

Thermal Energy Storage in HVAC Using Phase Change Materials

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Introduction

With the development of the economy and improvement in the standard of living, the use of air conditioning is becoming more and more popular in India. Due to this, the proportion of air conditioning load in the total electric power load is continuously increasing. The ever rising demand of electric power for air conditioning is pushing further the deficit between its generation and demand in several states of India. Thus, demand side management (DSM) has become a great challenge, especially during peak load periods. This has made load shedding a norm in many parts of country. The solution offered by electricity utility companies for demand side management is to incentivise customers to shift their demand from peak hours to non-peak hours. This is achieved through time of the day (TOD) tariffs, in which the tariff is higher than base tariff during peak periods and lower during night time.

Benefits of Thermal Energy Storage

Operation and Maintenance Costs

Through Thermal Energy Storage (TES), customers not only can shift their electrical demand for air conditioning to non-peak

hours, but can also use the stored cooling for air conditioning when electric supply is not available. Thus, in the first situation customers can take advantage of TOD tariff, and in the second situation they can significantly reduce back-up power cost, i.e. the cost of using a DG set during non-availability of electricity. In addition, maximum demand (MD) can be reduced leading to further savings.

Capital Costs

In a scenario where cooling demands are high for a short period of time during the day, TES can be used optimally in combination with a chiller through a reduction in the sizes of chiller, cooling tower, condenser, pump, electrical connection, cabling, switchgear and standby generator or back up. All these reductions together can provide substantial savings in capital as well as electrical installation costs.

About the Author

S.V. Naik is a graduate mechanical engineer. He has been working in the HVAC field for more than 30 years. His association with PCM thermal energy storage systems started in the early 1990s, and he has been involved in a number of such installations in the country.

By contributing significantly to DSM and reduction in air conditioning equipment and electrical installation sizes, TES directly contributes to energy conservation, reduced use of fossil fuels and refrigerant gases and reduction in green house gas emissions, thus protecting the environment.

Components of a TES System

A TES system has three components:

Refrigeration System

The refrigeration system produces solid ice at night when electricity tariffs and building needs are at a minimum and, if required, meets cooling loads during the daytime.

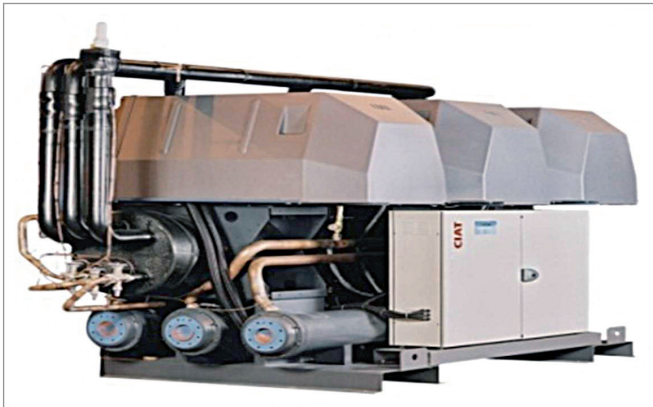


Figure 1: Refrigeration system

Ice Storage Tank

Ice storage tank creates and stores ice, which provides cooling to help meet demand during peak period the following day.

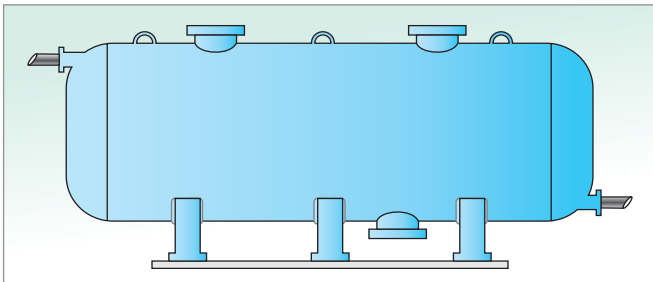


Figure 2: Ice storage tank

Interconnecting Piping, Pumps and Controls

Please see Figure 3.

TES Using Phase Change Materials

PCM TES means thermal energy storage using a phase changing material. TES has two main constituents: storage tanks and nodules. At the heart of the PCM TES is the spherical nodule, which is blow moulded from a blend of polyolefins and is filled with PCM. Please see Figure 4. PCMs store latent heat. As the source temperature reduces, chemical bonding starts within the PCM and the material changes phase from liquid to solid – a heat releasing (exothermic) process during which the PCM rejects heat. While releasing heat, the material begins to solidify when the phase change temperature is reached. The temperature then stays constant until the solidification process is completed. The heat rejected during the phase change process of the material is called latent heat.

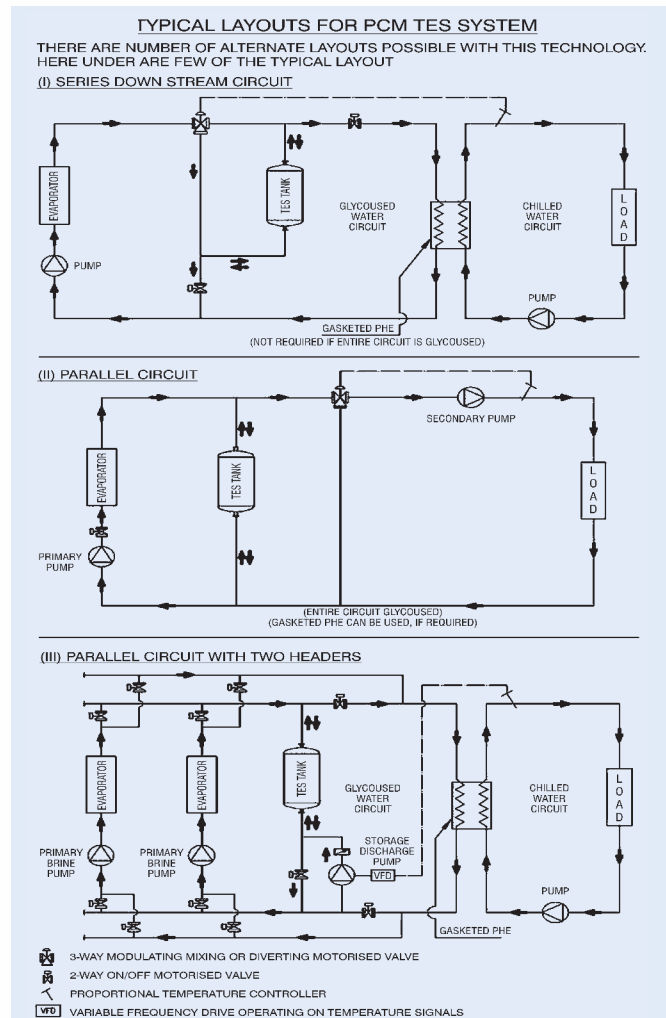


Figure 3: Typical layouts for TES systems using PCMs

PCM nodules have the following characteristics:

- Made from polyolefin material, thus chemically neutral towards eutectics and heat transfer fluid.
- Controlled thickness so that no migration of the heat transfer fluid occurs.
- The sphere is produced by blow moulding and sealing of the cap by ultrasonic welding, hence no leakage.
- Air pocket for expansion, hence low stress on the nodule shell.

The nodules are generally available in 98 mm diameter for

air conditioning applications and 77 or 78 mm diameter for industrial refrigeration applications. The nodules operate in a wide range of temperatures between -33 deg C and +27 deg C and provide remarkable thermal

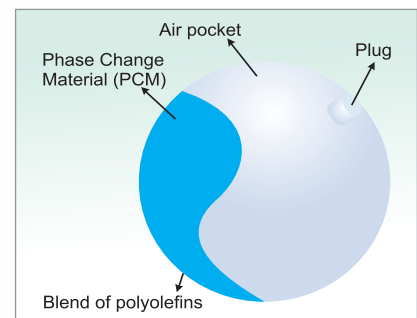


Figure 4: A PCM nodule

performance particularly in terms of exchange capacity, with a large life span (equivalent to 30 plus years of operation in normal conditions). The wide temperature range and other benefits make TES system using PCMs a viable and better technology for off peak cooling and reducing facility electricity costs.

Advantages of TES with PCMs

The advantages of an installation of TES system with PCM are:

1. High latent energy per unit volume, thus reducing the volume of the container to store a given amount of energy.
2. High specific heat to provide for significant amount of additional sensible heat storage.
3. PCM stores very high latent energy which makes it unique in terms of maintaining constant supply temperatures for longer durations, which usually no other TES technology can accomplish.
4. Small volume change on phase transformation reduces the containment problem.
5. Chemical stability.
6. Completely reversible freeze-melt cycle.
7. No degradation after a large number of freeze-melt cycles.
8. Non-corrosive to the construction materials.
9. Non toxic, non-flammable, and non explosive materials for safety.

Latent Heat Storage Tank

The nodules are filled up in the storage tank. The dimensions of the tank are calculated based on the plant space available at site and to satisfy the thermal performance requirements. The tank may be cylindrical with design service pressures up



Crystal IT Park, Indore uses 3 x 2160 TR HR thermal storage tanks

to 10 bars, or rectangular for atmospheric pressure. Cylindrical tanks can be designed horizontally, vertically or for burial underground. Tanks are fitted with upper manholes for filling the nodules and a lower manhole to facilitate emptying. Two internal headers (top and bottom) are designed to generate maximum heat transfer efficiency. Heat exchange between the nodules and the system is achieved by circulating the heat transfer fluid through the tank. The heat transfer fluid is usually mono-ethylene glycol-water solution. Other brines such as mono-propylene glycol may also be used.

The characteristics of the storage tank are:

- Black steel
- Horizontal or vertical
- Outside, inside, buried, built on site
- Rustproof exterior paint
- Insulation on site
- Efficient diffuser system
- High service pressure

- Pressure drop: 2.5m water gauge
- Made to measure according to site requirements

Storage Strategies

PCM TES manages the cooling energy according to customer requirements. However, there are various strategies that can be adopted.

Partial Storage (Reduced Chiller Capacity)

The chiller capacity is reduced to 30 to 60% of the maximum demand. During night the energy is stored in TES. During day, priority is given to chillers which provide cooling energy; when the demand is higher than chiller capacity, TES bridges the shortfall.

Low Season Discharge

A partial storage in high season can be easily transformed into a total storage or time of day storage during low season in order to increase running cost savings.

Time of Day

When TOD electrical tariffs charges at peak hours are particularly high, cooling can be stored during cheap off-peak periods, and discharged during the high tariff periods.

Total Storage

During the air conditioning period, the chillers are stopped and all the cooling energy is provided only by the TES.

Back-up

TES is used as back-up only when it is necessary. It replaces the main cooling system in case of failure. TES is regularly recharged to compensate for standing losses.

Case Studies

1. Petronas Towers, Kuala Lumpur

Electrical power generation by gas turbines 2 x 8.5 MW and 2 x 4.5 MW

Cooling machinery prior to retrofitting: 3 x 5000TR centrifugal chillers, 3 x 5000TR absorption chillers

After retrofitting, the system comprises:

Chilled water circuit: 3 x 5000TR centrifugal chillers

Brine circuit:

3 x 2200TR brine centrifugal chillers

6 x 2000TR plate heat exchangers

44,000TR HR PCM thermal energy storage

After retrofitting, the operation of absorption chillers was stopped. These chillers were incurring high operating and maintenance costs. Instead, brine chillers and thermal energy storage are being used during day time. During night time, power demand reduces because of lower cooling loads that were causing a drop in the efficiency of power generating gas turbines. Therefore, using PCM thermal energy storage system (charging by 3 X 2200TR electrical centrifugal brine chillers), loading of the gas turbines increased, thereby increasing their efficiency and reducing gas consumption. Thus, the entire power plant has better loading and operation after implementation of PCM TES system.

In addition, by using PCM TES system during day time, cooling tower operation also improved. Removal of absorption chillers and introduction of centrifugal chillers has reduced heat rejection resulting in better return water temperature from cooling towers.

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2. **Cadila Healthcare, Ahmedabad**

The objectives for installation of PCM TES system were:

- Saving in electrical installation cost for switching over from the prevailing 11kV connection to 33kV.
- Savings in operating energy costs and maximum demand charges.
- Additional savings accrued after start up of PCM TES system due to the prevailing operation of 700TR centrifugal chiller on DG sets during day time.

Cooling machinery group on brine side comprises:

- 3 x 240TR brine screw chillers
- 2 x 530TR plate heat exchangers (with provision for adding of 1 x 530TR PHE in future)
- 6340TR HR PCM TES system

Other PCM Storage System Installations

Details of a few other prominent PCM storage systems installed in the country and abroad are given below:

1. **Putrajaya District Cooling System, Malaysia:** Equipped with 3 x 2200TR centrifugal brine chillers and 52,000TR HR PCM TES system.
2. **Tidel Park, Chennai:** 3000 TR screw chillers and 24,000TR HR PCM TES system.
3. **National Stock Exchange, Mumbai:** 3 x 350TR brine screw chillers and 4800TR HR PCM TES system.
4. **Nirlon Technology Park, Mumbai:** 8 x 350TR brine screw chillers and 11000TR HR PCM TES system.

Conclusion

TES systems using PCMs have a very wide range of applications:

Air Conditioning

District cooling systems, apartment buildings, conference centers, shopping centers, recording studios, office buildings, malls, sports centers, museums, theatres, cinemas, hospitals, airports, banks and hotels.

Industrial Refrigeration

Slaughter-houses and meat industry, pharmaceutical and chemical plants, bottling plants, dairy industry, cold storage, breweries and ice rinks.

Back-up

Surgical operating rooms, ICUs, telephone exchanges, military headquarters, computer rooms, chemical plants, laboratories, cold stores and TV studios.

Besides these applications, due to its specific advantages of high latent energy with substantial amount of sensible energy available, higher charge and discharge rates and flexibility in installation, PCM storage systems have advantages in many applications such as:

- Retrofit in office buildings.
- Retrofit in pharmaceuticals industries.
- Retrofit in hotels.
- Retrofit for back-up against power failure in any type of building, industry or other application wherever stoppage of air conditioning results in huge losses.
- District cooling systems. ❖