APPLICATION OF THERMAL STORAGE, PEAK SHAVING AND COGENERATION FOR HOSPITALS

JAMES D. McCLURE, P.E.
Estes, McClure & Associates Inc.
3608 West Way
Tyler, TX 75703

JAMES M. ESTES, P.E.
Estes, McClure & Associates Inc.
3608 West Way
Tyler, TX 75703

MIKE C. ESTES
Estes, McClure & Associates Inc.
3608 West Way
Tyler, TX 75703

ABSTRACT

Energy costs of hospitals can be managed by employing various strategies to control peak electrical demand (KW) while at the same time providing additional security of operation in the event that an equipment failure or a disruption of power from the electric utility occurs. Some electric utilities offer their customers demand (KW) reduction rate incentives. Many hospitals have additional emergency back-up needs for electrical energy. Demand is relatively constant in many hospitals due to high internal loads. These factors coupled with the present competitive alternate fuel market and present opportunities for hospitals to significantly reduce operating costs and provide additional stand-by or back-up electric sources. This paper employs a hospital case study to define and illustrate three energy planning strategies applicable to hospitals. These strategies are peak shaving, thermal storage, cogeneration and/or paralleling with the electric utility.

Hospitals, combined with other health care facilities, collectively consume nearly 15% of the energy used in all commercial buildings in the United States. Because of escalating electricity costs many hospitals have been implementing energy saving projects to reduce their operating costs. Based on our observation, however, many hospitals have not given serious or detailed attention to controlling electrical costs.

The electric generating business has become very well publicized in the last few years especially in certain regions of the United States. About a decade ago many electric companies anticipated system peak growth and turned to nuclear power plants to solve their peaking problem and at the same time produce cheap electricity. However, as the years passed by so did the anticipated start up date of many nuclear facilities. The delays resulted in financial nightmares for the companies that had invested into these massive facilities. Most nuclear power plants have been at least five years behind schedule and five times over budget. Government regulations, which also affect other types of power plants (i.e. coal, lignite fired) have resulted in additional capital expenditures. These basic cost overruns and additional expenses are added into the rate structures of the electric companies in order to recapture the cost of the new power plants. Many of the companies that did invest in nuclear power have increased their rates from 20% to 60%. Hospitals in regions where nuclear power plants are being constructed, should begin planning for the effects of significant electrical costs increases.

Since electric companies are building plants to satisfy their peak demand, their rates are generally becoming more demand oriented. This philosophy further passes the cost of the new plants on to each individual customer based on the customers peak demand.

The peak demand of a customer is the maximum electrical load required to the electrical power system at any given time. The peak demand is measured in either KVA (kilo volt- amperes) or KW (kilowatt). Kilovolt-ampere (KVA) measurement differs from kilowatt (KW) measurement by the power factor which is the ratio of real power in watts of an alternating current circuit to the apparent power in volt-amperes. An electric utility system decreases in efficiency as the power factor decreases. Most utilities which measure KW have a power factor penalty for customers below 80% power factor. Electric utilities that measure KVA pass the penalty for poor power factor directly to each individual customer's through its metering equipment at the customers site. Peak demand is not based on the highest momentary load, but rather on the average load over some utility selected time interval. This interval is 15 minutes for most utilities. The demand charge for electricity will either be the highest average load which occurred during the current billing month or a load calculated from some minimum billing formula utilizing the highest average load in the preceding summer or eleven months depending upon the specific rate schedule and the utility.

Electric utilities offer many rate schedules depending on the size of the account. More than one rate schedule may be available within a certain customer class and size. Electric utilities experiencing or anticipating insufficient generating capacity to meet peak demand have established load management programs offering their customers incentives to reduce demand (e.g. Texas Utilities - Time of Day Rate Option Billing). Many of the companies offer rate schedules benefiting customers utilizing off peak hours for electrical consumption. Customers utilizing "off peak" hours to reduce their peak demand during "on peak" hours will realize substantial cost savings. These savings can be realized all year under most utilities rate schedules and ratchet clauses for demand.

Because hospitals and health care institutions consume large quantities of energy and operate continuously, they are excellent candidates for energy saving projects that reduce electrical demand and consumption. Three primary energy savings strategies herein

Proceedings of the Fourth Symposium on Improving Building Systems in Hot and Humid Climates, Houston, TX, September 15-16, 1987

illustrated for a specific hospital are peak shaving, thermal storage and cogeneration.

Thermal storage is a method of reducing peak demand and reducing energy charges (KWH) by shifting electrical consumption from conventional daytime operation ("on-peak") to less expensive nighttime ("off peak") operations with cheaper energy charges. This method typically incorporates chillers or ice machines to generate and store chilled water or ice during the chillers "off peak hours" in which a reduction of energy charges are billed.

Some utilities encourage the application of thermal storage to reduce peak demand by offering monetary incentives to help pay the added cost for thermal storage installations (e.g. Texas Utilities will pay $102,500 to an owner who will reduce their peak by 330 KW). Hospitals with existing excess chiller capacity installed in central plants exhibit the best economic potential for thermal storage among health care institutions. Excess chiller capacity is needed because hospitals operate 24 hours a day and currently utilize their chillers during off peak hours. The chiller plant must satisfy current conditions plus store enough chill water to avoid operating at least part of the cooling equipment operating during "on peak hours". This strategy reduces the peak demand set during "on peak hours". The following East Texas Hospital example of a thermal storage project utilizes Texas Utilities monetary rate incentives and Time-Of-Day Rate Option. On the Time-of-Day Rate Option the customers "on-peak" KW (which is used in determining billing demand) is based upon the highest 15 minute KW recorded during the Company's "on-peak hours" in the 12 month period ended with the current month. On-peak hours are the eight hours between 12 noon and 8 p.m. each Weekday (Monday-Friday), excluding July 4 and Labor Day, during the calendar months of June through September. One important consideration for this project is that the demand will always be billed for 50% of the highest 15 minute KW recorded at the premises in the 12 month period ended with the current cost. Therefore, it is essential in the design and operation of a thermal storage system not to allow the thermal storage system's electrical consumption (plus the ordinary off peak load) establish a peak demand based on the 50% ratchet clause. If this occurs, the hospital will be billed at this KW for a 12 month period which will effect the savings involved in the project.

The East Texas Hospital example has three 420 ton chillers presently installed with an efficiency of 0.8381 KW/ton. Table 1 represents the loads for a typical summer day (August 1986) of the chillers KW and tons. From this data, it is estimated that a total of 7,392 (allowing 5% margin for extreme day) tons-hrs of cooling in excess of current needs could be generated and stored during off-peak hours by utilizing all three chillers at full load. During "on-peak hours" two chiller would be off and one chiller would operate in an unloaded condition to reduce "on-peak" KW by approximately 800 KW. This includes cooling tower fans and condenser water pump KW.

The 800 KW "on-peak" KW reduction results in a decrease of 4,888 billed KW for the year based upon Texas Utilities rate schedule (see Table 2). A reduction of 132,000 KWH will also be achieved by turning off the condenser water pumps and cooling tower fans for two chillers during on-peak hours. This thermal storage strategy would result in a savings of approximately $38,500 per year for this specific hospital.

The total project cost of a thermal storage tank and accessories (for a complete project) is approximately $450,000 for this size application. Texas Utilities will offer $205,000 for an 800 KW reduction. This project has a simple payback of approximately 6.4 years.

Due to the 6.4 year simple payback and space requirements thermal storage may not be the optimum alternative at this time for this specific hospital. However, as electric rates change thermal storage should be kept as a consideration in controlling energy costs.

The second strategy evaluated for controlling energy costs by reducing peak demand is peak demand shaving with an electric generator powered by a diesel and/or natural gas engine. This approach (at the present time) is more applicable to hospitals than thermal storage because of the larger capital expenditures required for thermal storage. All hospitals have existing emergency generators installed that could be used for peak shaving. The strategy for this approach is to utilize the generators to produce a reduction in the KW demand for the billing period or to reduce the "on-peak" KW. Standby units for peak shaving applications are usually controlled by an automatic controller. The generator is automatically brought on and off line in accordance with a set demand limit window interval defined by the demand controller. The following example for this method uses the same hospital data and rate schedules as the previous example on thermal storage. Table 3 illustrates the electrical demand of the East Texas Hospital and the estimated savings due to peak shaving with a generator set.

The East Texas Hospital is equipped with 1,000 KW standby capacity. The generator can operate in-parallel with the utility during "on-peak" hours which will reduce the "on-peak" demand by 1,000 KW. As in the previous example, this will result in KW savings all year. Also a reduction of approximately 672,000 KWH will be realized due to the 8 hours a day operation of the generator during the months of June through September. The electrical savings for this project will be approximately $67,000 a year. Maintenance and fuel is approximately $24,000 a year. Net savings for the project is approximately $43,000 a year. The simple payback will depend upon the use of the existing generator or the purchase of new or used equipment. A simple payback of 2 years can be achieved for this project if the health care facility elects to purchase a slightly used generator with minimal hours of operation.

The third strategy, cogeneration, presented in this paper reduces peak demand, but its primary benefit is to reduce the overall electrical dollars charged to the hospital. Cogeneration is the sequential use of energy from a primary source such as oil, natural gas or bio-mass to produce two useful forms of energy (heat and power). Cogeneration can produce mechanical and/or electrical power.

Electrical power produced can be used on-site or transferred in part or whole to the electrical utility. On-site usage can be paralleled with the utility as in the example provided. By capturing and utilizing heat that would otherwise be rejected, cogeneration systems operate at efficiencies greater than those achieved when heat and power are produced in separate or distinct processes. Thus, the primary reason for selecting this option is to reduce the overall energy costs of the hospital. Other benefits include continuous operation during power outages, clean electrical power, owner control, and flexibility of operations. Cogeneration is not a new concept; however, the technology is maturing. The industry has developed standard package system in mass production which has resulted in lower initial capital expenditures. The authors have conducted for hospital applications extensive studies of various cogeneration systems, strategies, equipment, and installation procedures. For all cases, packaged cogeneration systems are recommended. Complete packaged cogeneration systems have many advantages including reduced design cost and time, reduced time in receiving electrical utility approval (due to integral electrical safety components having prior utility approval), systems can be tested by the manufacturer prior to delivery, space requirements less than defined, one source of responsibility for all components, reduced time spent in the field on-site and a reduced risk to the owner. These factors combined with electricity rate increases and a competitive natural gas market have stimulated a great deal of interest in cogeneration. Cogeneration systems, if feasible, produce savings each hour of on-line operation which benefits buildings operating 24 hours per day each day. Hospitals have personnel experienced with electrical generating systems and have a need for a reliable supply of both electrical energy and thermal power. Hospitals are therefore excellent candidates for cogeneration.

There are several different cogeneration system concepts and designs that apply to hospitals. For simplicity, this paper presents the concept and design employed to forecast savings and calculate a simple payback for that which was recommended at the East Texas Hospital project. The system is designed to capture the waste heat and utilize it for space heating and domestic hot water. Another major application not covered here is utilizing the waste heat to drive an absorption chiller.

This design parallels with the electric utility and is designed to operate 8760 hours per year in order to maximize savings. During periods of the cogeneration or paralleling system downtime, standby generators should be fired to prevent demand peaks from occurring. This is a common problem observed in many existing cogeneration systems. If some measures are not included in the overall strategy to prevent peaking (KW) when the Cogeneration system is down and the hospital is forced to use the electrical utility for its electrical needs, then the economic benefits will be lost for a year under most rate structures. The hospital will not be totally disconnected from the electric utility and no sell-back of electrical power to the utility will occur. The other major factor to maximize savings is to consume all the waste heat at all times.

After evaluating site characteristics, utility bills, thermal load, and the installed capacity of existing generators, an 800 KW turbine was selected for the East Texas Hospital. Tables 4 and 5 illustrate the hospitals current and projected energy consumption for this cogeneration or paralleling project. Because of the increase in natural gas availability and the competitive natural gas industry, a cheaper natural gas rate than the present rate was used in calculating the savings for this project. The rate used is a rate which (under current conditions) has been negotiated by others. The total savings for this project is approximately $240,000 a year with maintenance cost of $35,000 a year resulting in a net savings of $205,000 per year. This project has a simple payback of 3.9 years.

Table 6 provides a summary comparison of the three strategies evaluated for the East Texas Hospital. For this specific hospital peak, shaving and cogeneration were recommended because of existing standby generators and anticipated electricity price increases.

Each hospital is unique and must be individually evaluated to determine which, if any, of the three concepts presented are beneficial. Based on our experience and observations, the best approach is to conduct a detailed energy audit of the hospital to identify and define all maintenance and operating techniques and other capital intensive projects (including building envelope modifications) which could be accomplished to reduce the energy consumption and electrical demand. For example, an energy study at a North Texas Hospital recommended significant modifications to the old and deteriorated air-conditioning system which reduced the installed tonnage by 416 tons. This systems approach permitted the evaluation of a down-sized thermal storage system, peak shaving using engine/generator sets, and cogeneration unit.

CONCLUSIONS

1. Hospitals, due to their large consumption of energy and full time usage, have many opportunities for accomplishing economically justifiable projects for reducing energy related costs. Thermal storage, peak shaving and cogeneration all show promise at the present time. As

hospitals energy costs continue to increase these types of projects will become more economically attractive.

2. Specific electrical rate structures must be used to accurately present the economic benefits of energy savings projects.
3. Each hospital is unique and should be evaluated in detail before selecting any single approach to reducing energy costs. A detailed energy audit should be accomplished to identify and evaluate possible operational changes as well as potential capital intensive projects.
4. Thermal storage systems, in general, present the least attractive strategy for hospitals compared to cogeneration or paralleling, and peak shaving using engine/generator sets. This conclusion is based on several hospital studies.
5. Packaged cogeneration or paralleling units provide the Owner the most benefits and are recommended over site-constructed/assembled systems.
6. Hospitals in regions with nuclear power plants under construction should plan for significant increases in electrical energy costs.
7. Successful hospital cogeneration or paralleling systems provide for some on-site peak demand control when the system is shut down for maintenance.

TABLE 1

CHILLER LOADS FOR EAST TEXAS HOSPITAL

TIME	KW	TONS	
12 NOON	765	913	
1	790	943	
2	790	943	
3	765	913	
4	790	943	
5	765	913	
6	765	913	
7	757	903	
8	707	844	
9	715	853	OFF PEAK HOURS
10	607	724	(8 PM - 12 NOON)
11	590	704	12,379 TON-HRS
12	582	694	
1 AM	582	694	
2	574	685	
3	574	684	
4	569	679	
5	569	679	
6	632	754	
7	682	814	
8	732	873	
9	748	892	
10	748	892	
11	765	911	

DATA RECORDED IN AUGUST 1986

TABLE 2

KW BILLED UTILIZING THERMAL STORAGE AND TIME-OF-DAY BILLING OPTION

MONTH	PRESENT KW	ON-PEAK KW	OFF-PEAK KW	BILLED KW
JAN	2,137	-	2,137	1,950
FEB	2,164	-	2,164	1,956
MAR	2,306	-	2,306	1,992
APR	2,498	-	2,498	2,040
MAY	2,506	-	2,506	2,042
JUN	2,686	1,886	2,831	2,123
JUL	2,598	1,778	2,743	2,101
AUG	2,687	1,887	2,832	2,123
SEP	2,657	1,887	2,802	2,116
OCT	2,621	-	2,621	2,071
NOV	2,313	-	2,313	1,994
DEC	2,185	-	2,185	1,962
TOTAL	29,358 KW/YEAR	-	-	24,470 KW/YR

PRESENT KW (OBTAINED FROM UTILITY BILLING DATA)

ON PEAK KW = HIGHEST KW DURING ON-PEAK HOURS (800 KW REDUCTION FROM PRESENT USAGE)

OFF-PEAK KW = HIGHEST KW RECORDED DURING OFF-PEAK HOURS

BILLED KW = (OFF PEAK KW - ON-PEAK KW) 25% + ON-PEAK KW

TABLE 3

KW BILLED UTILIZING GENERATOR AND TIME-OF-DAY BILLING OPTION

MONTH	PRESENT KW	ON-PEAK KW	OFF-PEAK KW	BILLED KW (PEAK GENERATORS)
JAN	2,137	-	2,137	1,800
FEB	2,164	-	2,164	1,806
MAR	2,306	-	2,306	1,842
APR	2,498	-	2,498	1,890
MAY	2,506	-	2,506	1,892
JUN	2,686	1,686	2,686	1,937
JUL	2,598	1,598	2,598	1,915
AUG	2,687	1,687	2,687	1,937
SEP	2,657	1,657	2,657	1,930
OCT	2,621	-	2,621	1,921
NOV	2,313	-	2,313	1,844
DEC	2,185	-	2,185	1,812
TOTAL	29,358 KW/YEAR	-	-	22,526 KW/YR

PRESENT KW (FROM UTILITY BILLING DATA)

ON-PEAK KW = SAME AS TABLE 2 EXCEPT 1.000 KW

OFF-PEAK KW = HIGHEST KW RECORDED DURING OFF-PEAK HOURS EXCEPT 1,000 KW

BILLED KW = (OFF-PEAK KW - ON-PEAK KW) 25% + ON-PEAK KW

TABLE 4

KW, KWH, MCF BILLED UTILIZING PRESENT CONDITIONS

MONTH	KW	KWH	MCF
JAN	2,137	1,053,000	7,222
FEB	2,164	970,000	6,258
MAR	2,306	1,123,000	5,859
APR	2,498	1,106,000	5,150
MAY	2,506	1,345,000	4,953
JUN	2,686	1,357,000	3,997
JUL	2,598	1,424,000	3,895
AUG	2,687	1,530,000	3,968
SEP	2,657	1,244,000	4,132
OCT	2,621	1,286,000	5,219
NOV	2,313	1,067,000	5,638
DEC	2,185	1,008,000	8,512
TOTAL	29,358	1,451,300	64,803

TABLE 5

KW, KWH, MCF BILLED UTILIZING COGENERATION EQUIPMENT

MONTH	KW	KWH	MCF
JAN	1,498	457,800	10,773
FEB	1,498	432,400	9,464
MAR	1,506	527,800	9,409
APR	1,698	530,000	8,962
MAY	1,706	749,800	9,260
JUN	1,886	781,000	8,962
JUL	1,798	828,800	9,260
AUG	1,887	934,800	9,260
SEP	1,857	668,000	8,962
OCT	1,821	690,800	9,260
NOV	1,513	491,000	9,073
DEC	1,498	412,800	12,061
TOTAL	20,106	7,505,000	114,706

TABLE: 6

EAST TEXAS HOSPITAL EXAMPLE

SYSTEM	$SAVINGS/YR	EST. COST	SIMPLE PAYBACK
THERMAL STORAGE	$ 38,500	$245,000	6.4
PEAK SHAVING (ENG/GEN SET)	$ 43,000	$ 85,000	2.0
COGENERATION (PARALLELING)	$205,000	$800,000	3.9