Analysis on the Operation of Ice Storage Air Conditioning System in Practical Engineering

M M Zhang¹, M L He¹, Y X Wu¹, Z G Cao¹ and W J Zhang²

¹ The Architectural Design & Research Institute of Zhejiang University Co, Ltd, Hangzhou 310028, China
² School of Energy and Power Engineering, Nanjing University of Science & Technology, Nanjing, 210094, China

zhangwenjie001@139.com

Abstract. Cold storage technology is one of the effective means to alleviate the imbalance of power load during peak and valley period. Based on a practical project, the operation of the ice storage air conditioning system was monitored for 26 days. Temperature, pressure, ice storage and other parameters were recorded. Through the analysis of the operation data and air temperature, it is found that the operation of the ice storage system is stable and consistent with the design condition. But there are still some shortcomings in the operating strategy. This paper provides some suggestions for the design and operation of air conditioning system in future projects.

1. Introduction

As people have higher requirements for indoor environment, air conditioning is widely used which directly resulted in the shortage of power supply at rush hour. It has been estimated that the air conditioning system is the biggest consumers of the building energy [1]. As an effective means of peak shifting and valley filling, energy storage has been applied in various fields [2-5]. Many studies have shown that energy storage technology with good management strategies can bring good social and economical benefits [6-8]. Now, ice storage air conditioning system is designed and used in practical projects frequently[9]. So, there are a lot of researches related to it. The combination of distributed household photovoltaic and ice storage cold air conditioning can be used for cold storage during the day. At night, the ice stored in the tank during the daytime can discharge the cold to meet the demand of the family [10][11]. Certainly, there is an increase in total electrical cooling energy use since more energy is used for the load shifting process during off-peak hours. Optimal design and operation strategy of ice storage system can save energy cost to the maximum extent [12]. Lee [13] adopted particle swarm algorithm to facilitate optimization of ice-storage air-conditioning systems and to develop optimal operating strategies, using minimal life cycle cost as the objective function. Song [14] explored the impact of different control strategies and electric tariff structures on the optimal ice storage capacity in relation to system economy.

At present, the research on the design and operation strategy of ice storage system mainly focuses on theoretical analysis and experiment [15-17]. The analysis of the data of ice storage operation in practical engineering is relatively few. Based on a practical project, this paper monitors and analyzes the operation data of the ice storage system after it is put into use.
2. Method

2.1. Project and system overview
The project is located in Hangzhou with the floor area of 90609.05 m². The number of floors is 24 above the ground and 4 below the ground. The building height is 99.5m. The building functions are mainly for office and power dispatching process rooms, as well as a small number of catering, activities and other office supporting rooms. The cooling load index of above ground building area is 148w / m² and the cumulative cooling load of design day is 75096 kWh (including 24-hour load of process and estimated overtime load). The air conditioning of this building is divided into two parts: process air conditioning system and office air conditioning system. Two screw chillers with double working conditions are used as the cooling source. The refrigerating capacity of single chiller is 1406 kW in air conditioning condition and yet it is only 917 kW in ice storage condition. The ice storage system adopts the assembled ice coil ice storage tank with a total of 6 sets and a cold storage capacity of 15500 kWh. The ice storage system has five operating modes according to the operation requirements and economic optimization scheme: ice storage operation mode, chillers cooling mode, melting ice cooling mode, chillers and melting ice simultaneously cooling mode and chillers store ice and provide cooling at the same time.

2.2. Operating data
In this experiment, the operation of ice storage air conditioning system was monitored for 26 days (from July 22 to August 16). The monitoring contents include supply and return water temperature, supply and return pressure of chilled water, full load current, ice storage capacity and other parameters. This monitoring mainly involves two working conditions: ice storage operation mode (26 days), chillers and melting ice simultaneously cooling mode (5 days). Figure 1 shows the automatic control system of ice storage air conditioning.

![Figure 1. Automatic control system of ice storage air conditioning](image)

3. Results

3.1. Parameters in the stage of ice storage
Since the air conditioning system was put into use, the water chillers have been running smoothly. In the stage of ice storage, the chillers basically keep running at full load. The outlet pressure of chilled water of the two units is the same while there is a slight difference in return water pressure between
the two units. However, they remain unchanged during the operation of the units. These parameters in the stage of ice storage are listed in Table 1.

**Table 1. Parameters in the stage of ice storage**

| Parameters                              | Full load current (%) | Outlet pressure of chilled water (KPa) | Return pressure of chilled water (KPa) |
|-----------------------------------------|-----------------------|---------------------------------------|---------------------------------------|
| water chiller 1                         | 88.0±1.2              | 90.4±1.8                              | 0.15                                  |
| water chiller 2                         |                       |                                       | 0.15                                  |
| water chiller 1                         |                       |                                       | 0.3                                   |
| water chiller 2                         |                       |                                       | 0.35                                  |

3.2. Supply and return water temperatures

The ice storage of the chillers is carried out at night (starting at 10 p.m.), which is in line with the peak and valley electricity timetable of Hangzhou, China. The temperatures of supply and return water are recorded every two hours. This experiment recorded the operation of the cooling-water chillers for 26 days. Most of the time, the ice is made for 6 hours at night and some of the time, the ice is stored for 4 hours or 8 hours. Figure 2 shows the supply and return water temperatures over time. Both the supply water temperature and the return water temperature decrease with the increase of the water chillers running time and the temperature difference between the two chillers is very small. At the beginning of ice storage, the temperature difference is huge but the difference narrowed over time. This is caused by the unstable operation of the unit when it was just started and the difference in the recorder's recording time can also have an impact. After the operation is stable, the temperature of supply water is kept between -6.5℃ and -5℃ and the return water is kept between -2.5 ℃ and -1℃. It is basically consistent with the design condition. This means that the design is sound and the plan is feasible.

![Figure 2. Supply and return water temperatures over time](a: cooling-water machine 1; b: cooling-water machine)

3.3. Analysis of ice storage

Figure 3 shows ice storage for 26 days. The final ice storage capacity of the ice tank every day is between 3500-4500 RT and the maximum value is close to the ice storage capacity (about 4500RT). There are some differences in daily ice storage but they are not particularly obvious. The initial value of ice storage varies from day to day and varies considerably. It's related to the amount of ice melting the day before. During the 26 days, the chiller also operated in the daytime for only 5 days. This means that the air-conditioning system can only melt ice in the ice tank to meet the cooling needs most of the time. It has achieved a good effect of shifting peak and filling valley. However, it is found in the operation data of ice storage and melting that there is no good control strategy in the whole operation process. Besides, there is no good prediction for the ice demand of the next day. These shortcomings make the system unable to achieve the optimal energy saving effect.
3.4. Air temperature and ice melting capacity

Figure 4 shows the Maximum air temperature and the Minimum air temperature during the whole monitoring process and the amount of ice melting per day is also given. Overall, the temperature in late July is higher than that in August. However, there is no significant positive correlation between melting ice volume and temperature. It means that the demand for cooling capacity in buildings depends on more than just outdoor air temperatures. Of course, it also should be combined with the operation of the chiller in the daytime for comprehensive analysis. People's work and rest, rain and other factors will affect the demand for cooling capacity which directly affect the amount of ice melting. The maximum amount of ice melting per day is about 3700 RT, only 17.3% of the total cooling load of the whole building. Even if the process air conditioning load is removed, the daily cooling load demand of the whole building is relatively low, which is a certain gap with the total cooling load of the design day. If the chillers are directly turned on for cooling in the daytime, the chillers will operate at a lower load rate with a lower COP (Coefficient of performance) which is not favourable to save energy. However, if the chillers are used for ice making, they can operate close to full load with a high COP. It has practical significance in saving electricity.
4. Conclusions
1. The operation of the ice storage air conditioning system is stable and consistent with the design condition.
2. Melting ice refrigeration can basically meet the cooling needs of the building. However, the operation strategy of ice storage system is poor in the whole operation process.
3. The research of this paper can provide reference for the design and operation of ice storage air conditioning system in the future.

5. References

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