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Setting Up a Thermal Energy Storage System for Peak Load Management through Airconditioning Load Shift

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Abstract - This paper reports the conceptualization and installation of a Thermal Energy Storage (TES) system of total 775 TR HR capacity integrated to the air-conditioning system of an Institutional building inside Indian Institute of Technology (IIT) Kanpur campus. The TES system is utilizing glycol solution with phase change material, that cools down to -4 deg. Celsius during night-time in summer under off peak load condition [1], and it supports the building air-conditioning load during day time under peak load condition. The TES system has been installed under an Indo-US joint project 'UI-ASSIST' and is successfully under operation since two years. The plant is being monitored through the campus Supervisory Control and Data Acquisition (SCADA) system and its impact on Building Load management is established.

***Keywords*:** Thermal energy Storage, Phase change material, Airconditioning loads, Peak load shift, Nodules

1. Introduction

Thermal Energy Storage (TES) offers a potential solution to reduce the peak power consumption in a commercial/institutional building having large air-conditioning loads . Indian Institute of Technology Kanpur is leading a joint Indo-US project from India called as 'UI-ASSIST' focussing on Smart Grid and Storage Technology funded by Department of Science and Technology through Indo US Science and Technology Forum New Delhi, and Washington State University from USA funded by Department of Energy. Under this, ten field demonstration pilots are planned. One of them has a 775 TR HR TES system installed in an Institutional building of "Centre for Environmental Science and Engineering (CESE)" inside IIT Kanpur campus. TES system offers considerable advantages in the office and institutional buildings, which are having low power demand during the night-time. It utilizes phase change material with Brine solution as coolant, which takes low-cost energy during off peak period to achieve the coolant temperature up to -4 degree Celsius and supports the air conditioning load during peak period to the tune of 77.5 TR for 10 hours. One of the most important objectives of this project is to come up with the solution, which may be used by the others to minimize the peak demand and obtain cost benefits. This also results in significant energy saving that can be adopted in Smart Cities and data centre [2] applications.

2. Details of the Installed System

Thermal Energy Storage System installed in the IIT Kanpur campus is composed of a tank filled with "Nodules". The tank has upper manhole to allow the filling and a lower manhole for emptying. Inside the tank, two diffusers (inlet and outlet) spread the heat transfer fluid along the tank. The pressure drop through the tank is 2.5mWG. The thermal energy storage is determined by the phase change temperature and the volume. The quantity of energy stored for each type of nodule is proportional to the storage volume. The number of nodules in a system determines the heat exchange rate between the nodules and the heat transfer fluid.

2.1 Nodules

The nodules are of spherical shape with a diameter of 77mm (type SN), 78mm (type IN) or 98mm (type AC.00) – depending on its type. The Polyolefin nodules contain Phase Change Material (PCM) [3]. The mechanical and chemical characteristics of the nodule shell are adapted to the conditions encountered in the air conditioning or refrigeration systems.

Once filled with the PCM, the nodule plugs are sealed by ultrasonic welding to ensure perfect water tightness. The nodules are designed for higher service pressure up to 10 bars.

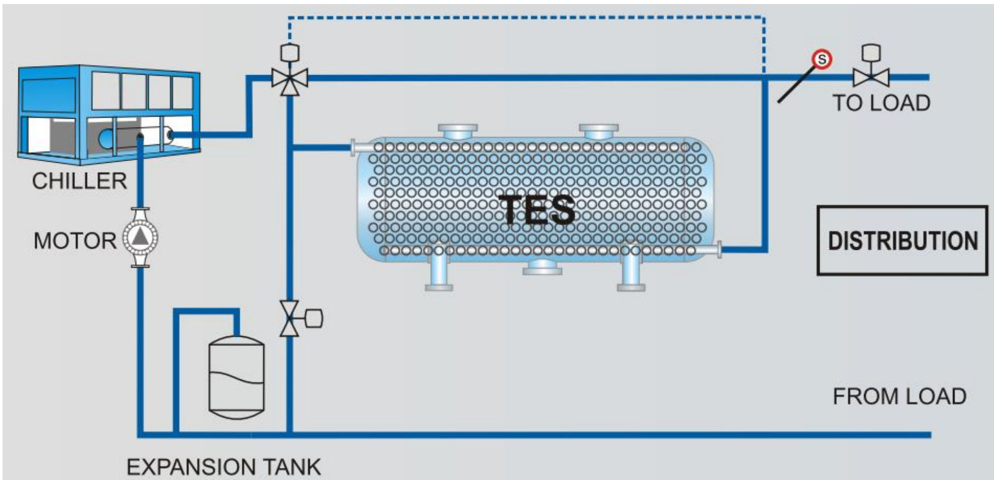

Fig. 1: Generic flow diagram showing the operation of TES system

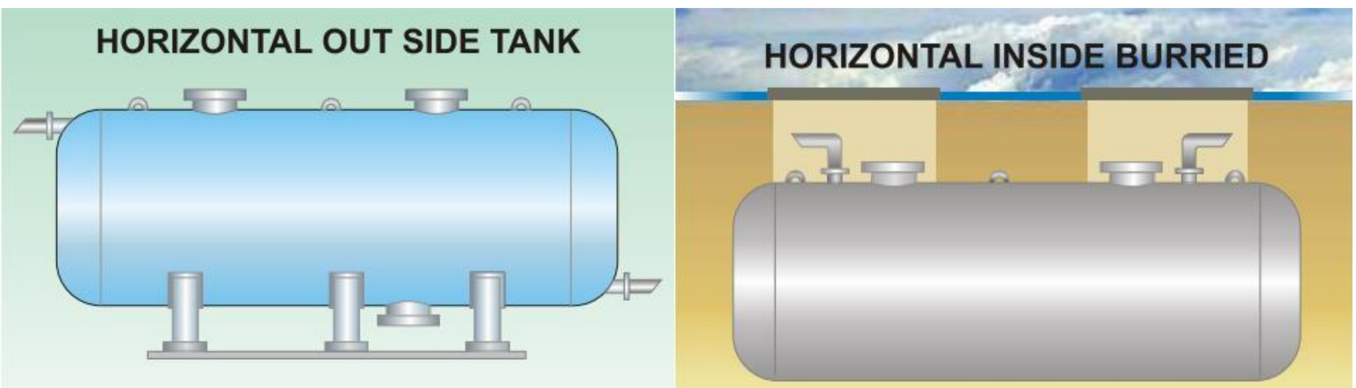

Fig. 2 (a): Horizontal Outside Tank [4]

Fig. 2 (b): Horizontal Inside Buried Tank [4]

2.2 Storage Tank

The horizontal cylindrical storage tank is manufactured in blank steel. The tank shape is usually cylindrical to withstand service pressure higher than 3 bar. The test pressure varies between 4.5 to 10 bar. The spherical shape allows an easy filling. The dimension of tank is calculated based on available space and thermal requirement. Tank can be horizontal or vertical, outside, or inside buried or built according to the site requirement. Two connections are fitted on the manhole covers for filling, air bleed valves and manometers. It is also possible to use rectangular tanks (in steel or concrete). Two internal headers (top and bottom) are designed to generate maximum heat transfer efficiency. The heat exchange between the nodules and the system is achieved by circulating the heat transfer fluid through the tanks.

3. Modes of Operating the Installed TES System

The operating cycle is divided into two distinct modes: Charge and Discharge modes – during which the nodules remain virtually at a constant temperature [4]. During the charge mode, energy is stored by crystallization of the salts contained within the nodules and in the discharge mode the stored energy is released by fusion of the salts contained in the nodules. During the charge and discharge cycle the temperature of the heat transfer fluid passing through the TES should vary as little as possible relative to the temperature at the end of the release mode. Distribution flow temperature is normally constant.

Air conditioning load of CESE building can be operated in four different operating modes, which are mentioned below with operating conditions.

Fig. 3: Thermal Energy Storage System Horizontal Outside Tank

3.1 Load Met by Thermal Energy Storage (TES) System – Discharging Mode

The installed capacity of 775 TR HR of Thermal Energy Storage system can be used for running the full air conditioning load of the building for approximately 6-7 hours. TES system is being utilized for running air conditioning load of the building as well as for peak load shaving of the institute load. From the actual operation of the system, it has been observed that the TES system is providing backup to the air conditioning system for approximate duration varying from 10 to 12 hours. Also, when it is operating at reduced load, it has been observed that installed system has provided backup for 3-4 days.

3.2 Load Met by Chiller

This mode of operation will be utilized when TES system is not under charged state or central air conditioning chilled water pipeline is not ready for operation.

3.3 Load Met by Central AC Plant

Installed system has been designed in such a way that Air conditioning load of CESE building can be met by operating the valves connected to central AC plant in case of failure of TES system or in case TES system not fully charged.

3.4 Thermal Energy Storage (TES) System – Charging Mode

The installed Thermal Energy Storage system is charged during the night-time when there is lesser power demand in the Institute. TES system gets completely charged till early morning and is ready for utilization during the daytime.

4. Power consumption profile

The commissioning of the TES system was completed around June 2020 and aggregated monthly comparison of energy consumptions of the CESE building for years 2019, 2020 and 2021 are shown below in Fig. 4. Due to pandemic situation, the Institute was closed completely so energy consumption from March 2020 to August 2020 had reduced but after that there is significant consumption compared with the previous year consumption.

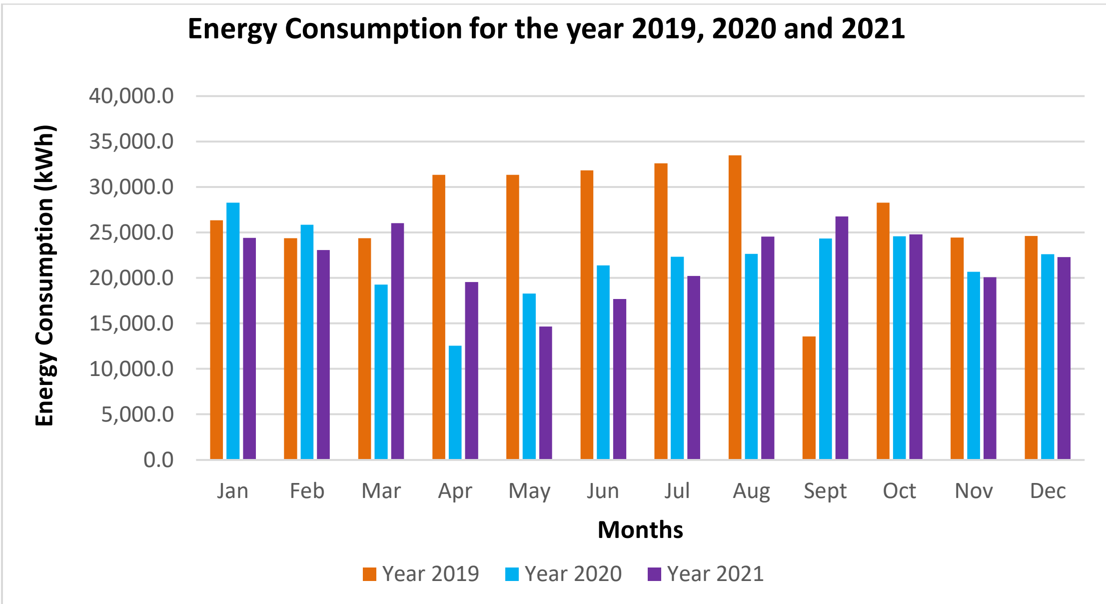

Fig. 4: Energy Consumption comparison for the year 2019, 2020 and 2021

4. Conclusion

A 775 TR HR TES system is successfully installed in an institutional building inside IIT Kanpur campus. After the installation of the TES system, peak load energy consumption of the building has reduced, which has been verified from the data being recorded through the SCADA system already in place for the Institute power distribution network. Installed system has helped in reducing the peak load of the Institute by operating it in discharging mode during the peak hours and charging it during off peak hours. Since the electricity cost is higher during peak hours, it offers a potential technology for the overall cost saving.

Acknowledgements

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