Optimizing Electricity Storage[1]

Commercial users of electricity purchase power at rates that vary both seasonally and within a given day. The rate for electricity in peak periods may be several times higher than the rate at times when consumption is lowest. Power is typically priced in $/kWh, where 1kWh corresponds to electricity used at a rate of 1 kW for 1 hour. In order to reduce electricity charges, commercial users may be able to shift some power-intensive operations to times when the cost of electricity is lower, but for many users these possibilities are limited. An alternative way to reduce the cost of electricity is to purchase and store power when it is cheaper for later use at times when the cost of electricity is higher. A number of different power storage technologies exist, or are under development, for commercial applications. These technologies typically are not based on batteries, which are suitable for some residential applications but cannot be scaled for commercial/industrial uses. With some systems the stored power is eventually converted back into electricity, while for others it is used to reduce the amount of electricity required for specific applications, such as HVAC.

The problem considered here is how to optimize electricity storage to minimize the cost of meeting the demand for electricity in a commercial application where the power consumed hourly over a 24-hour period is as follows:

Hour	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
$/kWh	0.03028	0.03028	0.03028	0.03028	0.03028	0.03028	0.03028	0.05081
kWh	52.8	52.8	52.8	52.8	52.8	80	80	120
Hour	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
$/kWh	0.05081	0.05081	0.05081	0.05081	0.1582	0.1582	0.1582	0.1582
kWh	128	136	160	160	160	160	160	160
Hour	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
$/kWh	0.1582	0.1582	0.05081	0.05081	0.05081	0.05081	0.03028	0.03028
kWh	160	80	52.8	52.8	52.8	52.8	52.8	52.8

In the above table, Hour 1 is from midnight-1:00 AM, Hour 2 is from 1:00-2:00 AM, etc. In addition to the cost per kWh for electricity consumed during each hour, there is a peak charge of $.30/kWh that is applied during the hour when consumption is highest. For example, for the consumption profile above the peak charge would be an additional $.30(160) = $48.

The electricity storage system can store power at a rate of up to 12 kW, can provide power at a rate of up to 20 kW and has a maximum storage capacity of 80 kWh. Therefore in a one-hour period the amount stored can be increased by up to 12 kWh, or the system can provide up to 20 kWh. The storage efficiency is 90%, so for example adding 9 kWh to storage requires that 10 kWh be purchased, while the retrieval efficiency is 100%. The storage efficiency accounts for the cost of operating the storage system, so once installed the system costs nothing to operate other than the cost of the electricity that is purchased for storage.

In addition to the storage system limit of providing power at a rate of up to 20 kW, in this application stored electricity cannot be used to satisfy more than 17% of the demand in any given hour. This limitation is due to the fact that the power drawn from storage must be dedicated to particular uses (such as HVAC).

Given the above demand profile, electricity costs, and operating limitations for the storage system, how should the system be utilized to minimize the cost of electricity purchased? Assume that the system is operated in the same way every day, so the amount of power that is in storage at the end of hour 24 is equal to the amount of power that is available in storage at the start of hour 1.

[1] Based on data provided by Professor Tom Rietz, Dept. of Finance, Tippie College of Business.