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Study on chilled energy storage of air-conditioning system with energy saving

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ABSTRACT

Due to higher energy consumption for application of chilled energy storage technology in air-conditioning system in China, this paper provides two new air-conditioning systems with chilled energy storage. With system both thermodynamic and economic analyses, the new system can achieve good economic performance, about 40% power cost saving, resulting from both peak-valley power price and energy saving. And the results also show that chilled storage technology can be adopted with energy saving, instead of just for cost saving in traditional use. The new systems supply a new direction for application of thermal energy storage technology.

1. Introduction

In the whole social energy consumption of China, building energy consumption is about 30%, including 50–60% of that for air-conditioning system. And the energy peak load of building matches with peak load of electricity grid, which is about more than twice of valley load, resulting in more peak load power plants being needed. In China, many hydropower stations for energy storage in off-peak period are built or to be built to shift peak load. In recent years, air-conditioning power consumption is more than 40% of the grid peak load and increases quickly. Therefore, air-conditioning load shifting is critical for the whole grid. Then the chilled energy storage technology for air-conditioning system has been paid more and more attentions, due to its less capital cost and fewer environmental effects [1–3].

For air-conditioning system with chilled energy storage, many researches focused on study on chilled energy storage technology, such as diffusers for chilled water storage, ice storage method and so on, but less paid attentions to the operating performances of the whole air-conditioning system, including considering both efficiency and economic performances. In fact, chilled storage has almost been adopted as the peak load shifting technology, storing thermal energy at night, and discharging thermal energy in the peak load periods, which always leads to more energy consumption than the air-conditioning system does, so its application just uses of its good economic performance and for safe of electricity grids, but less considering its thermodynamic performance [4–8]. For some literatures, thermodynamic performance has been mentioned, and also exergy analysis was adopted for system analysis, but how to improve the whole system performance and relationship between thermodynamic and economic performance are not very explicit [9,10].

According to the situation mentioned above, this paper will supply new air-conditioning systems with chilled energy storage, and both economic and thermodynamic performances will be discovered. The work will give a new direction for application of energy storage.

2. Conventional air-conditioning system with chilled energy storage

In traditional, chilled energy storage technologies are just adopted for peak load shifting. In normal, the peak load of grid shows in daytime, which is the same time of peak load of air-conditioning system. And chilled energy is stored at night and discharged for the peak load. In this way, the whole system always consumes more energy than system without storage.

The flow-sheet of the storage system is shown as Fig. 1. Conventionally, there are four basis cycles for system operation. Firstly, chiller produces chilled water and supplies for user only. Secondly, chilled energy out of chiller is supplied for storage equipment only.

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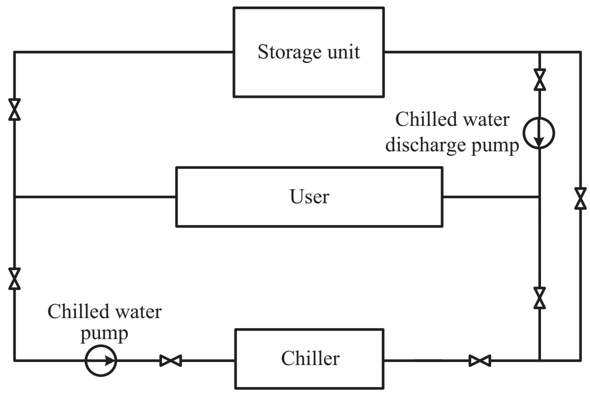

Fig. 1. Chilled water storage system.

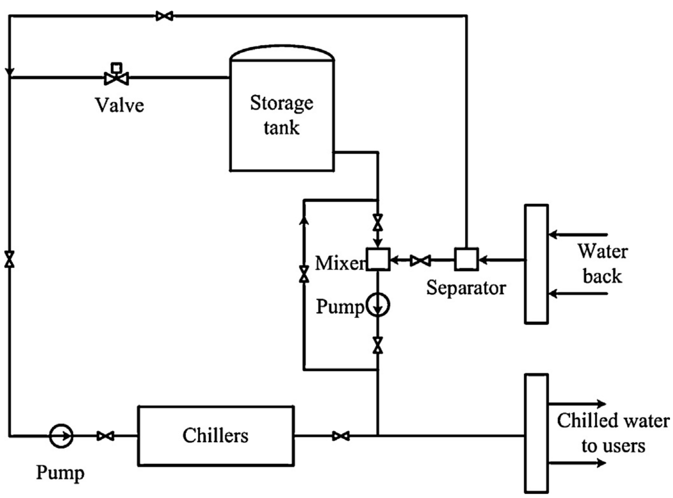

Fig. 2. Flow-sheet of the new system.

Thirdly, just storage unit releases chilled energy for users. Finally, both chillers and storage equipment supply chilled energy for users.

Valley loads of the grid, such as at night, chilled energy is stored, and it releases when the peak loads time. In this way, it uses the peak-valley power prices to save operating cost, but it consumes more 5 percentage points of power than the normal system without chilled energy storage. Therefore, it is good for the safe of power grid and saving power cost for users, but it is not good for energy utilization, with more energy consumption and greenhouse gas emissions.

3. A new system with chilled water adjustment

3.1. Configuration of the new system

A new air-conditioning system with chilled water storage is provided, as shown in Fig. 2. Water back from users is divided into two flows by separator, one is mixed with chilled water out of storage unit and is as chilled water supplied for users, and the other one is back to the storage tank, which flux rate is equal to chilled water out of tank.

With this configuration, chilled water can be adjusted to different temperature to meet the need of different users or loads, and also the valve linked to storage tank can be protected by less pressure difference resulting from part of water back.

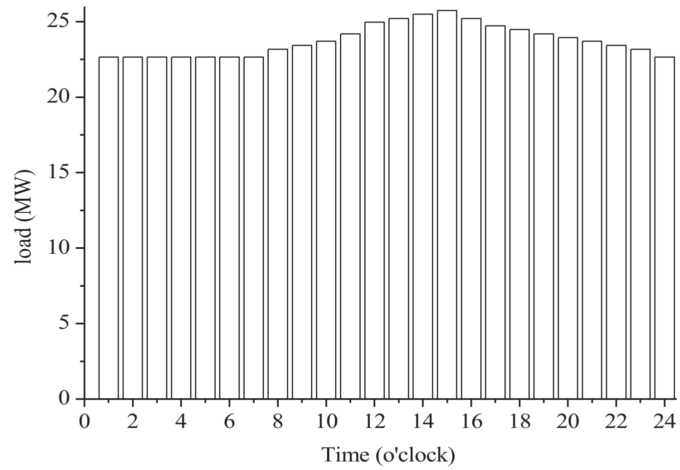

Fig. 3. Load distribution of the design day.

Table 1
Main parameters of system.

Parameter	Reference value	Value
$\triangle T_z$	5–18 °C	13 °C
η	>0.9	0.95
K	1.01–1.05	1.04

3.2. System performance analysis

An air-conditioning system can supply 52.8 MW (15,000 RT) chilled energy, mainly as process cooling energy for electronic factory. Time of annual cooling requirement is 365 days and 24 h per day. Peak load of air-conditioning system is about 26.0 MW (7400 RT), and the total cooling load of the design day is about 570.5 MWh (162,200 RTh), as shown in Fig. 3. At night, there are idle chillers to run 8 h for chilled storage.

Built up a water stratified storage tank, chilled energy is stored from 0 o'clock to 8 o'clock, and volume of the storage tank can be calculated as follow:

$$V = QK/\eta/\Delta T_z/C \tag{1}$$

where Q symbol is capacity of chilled energy, $\triangle T_z$ the temperature difference between water out and in to the tank when chilled water storage, being 13 °C (5–18 °C) in this case, η presents the volume efficiency of tank, 0.95 here, K symbol the chilled energy lost rate of tank, as 1.01–1.05, being 1.04 in the case, and C is specific heat capacity of water. Then volume of the storage tank can be calculated as 5120 m^3. All the parameter values mentioned in the paper have been chosen based on engineering experience in China, as shown in Table 1.

According to chilled storage and economic performance, it is reasonable to choose cylindrical tank, with less surface area to less energy loss to atmosphere. To achieve optimal stratified and economic performance, ratio of diameter to high of tank is 0.5–1.2 [2], then tank is chosen as 26 m and water deep 24 m, and diameter is 16.5 m. To reduce energy loss to atmosphere, tank is covered with 10 cm thermal insulation material.

In the case, the peak-valley load power price is shown in Table 2, and annual load distribution and power cost are shown in Table 3. In a year, there are 135 days and 120 days with 75% and 50% loads rate, respectively.

For the air-conditioning system with chilled water storage, because users need hot water provided by chiller with thermal energy recovery of cooling medium, in cold seasons, chillers must run to meet the need of thermal energy requirement and there is cool energy surplus, chilled water storage don't need to run in