Thermal Energy Storage is Electric Energy Storage

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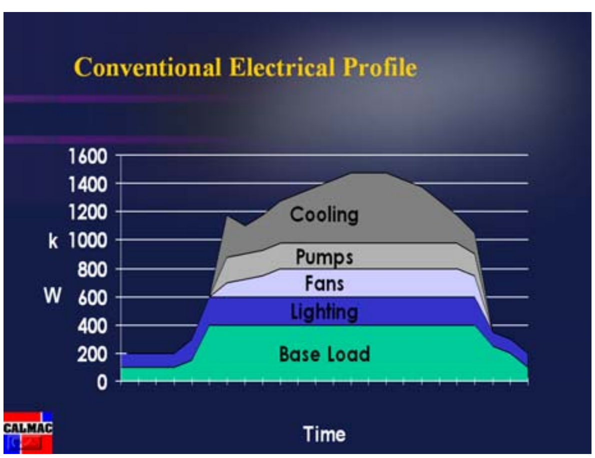
Thermal Energy Storage (TES) is not normally recognized as a form of Electric Energy Storage (EES) yet its similarities and its applications are so close that the Electric Energy Storage (EES) customers and suppliers should have a good working knowledge of the technology. TES systems are used to reduce customer's electric bills by shifting electric usage from on peak to off peak hours. Used together, TES and EES can be a powerful tool in creating buildings and an electric grid that are more prepared for the demands of the 21st Century.

Thermal Energy Storage does not store electrons although neither does pumped hydro nor compressed air, although they are considered "electric storage" technologies. Instead of storing potential energy (like pumped hydro or compressed air) and then using it to make electricity when you need it, TES tanks are "charged" using electrons before they are needed. The difference is simply when and in what form you are storing the energy. Granted you can't run a motor with TES however, as you will see, those very large motors used for air-conditioning will not need the expensive, on-peak electrons. Basically you have simply committed the electrons for a purpose prior to their need.

One of the most basic examples of TES is the domestic hot water heater. For domestic use, a small electric heating element (4.5kW) is used to heat up water and the hot water is then stored for future use. For a shower with a low flow shower head, if the water was to be instantaneously heated to meet the load, 18 kW of power would be needed (or 36 kW for 2 simultaneous showers). However, because we have stored the thermal energy we have reduced the electrical demand requirements for the house by a minimum of a factor of 4. Since electricity is a very refined type of energy, heating water with it is not a very prudent use and therefore, TES with water heaters has not had a large effect on our grid requirements. However electricity is the major energy source for air conditioning and so TES could have a huge effect if utilized appropriately.

Air-conditioning (AC) for buildings accounts for about 30% of the peak electric demand on the grid in the summer months. The AC electric loads for buildings consist of refrigeration compressors (chillers), pumps and blowers, the largest portion being the chillers (Figure 1). By running the chillers at night and storing the cooling in the form of chiller water or ice, and using it the following day to cool the building, approximately 40% of an office building's on-peak electric load can be shifted "off-peak" (Figure 2). The stored cooling is very efficiently stored and the systems are cost competitive with conventional systems. This type of system is more descriptively called Off-Peak Cooling (OPC), which states what it does, not what technology it uses (TES).



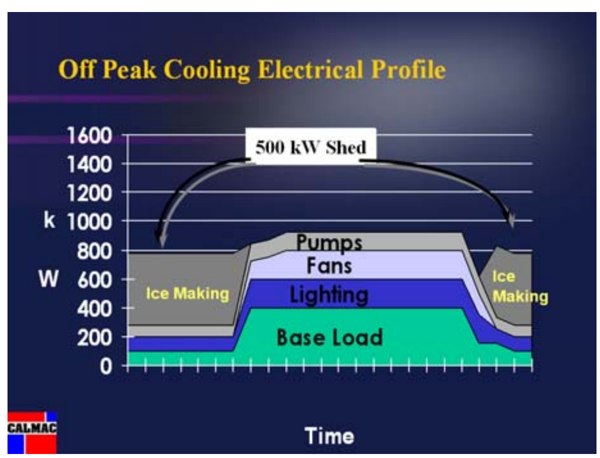


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Figure 1 Conventional Building Electric Load Profile Figure 2 TES Electric Load Profile

The chart below shows how TES, used for Off-Peak Cooling, compares with other more familiar EES technologies relative to capacity of storage and rate of discharge. TES has the ability to discharge in a matter of 20 minutes to many days and has been used in systems from a few kilowatts to tens of megawatts. It is clear that TES has a wide range of sizes which covers a lot of the EES technologies however, TES's major application is simply for cooling.

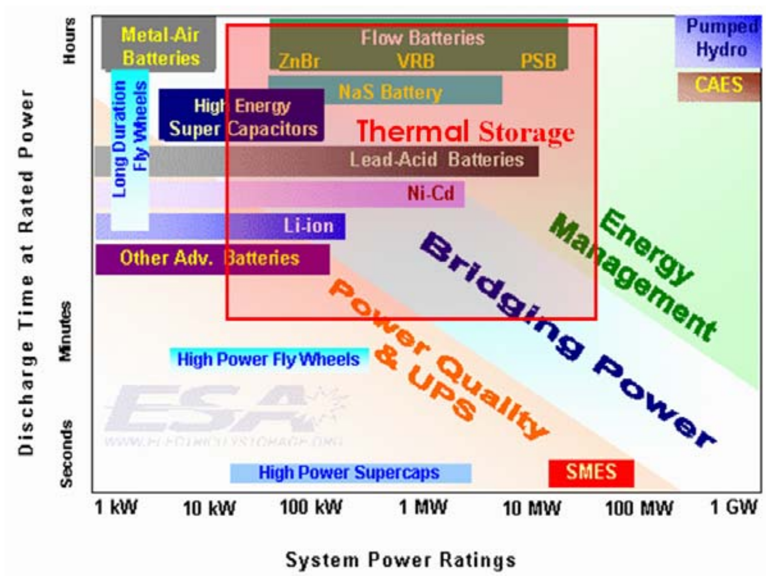

Figure 3 Storage Device Capacity and Power Ratings

The relative value of electric storage depends on what it is being used for. Obviously UPS and power quality systems have a very high value in our digital world and so their cost can be high because of the application. Using EES to supply clean, stable peak power, or back-up power, to an entire building affords owners many advantages however the cost of EES in this application is still a major point of consideration. As the chart below demonstrates, the relative cost of TES is below almost all of the EES technologies when considering the storage capacity or power output. Therefore, when applying EES to power buildings and since such a large portion of building power is for air conditioning, EES technologies can be much more cost competitive with conventional systems, if Thermal Energy Storage is used to handle the cooling loads and EES the balance of the electric loads.

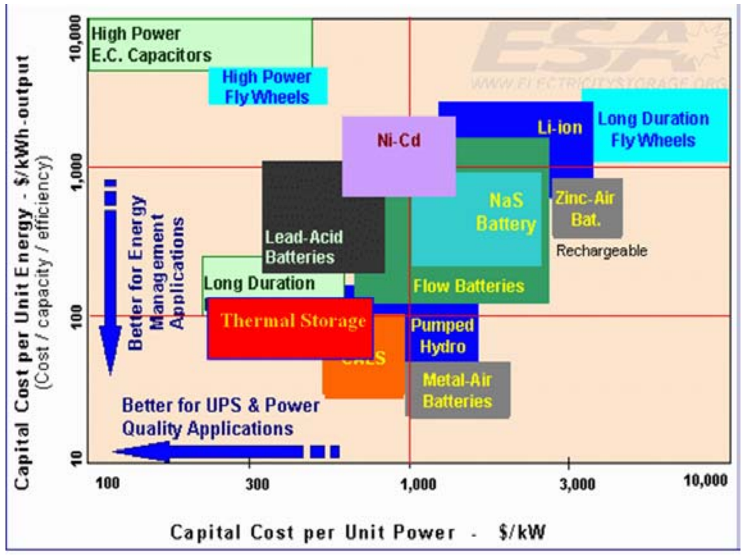

Figure 4 Storage Costs

One final way to assess the different methods of storage is by energy density. In this way the more conventional EES devices shine pretty bright and it highlights the main issues differentiating the two methods of storing thermal energy, namely water and ice. In Figure 5 below you can clearly see that the TES devices are on the low end of the density scale meaning that more space is needed per unit energy stored. However you can see that water is even much worse, to the tune of 5-8 times worse that ice. This factor becomes very important when you consider that 80% of the buildings that we will be using in 2020 have already been built. Therefore with TES, unless space is not an issue, ice based TES systems are the likely choice in commerial AC system.

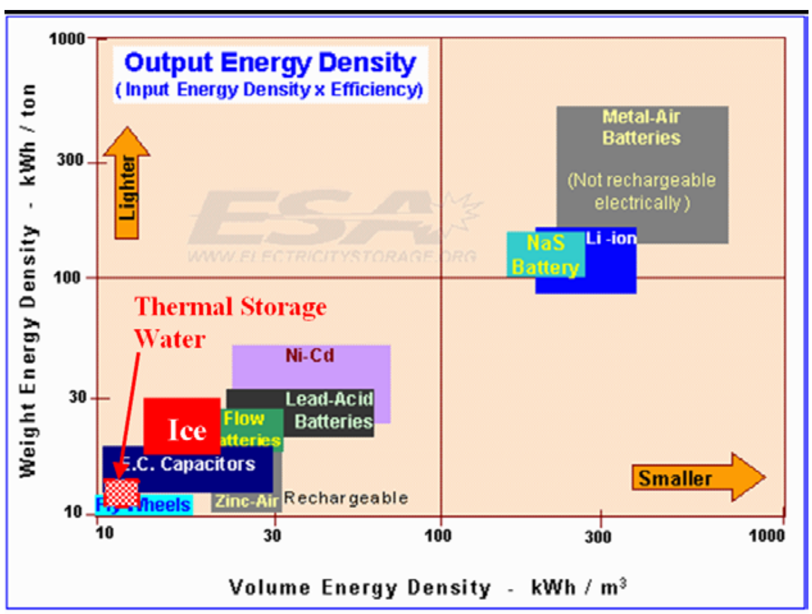

Figure 5 Storage Densities

So with the application and value clearly in the range of other EES technologies lets look at the specifics of how Ice based TES, used for Off Peak Cooling (OPC), really works. First a quick review of the basic type of design strategies. All buildings have a particular cooling load profile on design day which is used to design the size of the storage (Figure 6). The cooling is provided normally by a chiller and pumps which circulate the coolant throughout the building. In a Full Storage system the entire days cooling needs are created by a chiller and stored the night before. This requires a chiller about the size of the conventional system's chiller and a relatively large amount of storage. A Partial Storage system uses a chiller which is about half the size of what is normally required. It is run at night to store cooling and used to meet part of the daytime load, with the balance being met by storage (Figure 7). This system needs a much smaller chiller and much less storage. With the money that is saved on smaller chillers, cooling tower, and electric capacity to the mechanical room, you can essentially pay for the storage devices, thereby making the costs very competitive with a conventional system.

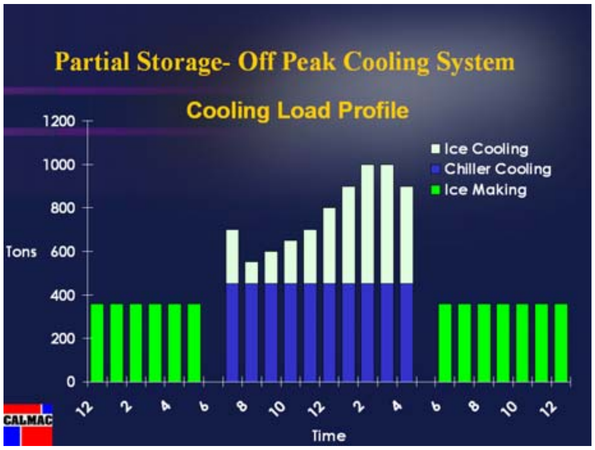

Figure 6 Design Day Cooling Load Profile

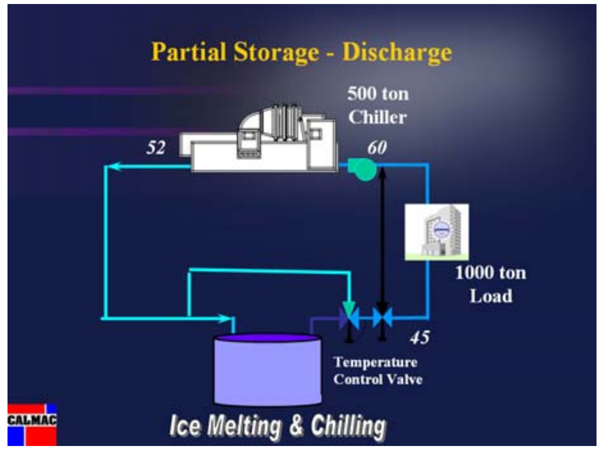

Figure 7 Off Peak Cooling System Schematic

The most commonly used TES system is Ice-On-Coil, Internal Melt. The storage devices are made up of a coil of heat exchange tubing, submerged in water, in an insulated tank. The water in the tanks never leaves the tank and is regularly frozen from water to ice, using 25 F coolant coming from the chiller, which is circulated through the heat exchanger tubing. The CALMAC system uses modular, polyethylene, rotomoulded tanks, which are about 7.5 ft. in diameter and 8.5 ft. high and contain about 3 miles of 5/8’ diameter PE tubing. The heat exchanger is 100% welded. The submerged heat exchanger takes up about 10% of the volume of the tank, with 90% left for water and the 10% expansion, which occurs during the freezing process. There are no moving parts and nothing to corrode. The PE pipe that is used is identical to the pipe which is now being used for 95% of the natural gas pipelines throughout the world.

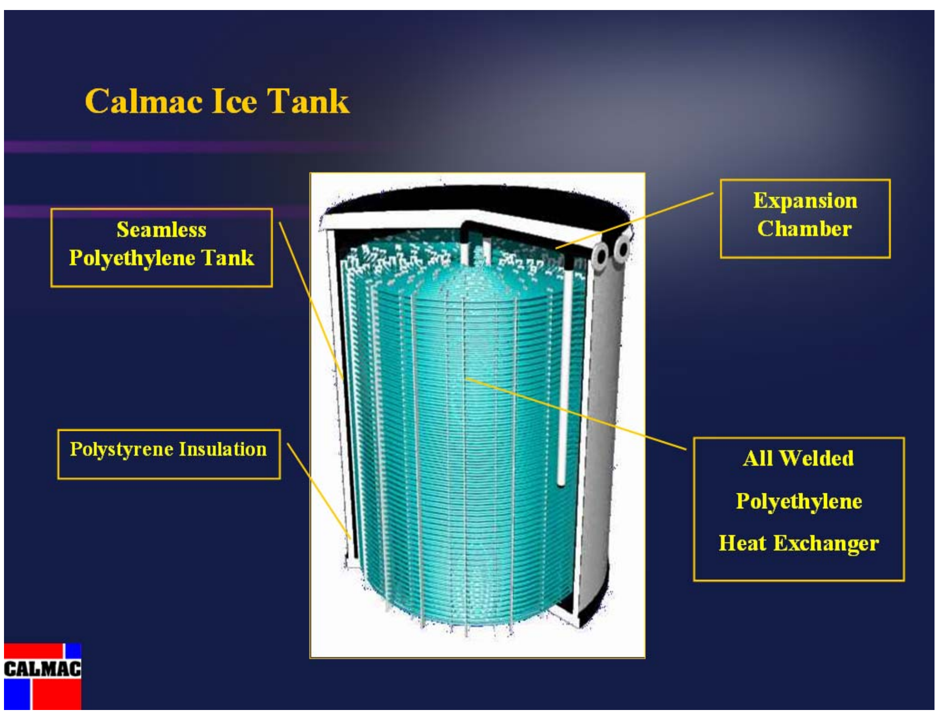

Figure 8

So obviously the lives of these tanks are going to far exceed the life of the chiller system they are connected to and the ones that they replaced. They also integrate easily in most large building retrofits, requiring a relatively small amount of space. The space required for a Full ice storage system works out to be about 0.07% of the cooled space. However most retrofit systems are Partial storage, having the storage handle about 33% of the peak load. In those cases the space requirements is less that 0.25% or in other words, a 100 story building like the World Trade Center would only need a ¼ of the roof space.

Figure 9 Nation Air and Space Museum, Dulles Airport

Figure 10 CALMAC IceBank Tanks at Air and Space Museum

The obvious reason to use TES for OPC is to reduce a building energy costs by lowering peak demand and shifting usage to off peak hours, when energy costs are low. However there are other advantages that can be almost as important. Better load factors on buildings can help customers negotiate better rates in a deregulated energy market. Systems can be designed to use less energy at the building because of less part load operation. However, even if a building uses the same amount of kWh with a OPC system in the building, there can still be major energy savings. That is because, as reported in the Californian Energy Commission report[1] on TES and Source Energy, it is much more fuel efficient for power plants to generate and deliver power during the night as opposed to during the heat of the day. It has to do with using more efficient base load plants and lower line losses at night. The numbers reported were anywhere from 8-30% less fuel for 2 of California's largest utilities, which is not a small number. In addition the emissions are reduced. So there are truly societal benefits as well to using TES for OPC.

The use of EES has many advantages including power quality and backup power. However, using EES for cooling a building if a blackout occurs is a very expensive use of that asset. EES combined with TES has the ability to drastically reduce the cost of a backup EES system and possibly make some jobs a reality which otherwise might be knocked out because of cost constraints.

With over 6,000 OPC systems around the world now in operation, and with the increased awareness of the consequences of power quality and blackouts, these installations may well be excellent candidates for retrofit installations of EES. The combination of these two types of storage technologies to address the realities of our electric grid and customer requirements for clean reliable power, creates major market opportunities for suppliers, while affording a stable building environment for all to prosper in.


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