BY PAUL VALENTA, LEED AP

Making Buildings More Efficient with Hybrid Cooling

I love a good sale—don't you? I'm specifically thinking about those Black Friday sales that occur after Thanksgiving. Stores offer door-buster sales to entice customers to shop early to get the best bargains. Items can be purchased for 50 percent off or more if you shop before the birds are awake.

Similar to the Black Friday sales, most electric utilities offer discounts every night for commercial customers, but can all HVAC systems take advantage of such sales? Using electricity at night offers savings to building owners in the form of a demand charge reduction (dollars per kilowatt), cheaper energy, or both, but the building must have the ability to "go" to the sale.

THE POWER PROBLEM

Electric utilities are near capacity during the peak of a summer day because of air-conditioning loads in buildings. According to the North American Electric Reliability Corporation, summer peak demand was 1.8 percent less than last year, so utilities had enough generation resources and transmission capacity this year to cover their obligations. Over time, though, those companies will not be able to produce enough electricity unless significant investment is made in the nation's infrastructure. According to the "National Transmission Grid Study" by the U.S. Department of Energy, released in 2002, demands on the network will grow by 20 percent in the coming decade, but the capacity to carry electrons will increase by only 6 percent.

Instead of building new infrastructure, utilities can use existing assets more efficiently by helping customers change behaviors. Electricity companies have unadvertised sales at night because nighttime demand is low, and they want to encourage customers to use plentiful and efficient nighttime generation. Electricity is more efficiently generated and transported at night, which reduces emissions as well. Utilities use their most efficient generation for base loads, and the temperature at night is cooler, offering better nighttime efficiency. By shifting loads to off peak, utilities don't have to use their peaking units, which are typically not very efficient.

HYBRID COOLING TO THE RESCUE

To take advantage of this nighttime sale, a building must have the ability to store energy purchased at night for use during peak load (expensive) consumption periods. The biggest load in buildings during the summer that can be shifted off peak is comfort cooling.

Hybrid cooling systems with energy storage can take advantage of the nighttime sale and more efficient nighttime generation to decrease source fuel consumption. A hybrid cooling system is not much different than a typical chilled water cooling system. The hybrid system with energy storage consists of a right-sized chiller, energy storage tanks, some extra valves, and a few more control points. Just as a hybrid car offers great miles per gallon, a hybrid cooling system with energy storage can increase cooling performance.

The stored energy can be in the form of water or ice. Because ice storage uses less space, is cost effective over a wide range of sizes, is modular, and is offered by single-source providers, I will focus on ice storage in this article.

WHAT DOES A BUILDING NEED FOR A HYBRID COOLING SYSTEM WITH ENERGY STORAGE?

To design a hybrid cooling system with ice storage, a load analysis must be performed on the building to obtain a 24-hour peak day cooling load profile. Hybrid cooling with storage must be sized for the total cooling load and the peak cooling load, so a detailed profile is required. For a new building, this data is determined by a load analysis program and includes information about the location, weather, hours of operation, type of use, and occupancy. For an existing building, a load profile can be determined based on existing cooling equipment operating data.

Some buildings have no occupancy after business hours, so temperatures drift up at night. In the morning, this load is quickly removed from the building before occupancy. Other buildings have nighttime loads that must be met, so be sure to include that information in the cooling load profile.

Once the cooling load is determined, other design parameters must be defined, such as design temperatures for the distribution system and nighttime charging hours. Be sure to review the utility rates offered in the area because this information can affect the design choices. Also, build some flexibility into the design, as utility rates and building usage can change over time, and the design must be able to adapt and grow. Flexibility can be built into the design with unscheduled chiller operation. Said another way, don't reduce the chiller size to the absolute minimum.

FOR EXAMPLE

A 200-ton building has the load profile indicated in Table 1, which includes 11 cooling load hours and eight ice-making hours from 10 p.m. to 6 a.m. Therefore, the chiller is scheduled to operate 19 hours, leaving five hours of unscheduled time.

The chiller size is determined by the following formula:

$$\frac{\text{Total building cooling load, in ton-hours}}{(\text{Ice-making hours x Chiller capacity at ice-making}) + (\text{Cooling hours x Chiller capacity at nominal})}$$

When making ice, chillers have less capacity than usual because they operate at colder temperatures. Ice-making chillers on average have 35 percent less capacity at ice-making temperatures when they cool an antifreeze solution to 25°F. Air-cooled chillers making ice at night tend to have the same energy-

Table 1 Example building load profile	
Hour	Load (tons)
8 a.m.	160
9 a.m.	140
10 a.m.	120
11 a.m.	140
Noon	160
1 p.m.	180
2 p.m.	200
3 p.m.	200
4 p.m.	180
5 p.m.	160
6 p.m.	140

Figure 1 Example design day

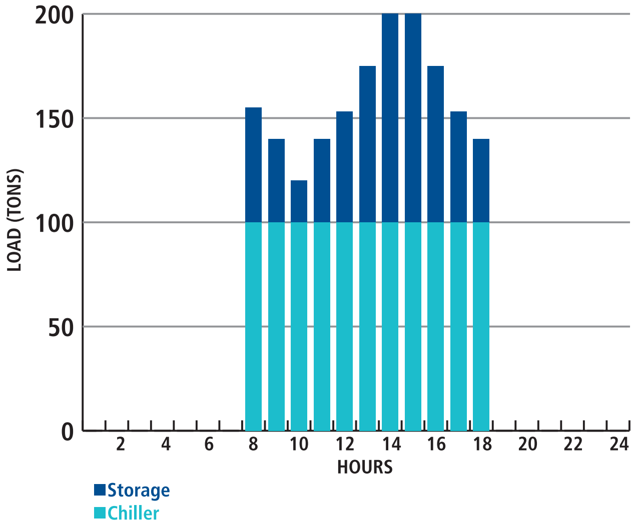

Table 2 Comparison of conventional and hybrid cooling		
	Conventional Cooling	Hybrid Cooling with Energy Storage
Chiller size	200 tons	125 tons
On-peak usage	200 tons	102.5 tons
On-peak kW (at 1.2 kW/ton)	240 kW	123 kW
Energy storage	0	651 ton-hours

efficiency ratio (EER) as a chiller operating during peak demand on a design day because of lower ambient temperatures. Also in this case, you may consider adding some capacity or a safety factor (approximately 18 percent) should the facility increase occupancy over time.

With this data, the chiller size equals 125 nominal tons, or

$$\frac{1{,}780 \text{ ton-hours}}{(8 \text{ hours} \times 1 \times 0.65) + (11 \text{ hours} \times 1 \times 0.82)}$$

This chiller will charge the tanks at 81.25 tons per hour (0.65 de-rate x 125 tons) for eight hours, storing 650 ton-hours of cooling. Four ice tank modules will store the required cooling. During the day, the chiller is limited to 102.5 tons by design (125 tons x 0.82), with the remaining capacity coming from the stored cooling. Graphically, a design day looks like Figure 1.

For non-peak-load cooling days, smaller contributions from the chiller will be needed, saving more money.

Even though the chiller is smaller than a conventional design, this design includes a safety factor for flexible building operation to handle different usages or higher-than-expected loads. The chiller has 125 tons of cooling capacity, but the peak day design requires only about 82 percent of the chiller's capacity, or 102.5 tons. Additionally, the chiller is scheduled to be off for five hours. This time could be used by the chiller to cool unexpected loads up to 125 tons directly between 6 a.m. and 8 a.m. or between 6 p.m. and 10 p.m. This unscheduled time also could be used to charge additional storage tanks if an expansion occurs at a later date. See Table 2 for a comparison of a conventional cooling system and a hybrid cooling system with energy storage.

WHAT ABOUT THE ECONOMICS?

The hybrid cooling system has a smaller chiller and fewer electrical requirements than a conventional system, offering first-cost savings. Additional savings can result if you choose to reduce the fluid flow in the system. Because ice storage is cold storage, the pumping system can send colder fluid to the coils. Colder fluid means less flow, which can reduce pipe sizes and save additional costs. However, the system will require ice tanks, an antifreeze solution, a modulating valve, diverting valve, and a few more controls, which will increase costs.

Construction data has shown that some new systems can have an immediate payback with partial energy storage. Most new hybrid cooling systems will pay back in less than three years. Existing systems are best converted to hybrid cooling systems when the chillers need to be replaced and simple payback is between three and five years. In the above example, assuming 6 cents per kilowatt-hour and a $12 per kilowatt demand charge, the hybrid cooling system will save about $6,000 over a six-month cooling season.

As utilities shift to renewable wind energy to reduce our dependence on fossil fuels and reduce carbon dioxide emissions, energy storage can help make this type of generation more economically viable by increasing wind energy usability since wind blows more regularly at night.

The smart grid, renewable energy, and nighttime generation most likely will offer many opportunities to lower cooling costs and reduce the impact of cooling on the environment. Will your client's building be able to take advantage of these current and future savings opportunities? PSD

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