Application of PCM thermal energy storage

Zafer Ure from EPS Limited, Peterborough explains how a recent project in Turin, Italy, based on the innovative use of geothermal heat pumps and phase change material (PCM) thermal storage devices, achieved energy savings of around 46% compared with traditional best practice.

This project began with a single over-riding requirement from the customer EIDOS, to guarantee environmental comfort for the whole year round for the occupants of a large glass façade building of 5,000 square meters, at maximum energy efficiency.

The solution designed and installed by the Italian contractor is based on a geothermal heat pump technology that draws energy from the ground through heat pumps during winter and releases it back into the ground during summer. This allows a complete thermal cycle that does not thermally dry up the ground itself. Only energy not captured/released from/to the ground is provided electrically.

Compared to traditional systems this technology guarantees the following benefits:

- It is environmental friendly
- It has very few design constraints
- It does not require any protection measures such as vents, gas sensors or fire & explosion prevention devices

Critical to meeting the customer's desire for lowest possible energy use, the contractor purchased two independent Phase Change Material (PCM) Thermal Energy Storage (TES) storage devices from EPS Limited, designed for +46°C during winter and +13°C during summer, to store the energy equivalent to three days usage at average load.

Benefits provided by PCM-TES

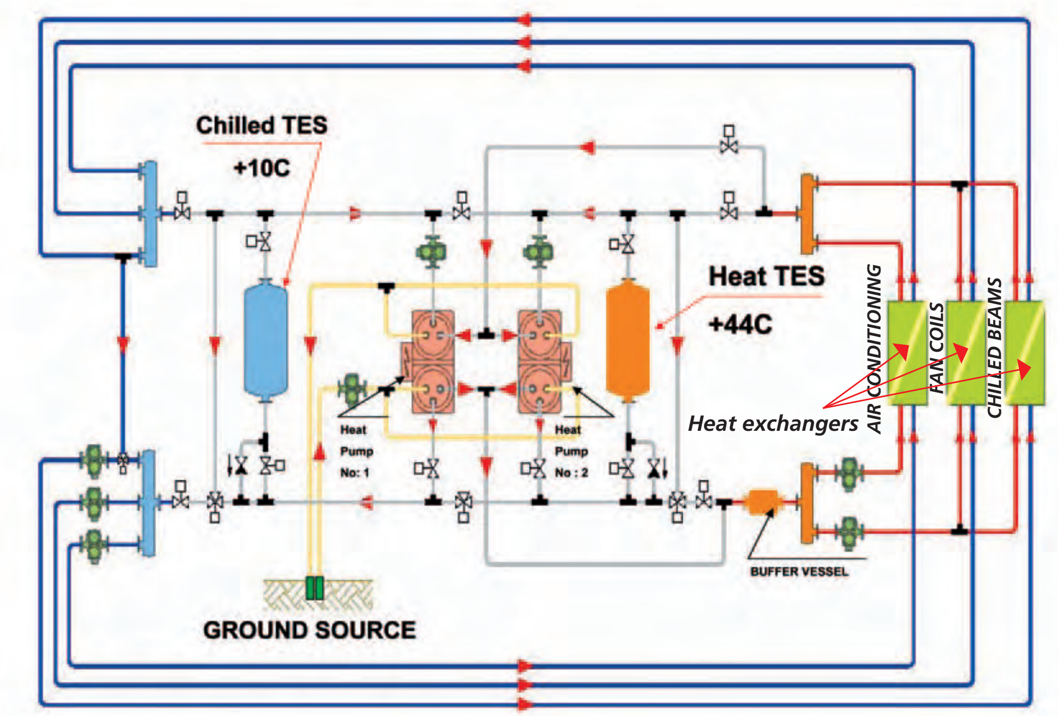
The main benefits of utilizing the PCM thermal energy storage concept are clear and tangible.

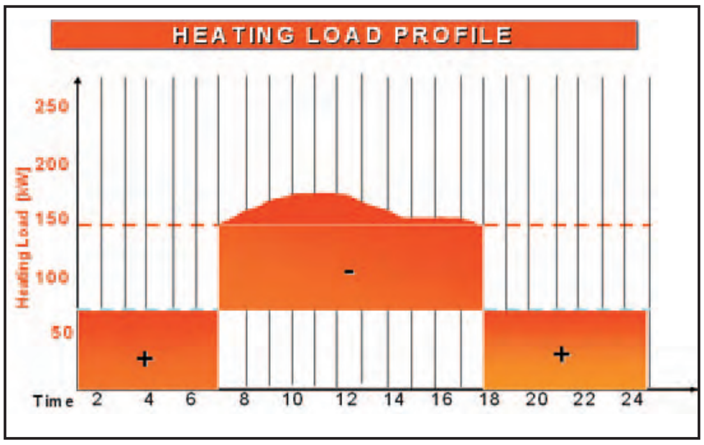
Normal working hours for the building are between 8am and 6pm and therefore the target environmental comfort conditions were aimed only at this period. During the rest of the time very little energy was needed to achieve accurate temperature control. PSM energy storage enabled the contractor to reduce by half the number of bore holes normally required by the geothermal heat pumps, in order to reject heat from the heat pumps, especially by running them during night periods.

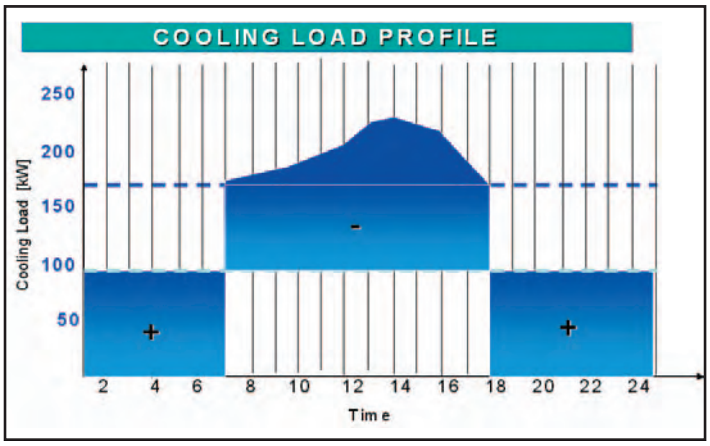
During day-time at low/medium heating and cooling load conditions, the stored energy within these TES tanks for both heating and cooling is utilized to satisfy the building loads, lasting as much as three days without the need for the heap pumps to operate.

During high demand periods namely winter heating loads during December/January and summer cooling loads during July/August, the stored energy within the TES tanks for high temperature +46°C and low temperature +13°C storage tanks respectively are utilized to top up the peak load conditions. TES tanks level the loads by simply using the surplus capacity of the heat pump overnight and by using this stored energy to reduce the heat pump capacity requirements by simply releasing the stored energy back to system.

Figure: Simplified system schematic







Load profiles are as follows

The design is based on running the heat pumps during daytime only, which equates to approximately 200 hours out of a total of 1800 hours of energy supply during winter periods. This corresponds to approximately 11% of total running time, the rest of the capacity being provided by the TES tanks.

In summer mode, it is anticipated that the heat pumps will only run for 100 hours, ie 5.5% of the time, to top up the cooling loads out of 1,800 hours total running period.

As a result the design required only half the number of geothermal holes and heat pumps as well as only 300 hours (16.5% of the total needed) of load to be directly produced by the heat pumps during annual operation. This reduced running hours and achieved significant running cost savings and a faster payback for the installation.

Without the use of TES storage devices, the geothermal field and heat pumps would have been doubled in size, which most of the time would only have produced unnecessary surplus energy.

By halving the system size, the design managed to achieve other benefits;

- Halving the infrastructure cost
- Reduced physical sizes
- Main energy consumption is at low, night-time rates
- Electrical energy not used for heating and cooling can be used for other purposes.

PCM energy storage systems versus other options

Water could have been used for storage purposes but the tanks volume for the Phase Change Material (PCM) TES storage is only 20% of an equivalent water storage tank and since the energy needed is high, the system would have required large water storage which was not practical due to space restrictions.

Furthermore it would not have allowed energy storage at constant temperature. The biggest problem with water storage tanks is the stratification within the tanks during both charging and discharging. Effectively in order to obtain a result similar to the one attained, water would have had to be heated/cooled to much higher/ lower temperatures in winter/ summer with resulting significant energy waste.

Energy saving occurs when the temperature delta between supply and return is as small as possible.

Using traditional technology:

- In summer supply temperature is 7°C and return temperature is about 12°C with delta T equal to 5°C
- In winter supply temperature is 70°C and return temperature is about 60°C with delta T equal to 10°C.

Through PCM energy storage the system provides evident benefits by storing during summer at +13°C and during winter at +46°C thus obtaining:

- In summer supply temperatures of +17°C and return temperatures of +19.5°C with delta T of 2.5°C
- In winter supply temperatures of +40°C and return temperatures of +36.5°C with a delta T of 3.5°C

Pay-off for the client

The average annual energy saving compared to a traditional best practice energy saving technology is forecast to be around 46%. In Italy, this means a pay back period without any regional utility incentives of 8.6 years, or with regional utility incentives of just over 4 years.

Obstacles

So far, the project has not encountered any specific obstacles. The local authorities were very keen to support such low energy technology and there were no side effects such as safety or pollution issues. The system did require a relatively sophisticated management system but this was procured locally by the installation contractor.

Why the client invested in this technology

The customer EIDOS decided to invest in such a highly efficient technology because within a short period their investment will be repaid and because the project makes a clear and strong statement to its clients, that confirms that EIDOS is oriented towards high standards of quality, environment friendship and innovation.