Design & Analysis of Cold Thermal Energy Storage

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Abstract— In this project, the concept of cold energy storage with flooded tube is discussed. Special attention was paid to the design and analysis of flooded tube. Demands for energy savings and improved energy efficiency are becoming increasing day by day. A very promising possibility is the storage of energy whose main objective is to deliver the cold energy when the system is running on peak load. Cold thermal energy storage by itself is not ultimately an energy savings technology; first of all it is a cost savings technology. By shifting chilling operations to off-peak times, when demand and energy rates are decreased, significant money savings can be realized. Among built environment, buildings are maximum energy intensive consumers of energy and main contributors of greenhouse gas emissions. Maximum demanded energy for buildings is thermal energy because of its thermal energy-consuming appliances such as heating, ventilation, air conditioning (HVAC) and domestic hot water (DHW) systems. In order to supply the achieved amount of energy to these appliances, most of the time conventional energy sources are used which are not eco-friendly and hazardous.

Keywords: Phase Change Material, Cold Storage System, Solar Energy, Solar Air-Conditioning, Phase Change Material Application

I. Introduction

Cold thermal energy storage is a proven that It can be the most cost effective in thermal energy, reliable system approach to cooling offices, schools, hospitals, malls and other buildings, and provides a steady energy source of low temperature fluids for process cooling. Peak load exists for only a couple of hours during the day or a couple of months during the year. It is not feasible for the electric companies to expand their generation to tackle only this partial load. Many solutions have been suggested to reduce this risk, such as utilizing energy conservation, using renewable energy during a peak load, increasing the efficiency of the electric devices, and finally starting energy storage so that during the off-peak load, energy can be stored and then used later at a peak load time. The thermal cold energy storage can be defined as the temporary energy storage of thermal energy at high or low temperatures.

II. Problem statement

- During high-peak load time there is large amount of electricity is required.
- In mid day we need more cooling effect comparatively early morning and night
- In conventional Air conditioning there are various hazardous gases are used which are directly affects on human body.
- Its also affects on ozone layer i.e. O3 layer.
- So conventional system is very dangerous as well as less efficient.

III. Objectives

- The aim of the research of Cold thermal energy storage is to study fundamental aspects and address the scientific and technological challenges associated with the CES technology.
- Use phase changing material (PCM) for better effect.
- Study the use of flooded tubes.
- Study the time required for ice formation during low peak time using flooded tube.
- Study amount of Ice formation during low peak time using flooded tubes.

IV. Literature review

The present research is focused on the free cooling of buildings with the PCM-based thermal energy storage heat exchanger. Hence, a detailed literature survey has been made on the various studies carried out by the researchers on the different passive cooling techniques, free cooling potential and night ventilation, free cooling with direct ambient air circulation, free cooling with PCM for cold storage applications, studies on PCM and modeling of the phase change storage system.

A. Passive Cooling Techniques

1) Solar and Heat Protection Techniques (Reduce Heat Gains)

The presence of water, plants and trees contributes to microclimate cooling, and is an important source of moisture within the mostly arid urban environment (Robitu et al (2006)). Indoor simulations still tend to be isolated from an important element affecting urban microclimate, such as urban trees. The main advantage of urban trees, as a bioclimatic responsive design element is to produce shade, whereas its main disadvantage is blocking the wind (Yoshida et al (2006)). In addition, the effects of specific urban tree types - for example, the different leaf area densities and evaporate inspiration rates of urban trees influence solar access and heat exchanges, if planted around buildings (Radhi (2009)). Eumorfopoulou and Kontoleon (2009) and Kontoleon and Eumorfopoulou (2010) analyzed thoroughly the influence of the orientation and proportion (covering percentage) of plant-covered wall sections on the thermal behavior of typical buildings in Greece during the summer. Limor et al (2010) have analyzed the thermal effect on an urban street due to three levels of building densities. The study indicated the importance of urban trees in alleviating the heat island effect in a hot and humid summer. In all the studied cases, the thermal effect of the tree was found to depend mainly on its canopy coverage level, and planting density in the urban street, and a little on other species characteristics.

V. Components

1) Compressor

2) Condenser
3) Evaporator
4) Water tanks
5) Copper coils

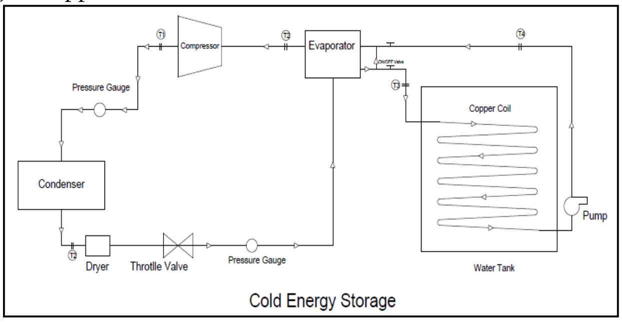

Fig. 2: Constructional Diagram

VI. WORKING

The system works same as the conventional refrigeration system. Flooded tube is an added component to the system. In flooded tube there is a copper coil which carries refrigerant through it and the coil is immersed completely in the water tank. When the system is running on normal load or of load, the water in the tank gets frozen. The ice is formed within the tank. The cold energy from the tank can be used when the system requires more cold energy. This condition occurs during the peak load demands.

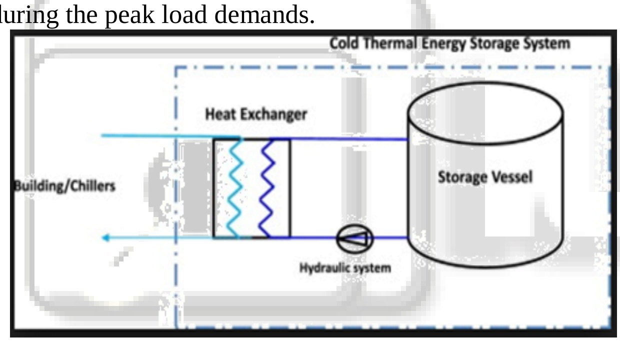

Fig. 1: Working of Cold Energy Storage

A. *Thermal Energy:*

Sources/media of thermal energy for storage include heat or cold produced with heat pumps from off-peak, lower cost electric power, a practice called peak shaving. TES not only reduces the discrepancy between the demand and supply by conserving energy, but also improves the performance and thermal reliability of the system. Capacity, power, and discharge time are interdependent variables. The use of thermal storage, initially, could not provide effective backup but helped the system to thermally stabilize. Thermal energy storage (TES) is achieved with different technologies. Depending on the technology, it allows excess thermal energy to be stored and used hours, days, or months later, at scales ranging from individual process, building, multiuser-building, district, town, or region. Examples are the balancing of energy demand between daytime and night time, storing summer heat for winter heating, or winter cold for summer air conditioning.

B. *Cold Energy storage*

Such a technology produces cold energy by consuming electricity in a refrigerator and stores cold energy in an eutectic phase change material (PCM) in a temperature range of (TPCM is the PCM storage temperature and Ta is the environmental temperature), resulting in a cold energy efficiency less than 100%. The stored cold energy can be either directly extracted by a cold discharge process or utilized through a Rankin cycle at peak hours for electricity generation. Cold discharging rate, defined as the power transfer of cold energy per unit time during the discharge process, is greatly affected by thermal diffusivity and thermal conductivity of the PCM composite. Thermal energy storage systems allow energy to be captured/stored during times of cheaper energy or when energy is most abundant and 361tilized during peak hours.

1) *Types of Thermal Energy Storage*

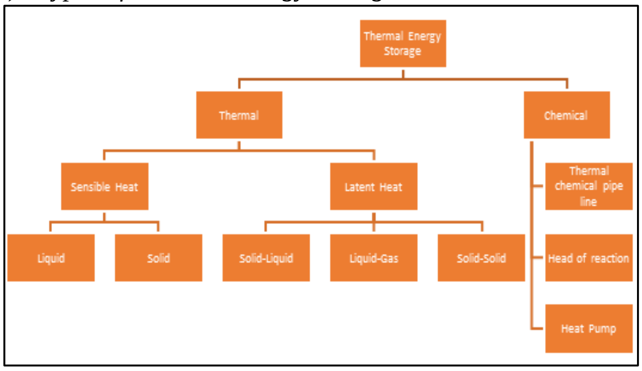

Fig. 2: Flow diagram of types of thermal energy storage

2) *Flooded Tubes*

A flooded tube for cold energy thermal storage was built to study the formation of ice experimentally. The flooded tube was subjected to stagnant water, stirred water, and recalculated water. The tubes are internally cooled by a controlled subzero temperature coolant. Shape and size of the tube is depends upon the area of water storage tank. A copper is used as a material for the flooded tube.

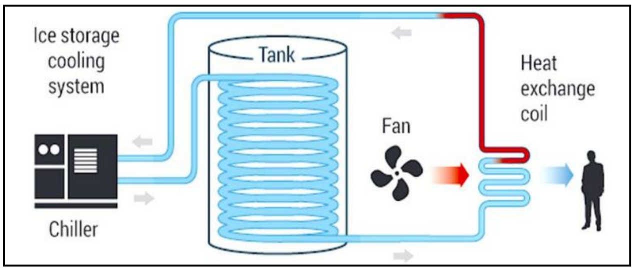

Fig. 1: Flooded tubes

VII. CALCULATIONS

Time required for the formation of ice:

$$t = \left(\frac{dL}{2KT}\right)(x_2^2 - x_1^2)$$

Where,

d=density of ice=0.9340g/cm^3

L=latent heat of fusion=79.7cal/g

K=conductivity of ice=2.22w/mk

T=temperature of water=34^0c

x_1=initial thickness of ice= 0cm

x_2=ultimate thickness of ice= 2cm

$$\therefore t=\left(\frac{0.9340\times 79.7}{2\times 2.22\times 34}\right)(2^2 - 0^2)$$

t=1.97hrs

A. Work done by reciprocating compressor

1) Isothermal Compression

We know that work done by the compressor

$W=2.3\ p_1 \times v_1 \log\left(\frac{p_2}{p_1}\right)$

$=2.3\times1\times1.4\log\left(\frac{7}{1}\right)$

$=3.22*10^5*0.8450$

$=2.72*10^5$ N-m/min

$\therefore$ Power required to drive the compressor = $\frac{W}{t}$

$= 2.72*10^5/118$

= 2305W

= 2.4 KW

2) Polytrophic Compression

We know that work done by the compressor

$W=\frac{n}{(n-1)}*p_1 v_1 \left\{\frac{p_2}{p_1}^{\frac{n-1}{n}} - 1\right\}$

$=\frac{1.2}{(1.2-1)}*1*10^5 * 1.4\left\{\frac{7}{1}^{\frac{(1.2-1)}{1.2}} - 1\right\}$

$= 8.4*10^5(1.38\text{-}1)$

$= 3.06*10^5$ N-m/min

$\therefore$ Power required to drive the compressor = $\frac{W}{t}$

$= 3.06*10^5/118$

= 2593 W

= 2.5 KW

3) Isentropic Compression

We know that work done by the compressor

$W=\frac{\gamma}{(\gamma-1)}*p_1 v_1 \left\{\frac{p_2}{p_1}^{\frac{\gamma-1}{\gamma}} - 1\right\}$

$=\frac{1.3}{1.3-1}*1*10^5 * 1.4\left\{\frac{7}{1}^{\frac{1.3-1}{1.3}} - 1\right\}$

$= 6.06*10^5(1.56\text{-}1)$

$= 3.42*10^5$ N-m/min

$\therefore$ Power required to drive the compressor = $\frac{W}{t}$

$= 3.42*10^5/118$

= 2898 W

= 2.8 KW

– Piston displacement volume or swept volume or stroke volume:

$V_p = \frac{\pi}{4}*D^2*L$

$= \frac{\pi}{4}*0.1^2*0.2$

$= 0.0015\ m^3$

Where D is the diameter of cylinder = 100mm

L is the length of piston stroke = 200mm

As per conventional cold storage system, 1500 W power is required to produce cooling effect in 1 hour. But our cold storage system requires 1200 W power to produce cooling effect in 1 hour. So our system is more efficient than existing one.

– $COP=\frac{\text{output power}}{\text{input power}}$

Here output power is the power required by the compressor = 2.4 KW

Input power is the power given to the compressor = 1.9 KW

Thus COP = $\frac{2.4}{1.9}$

= 1.26

VIII. ADVANTAGES

1) Non-corrosive
2) Chemically and thermally stable
3) No or little sub-cooling
4) It improves performance of the system at peak loads
5) It is easy for installation
6) Initial cost is low

IX. APPLICATIONS

1) Thermal storage plants
2) Air-conditioning
3) Refrigeration system
4) In a vehicle refrigeration system
5) For armed forces
6) For the medicine manufacturers.

X. CONCLUSIONS

1) The PCM cold storage working principles and features, including the PCM cold storage system, the commercial market evaluation. The most common system is the Cold thermal energy storage that is integrated with the PCM storage system. With the current development, the PCM also has a bright potential with its relative simplicity and low capital cost.
2) Research into TES for both cooling and heating continues, which has also been considered for waste heat recovery, energy generation, building energy conservation, and air-conditioning. Using PCM in the energy storage systems, heat exchangers and thermal control systems are potential techniques. A novel composite PCM has suitable thermal properties for the TES applications in energy buildings and condensation heat recovery. Applying forced convection (pumping) would be beneficial to the PCM cold storage system. The concept of energy-saving building envelope, which is used to guide the building envelope material selection and thermal performance, was designed.

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