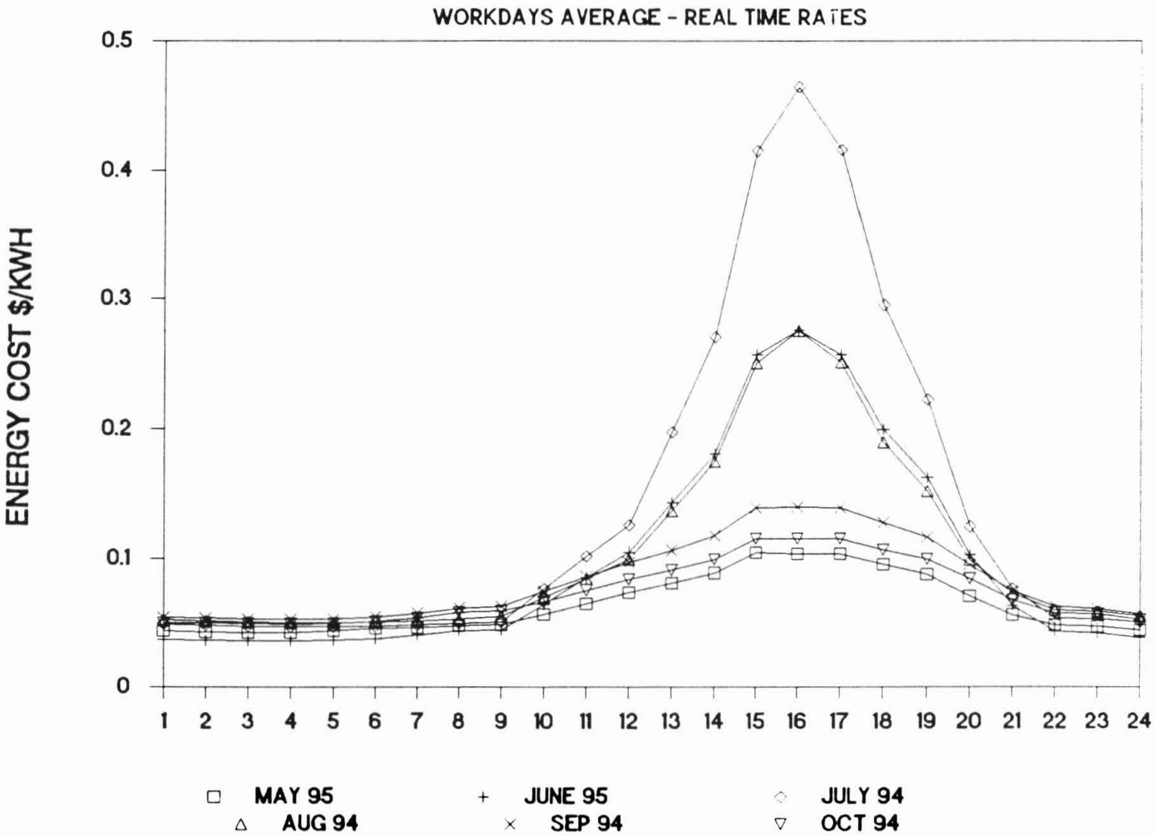
Graphs of Typical Days

In order to plan operational strategies for TES systems one must understand the charging patterns of the RTP rate schedule. Plotting graphs on a daily basis and averaging monthly values, and plotting them for workdays and weekends, shows the trends that drive the cost of electricity.

By plotting average values for the various months the effect of seasonal loads become evident. Figure 1 depicts the average workday daily cost profile for the six summer months. The influence of the T&D days during June, July and August is clearly visible.

Figures 2A and 2B show the maximum and minimum charges for a peak day and for an average low rate day for summer and winter. The bottom graph represents the same curves on a larger scale for the y-axis.

Figure 3 depicts the average workday daily cost profile for the six winter months. The influence of increased electrical usage for evening hours during workdays is observed. This effect explains why some utilities do apply a winter peak period during the hours of 5 pm to 8 pm.



WORKDAYS AVERAGE - REAL TIME RATES
ENERGY COST $/KWH
0
0.1
0.2
0.3
0.4
0.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
MAY 95
JUNE 95
JULY 94
AUG 94
SEP 94
OCT 94

Figure 1.

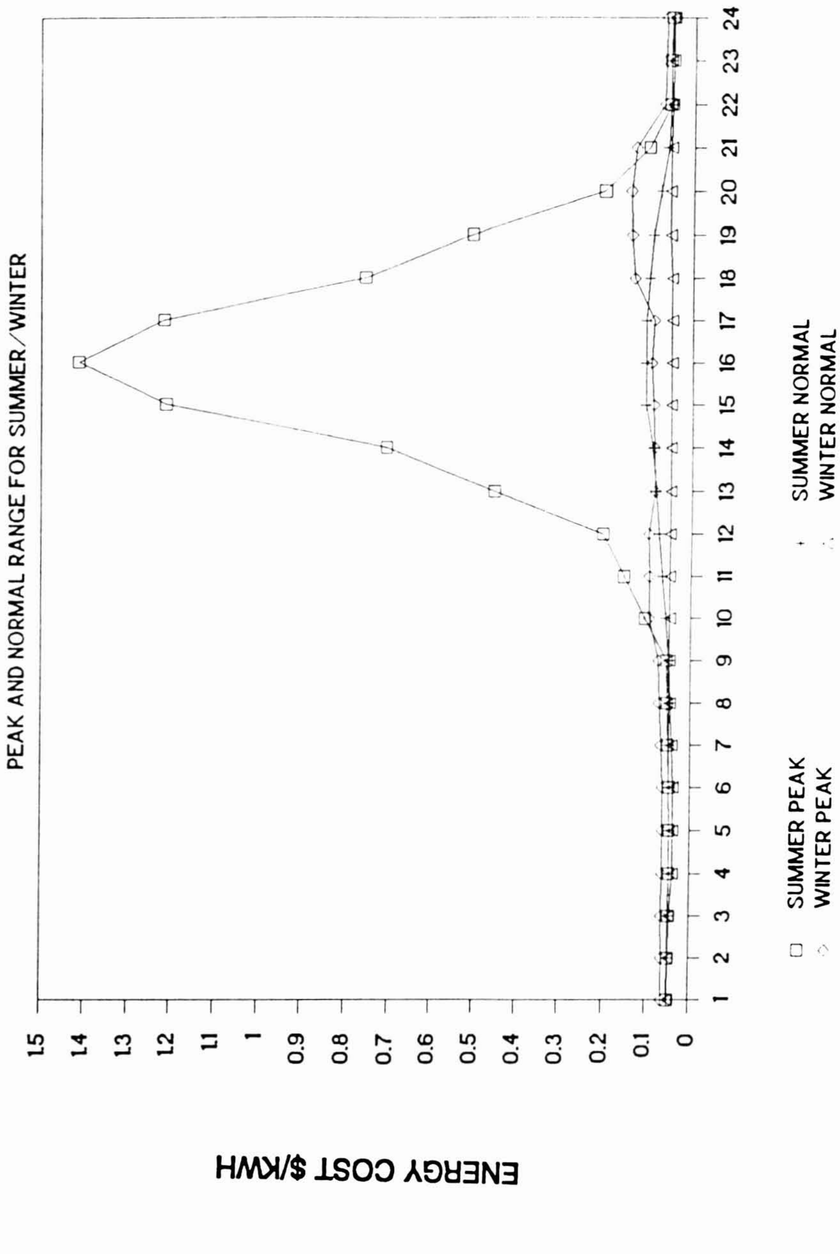


Figure 2A. RTP Rate Schedule

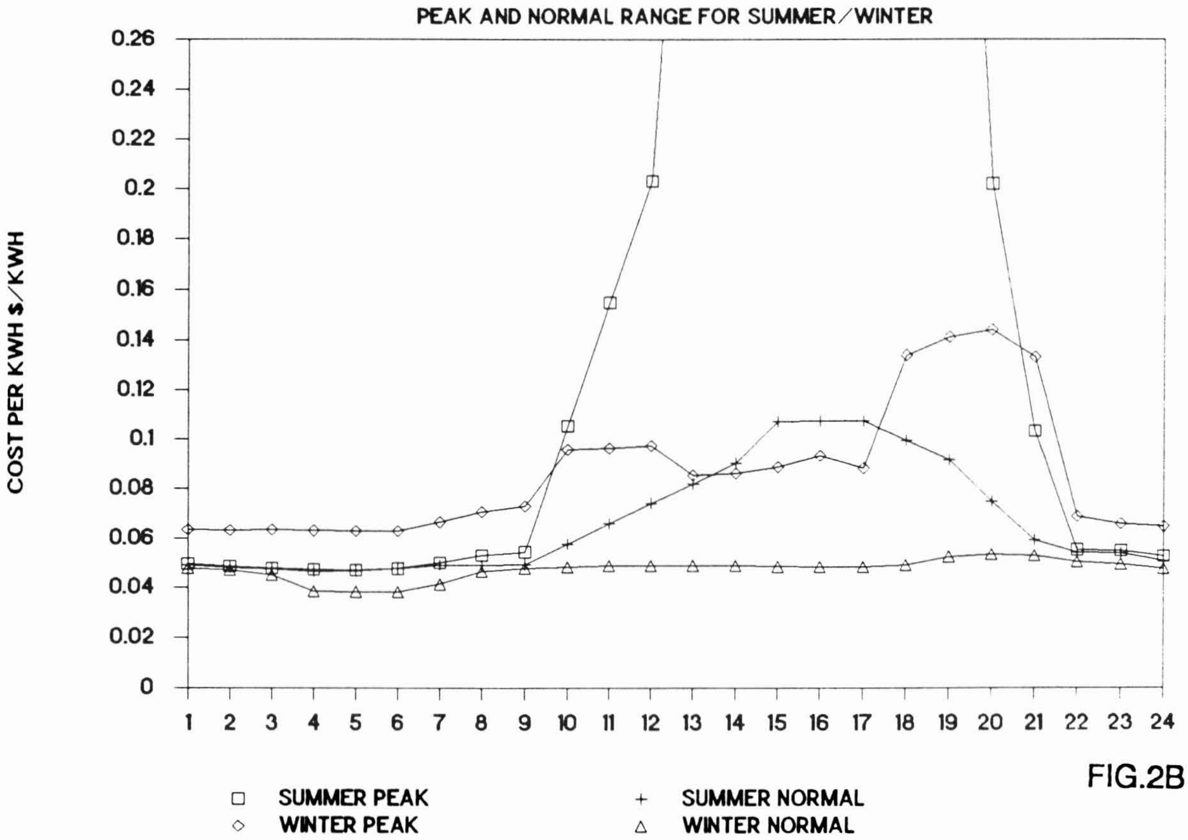


FIG.2B

Figure 2B.

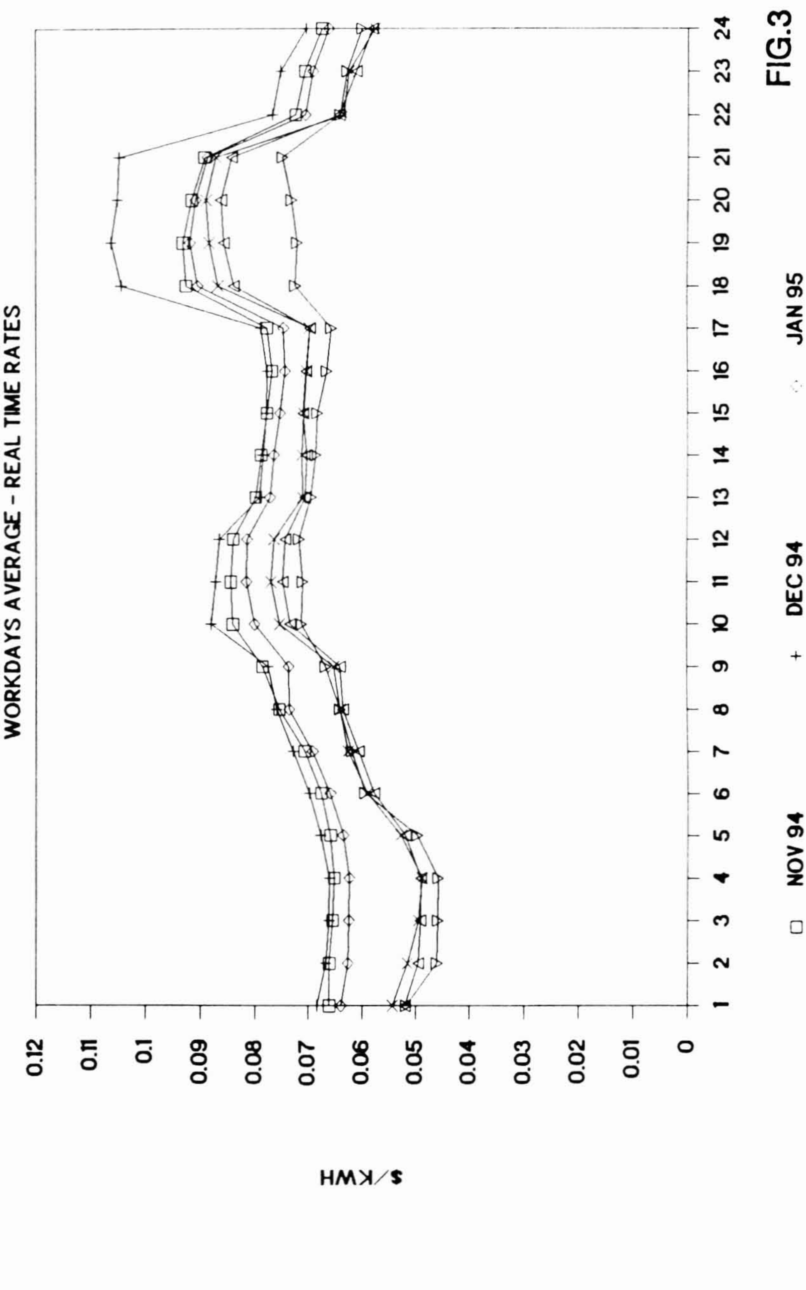

WORKDAYS AVERAGE - REAL TIME RATES
$/KWH
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
NOV 94
DEC 94
JAN 95
FEB 95
MAR 95
APR 95
FIG.3

Figure 3.

Figure 4 depicts the average weekend daily cost profile for the six summer months and Figure 5 depicts the average weekend daily cost profile for the six winter months.

Figure 5 depicts a typical peak day electrical load profile for a hotel in the Bay Area. Superimposed are the corresponding peak day RTP charges for that day. Combining the available load with the cost profile in the most economical manner yields the most savings.

As both vary on a daily basis, it can be seen that calculations to estimate savings should be based on a daily basis. We have tried to simplify calculations by using the average monthly costs as depicted in the graphs to estimate savings. We found that when we compared the estimated savings with the savings calculated on a daily basis, values were somewhat over-optimistic.

It is our experience that for more accurate savings calculations it is necessary to calculate on an hour by hour basis. Actually the approach to calculating the savings is somehow reversed. Instead of using the storage capacity to bridge the on-peak window, we now use the available storage capacity to shift load during the most expensive hours. Large spreadsheets with every hour of the year represented (8,760 hours) are used.

The same basic approach will also have to be applied to determine the control strategy for TES systems on RTP.

THE EFFECT ON TES

On-Peak WINDOW Eliminated

One of the advantages that the RTP rate schedule provides for TES systems is the elimination of the window for the on-peak period. This changes the concept of TES design considerably. The governing concept for TES is now to shift load as much as possible during the hours when electricity costs are the highest. From the graphs shown Figure 5, it can be seen that the three hours during summer afternoons are the most expensive.

Another advantage arises from the fact that if the demand is blown on a day for some reason or other, the effect is limited to the lost opportunity to achieve savings for that particular day only. With the TOU rate schedule the demand savings are lost for that whole month.

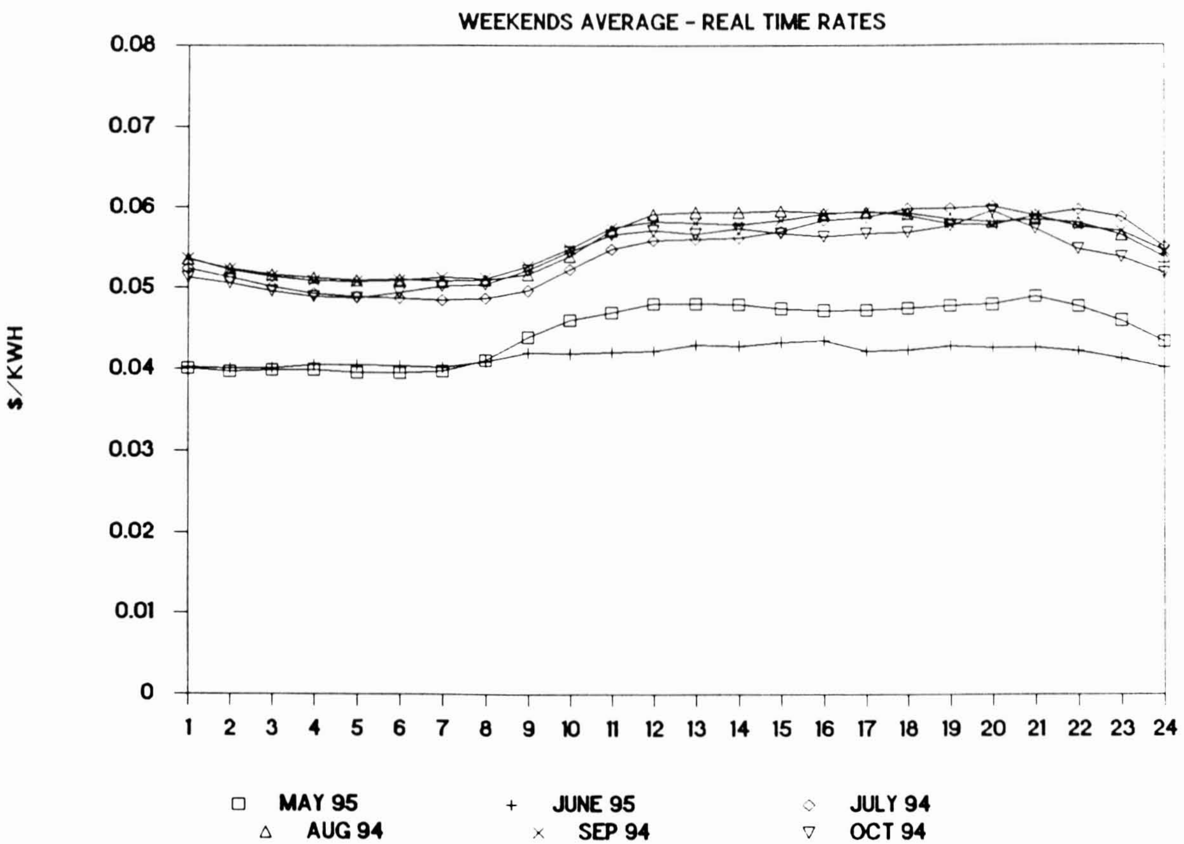


Figure 4. Typical Peak Facility Elec. Profile

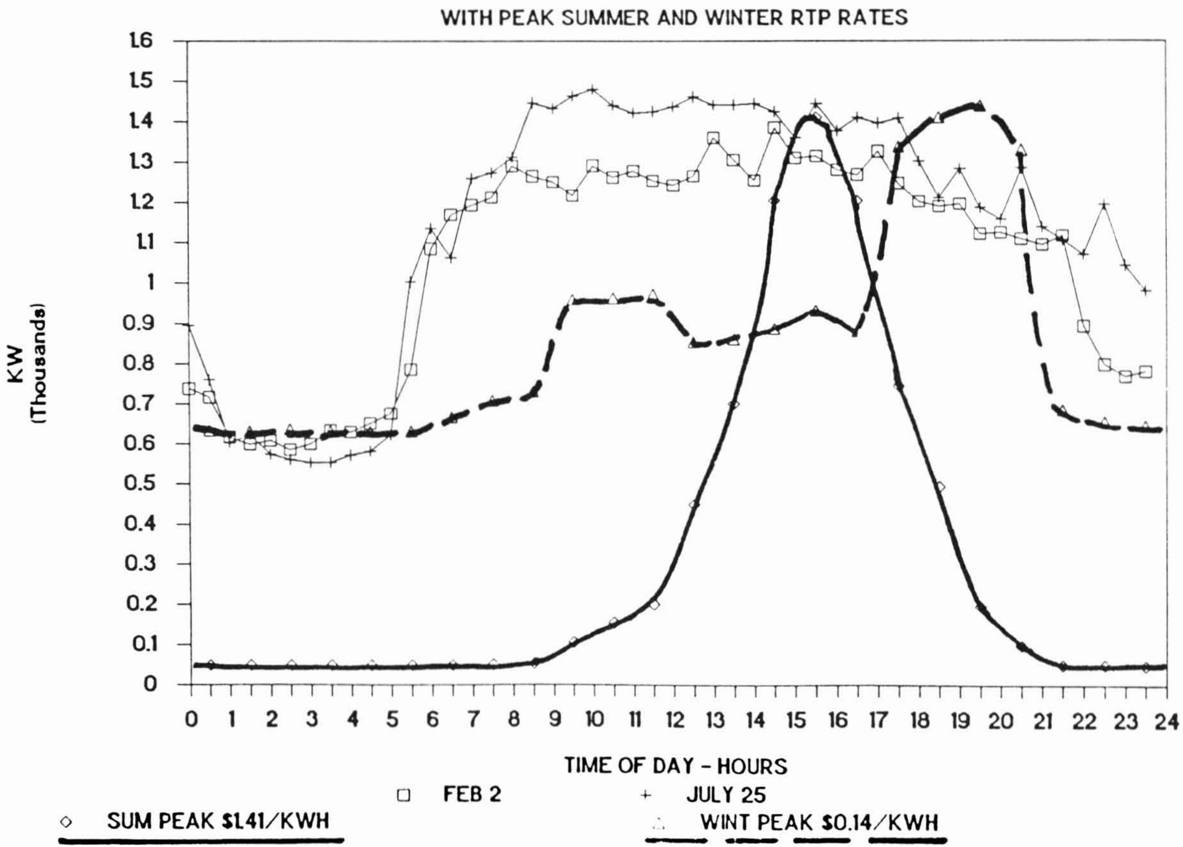

WITH PEAK SUMMER AND WINTER RTP RATES
KW
(Thousands)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIME OF DAY - HOURS
FEB 2
JULY 25
SUM PEAK $1.41/KWH
WINT PEAK $0.14/KWH

Figure 5.

Storage Capacity

Generally the storage capacity is determined by the condition required to satisfy full storage, full demand period storage or partial storage of the peak cooling load for the facility. RTP allows more freedom in selecting the storage capacity. There is of course a minimum capacity which for practical purposes should allow for a full demand shift of three hours.

But after that it is really a question of available funds, available space, chiller charging capacity and plain economics. Capacities can now also be made suitable for certain tank sizes as long as we shift in hourly chunks.

Peak Capacity

The heat transfer capability may now become the limiting factor of the TES system. For ice systems, it is the melting capacity of the ice and the size of the heat exchanger that governs the rate of cooling that can be supplied to the system. Generally for ice systems, a four hour "melt down" is about the best possible performance of standard ice TES systems and the eutectic salt TES systems.

The chilled water storage system opens up a new potential advantage. The "melt-down" concept could by changed to a "pump down" concept. The limitation is given by the pump capacity under the given system characteristics.

Theoretically the largest savings possible on a peak day would be to empty the tank during the most expensive hour, provided the load is as great. In practice there would be a three hour discharge if the load is available and the pump capacity is sufficient to provide the increased flow during that period.

Control Sequences

By the nature of the "beast" (UTILITY RATE SCHEDULES) it can be seen that control sequences cannot be placed in a straightjacket anymore. To achieve the largest savings the operational sequences have to take into account the hourly rates for the day and the actual cooling load for that day. Basically, the dominant rule is to "empty" the tank every day during the hours when energy costs the most.

Control sequences are now dependent on the two variables, the load and the hourly varying rates. The strategy therefore changes daily. It is highly likely that a facility applying for RTP rates is a larger consumer of electric power and some form of EMCS energy management system is in place.

As far as it is known there is only one facility so far on RTP rate schedule and a TES system in the PG&E territory. SDG&E is using one facility as an experiment. The method of control sequence is done manually. In other words, the operators decide when to use up the storage capacity.

It remains to be seen whether it is worthwhile to develop an optimized computer program that actually controls the sequences. Predicting the cooling load profile is never an easy task and really depends on actual experience gained at the facility. So it can be expected that initially the operators will develop their own methods of controlling the TES system.

It may be feasible to develop a relatively easy program that calculates the most economical starting time based on standard cooling load profiles that represent typical conditions for the facility. Inputting the daily RTP rates and then picking the expected cooling load profile allows the program to determine the optimal starting time to operate the tank. Once the temperatures rise due to an "empty" tank the normal chiller controls can start to take over cooling duty.

CONCLUSIONS

Know Your Options for both RTP and Time-of-Use

When performing a TES feasibility study it is essential that the study also addresses the performance of the TES system under the normal TOU rate schedule as a partial storage system. It may be possible that the system may have to go back onto a TOU rate schedule at a later stage. Naturally it is prudent to know in advance how the system performs on the regular rate schedule just in case future conditions change.

It is essential that the storage system developed under the RTP rate schedule conditions is analyzed for performance as a partial storage system under the regular time-of-use rate schedule. The option must always be left open to revert back to "normal" rate schedules.

Rate Comparison on Hourly Basis

For an accurate comparison between the time-of-use rate schedule and the Real Time Pricing rate schedule it is essential that the costs are calculated on an hourly basis just as the original bill is being calculated. A spreadsheet is required to calculate the costs on an hourly basis with the RTP costs per hour as given by the utility for the last twelve billing periods.

The electrical load profile of the facility determines if there is an advantage to change to RTP. Each facility is a different case and only a customized rate comparison can predict the advantages of Real Time Pricing.

Shift from "Window" to "Melt-Down"

The critical factor influencing the design of TES systems changes from the on-peak period or "Window" to the thermodynamic property of the melt-down capability of the system or the peak flow capacity in case of a chilled water storage system.

Load Shedding

Major savings can be achieved with the RTP rate schedule if some energy engineering is consciously applied to the rates on a daily basis. Some load shedding plan must be developed to see where electrical load can be shed during those very expensive hours.

Finally

It is like with many things in our complicated world that I would like to adapt the proverb that is used to describe happiness to our field and state that:

Energy Efficiency and Energy Cost Savings
Are not a destination...
But a way of travelling!

ABOUT THE AUTHOR

Klaus Schiess, P.E., CEM, holds a bachelors degree in mechanical engineering from the Witwatersrand University in Johannesburg, South Africa. He worked in South Africa, Germany and Switzerland before coming to America in 1968. Since 1987 he has been president of his own consulting firm, KSEngineers, in La Jolla, California. The firm specializes in feasibility studies, design, specification and supervision of mainly energy-related HVAC projects and thermal energy storage.