Operating Performance on the Application of a Water Source Heat Pump and Ice Storage System of One Chinese Typical Project

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Abstract: As a renewable energy technology, the water source heat pump system and ice storage technologies have increasingly attracted world-wide attention due to their advantages of energy efficiency and environmental friendliness. A water source heat pump system and ice storage system were designed and constructed in the China pavilion for the Shanghai world expo 2010. This system has continuously run for nearly three years. It was shown that the indoor thermal environment met the “GB/T 18049—2000” issued by China national standard council. Compared with conventional air conditioning system (water chilling and gas boiler) which was widely used in Shanghai, the operating cost of this system is reduced by 55.8% and the payback time is about 4.6 years. Furthermore, the annual load shifting ratio could reach up to 63.24%. Owing to its great potential in energy conservation, such kind of combined system is testified to be applicable to the air-conditioning systems of symbol buildings. What’s more, the applications of this systems corresponding to different climatic zones of China were discussed.

Key Words: water source heat pump, ice storage, operating performance, application

1 INTRODUCTION

China Pavilion is the iconic buildings and permanent venues of 2010 Shanghai World Expo. The main building was divided into National pavilion and Regional pavilion. The basements are connected as a whole, the upper part was divided into two relatively separate buildings, the National pavilion was raised in the middle and regional pavilion was stretched horizontally. During the Expo, National Pavilion displayed from China city's historic, present and future developments, showing a splendid Chinese urban civilization picture. Regional pavilion provided exhibition spaces to 31 provinces, municipalities and autonomous regions of the country, showing out Chinese multinational presence and the achievements of different provinces, municipalities and autonomous regions. After the Expo, the National pavilion will serve as an exhibition base to display Chinese history, culture and art, and the regional pavilion will transform as a standard exhibition venues. China Pavilion is located in the east side of Expo Axis in enclosed area B, Shanghai World Expo Planning. The pavilion reaches the North Ring Road from the north, south to the South Loop, west to the South road, and East to the Heights Road. China Pavilion which is the permanent venues of 2010 Shanghai World Expo covers an area of about 153,000 square meters. The main building is divided into National pavilion and Regional pavilion. The basements are connected as a whole, the upper part is divided into two relatively separate buildings, the National pavilion is raised in the middle with a height of about 69.9m; The regional pavilion is stretched horizontally and as high as about 13m. The design sketch and profile map of this typical project was shown Fig.1.

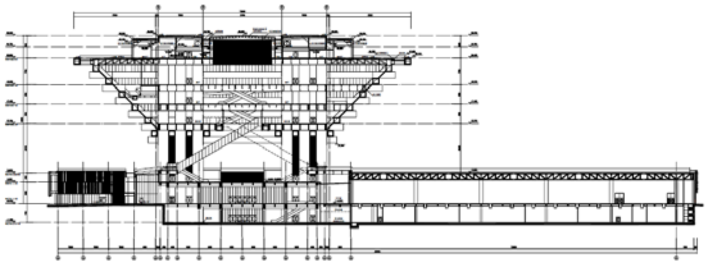

Figure.1 The design sketch and profile map of the typical project

2 COLD AND HEAT SOURCE SELECTION

The maximum design cooling load in summer air conditioning is 19950kW (4250R t), and cold load index is 119W / m^2; the winter air conditioning's maximum design heat load is 14200kW, and heat load index of is 74W / m^2. The service condition of air conditioning cold and heat sources in a whole year are shown in Table 1.

Table.1 service condition of air conditioning cold and heat source in a year

Load rate/%	Cooling time/ day	Heating time/ day
100	30	20
75	60	25
50	50	25
25	40	20
summation	180	90

China Pavilion in Shanghai Expo is adjacent to the edge of the Huangpu River. According to the hydrological data, in summer the surface temperature of the Huangpu River is (26 ~ 32) ℃, the middle and lower temperature is (15 ~ 22) ℃; in winter the lowest temperature is (3 ~ 8) ℃, the middle and lower temperature is (10 ~ 15 ℃) (Zhang WY and Long WD 2008). The temperature characteristics of the river (Table 2) make Huangpu River as an ideal heat source of the water source heat pump. However, because the water quality of the river belongs to V class, there are many impurities in the water. It can be used directly under corrosion prevention, of course, combined with the water filtration system in Expo area to meet the use needs.

Table.2 the actual measured data of surface layer water temperature of Shanghai Huangpu River

The annual average temperature	The annual highest temperature Aug.	The annual lowest temperature Jan.
18.9	32.2	3.4

The river water is used as a cold and heat source for air condition system. The low temperature level heat energy can be transferred to high level heat energy by importing a little high grade energy such as electricity, thus the energy expense of users and environmental pressures can be greatly reduced. Considering that the cooling load in summer is much bigger than heating load in winter, and the cooling load demand at night is small, the river water source heat pump and ice storage air-conditioning programs are advised. Besides making use of low ebb electricity to storage ice at night in summer, using the cooling capacity which is used for storage ice and river source heat pumps when the power use is peak in daytime to supply cool for the end of the air condition (He CF. et al). In winter, the river source heat pump heat covers 55% of the total load, the rest of load is supplied by boilers.

3 RIVER WATER ICE-STORAGE SYSTEM

The ice-storage system in the project uses three level 3 compressed centrifugal water chilling units and the ice storage system diagram was shown in Fig.2. The cooling capacity of a single unit air condition (7℃/13℃) is 2286kW (650Rt), COP = 5.1; cooling capacity of ice condition (-2.3℃/-5.6℃) is 1498kW (426R t), COP = 4. 4. The total amount of ice storage of the ice storage device is 32000kWh (9098Rth), occupying 20% of the total air-conditioning cooling capacity in design days. Refrigerating medium uses ethylene glycol solution whose concentration is vol.25%. In this project, the ice storage system control by mature component of the ice storage, design with the host operating strategy priority, and melt ice priority with partial load. The total floor area was 144502 m^2 and the air-conditioning area was 96201 m^2 and the capacities of TES tanks and heat pump were 6858KW and 8695KW respectively. Air conditioning cooling water directly uses river water which is disposed by grading filtration, thus dirt can be reduced and the heat transfer can be improved. Meanwhile, equipped with copper-nickel alloy tubes, the heat exchangers of the units enhance the anticorrosion function and configure the automatic device (L.P.E. Paul and J. Sanchez 2006)

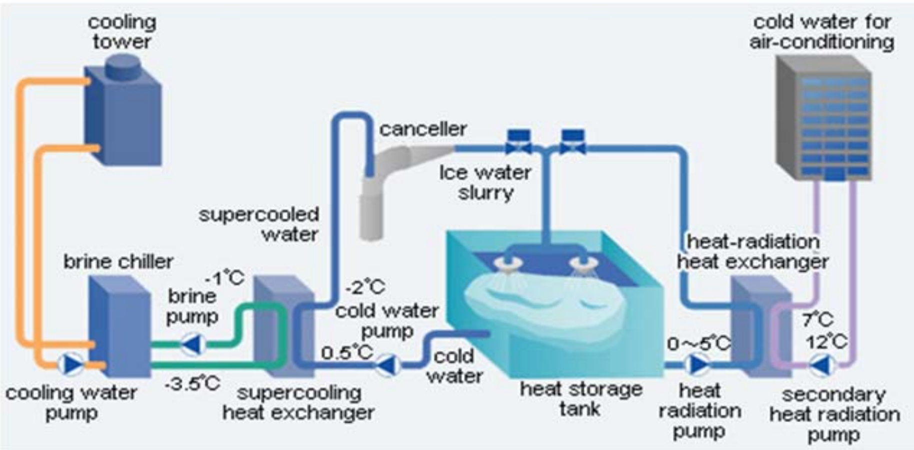

Figure 2: Ice Storage System diagram

4 RIVER WATER SOURCE HEAT PUMP SYSTEM

In this project, the river water source heat pump uses two Level 3 compressed centrifugal water chilling units. The river designed temperature in summer is 28℃/36℃, supplying air condition cool water at 4℃/12℃, COP =4.8; the river designed temperature in winter is 7℃/4 ℃, supplying air condition hot water at 37℃/45℃, COP=4.3(Hu XB et al. 1997). According to the parameters above, it is easy to notice that the units have a poor cooling function and their energy-saving advantage lies in heating working condition. Because most of operation time is better than designed working condition in winter, the energy-saving effect is outstanding by consideration for a whole year.

5 OPERATING EFFECT EVALUATION

The running strategy of the project is shown in figure 3. Assuming the values of COP of the cooling machine working in cooling working condition and working in ice-making system working condition are respectively 5 and 3.5, then the comparison of gradual heat extraction values which is applied in regular air condition system and water source heat pump coupling storage ice cooling system are shown in Fig.4.The peak heat extraction rate of regular heating system is 19861.2kW, the full day accumulative total of heat extraction is 236885.6kWh; the peak heat extraction rate of water source heat pump coupling ice storage cooling system is 10112.4kW, the full day accumulative total of heat extraction is

232442.5kWh. After cooling by water source heat pump coupling ice, the intension of underground heat extraction reduces by 44%. With calculation, the load peak value of water source heat pump coupling ice storage cooling is 63.24% in a whole year.(Yang G et al. 2010).By monitoring the room temperature of the system (running 125days continually), the temperature range lied in 18-22℃, which is shown in Fig.5, meeting the requirements of standard temperature heat comfort of “GB/T 18049_—2000”

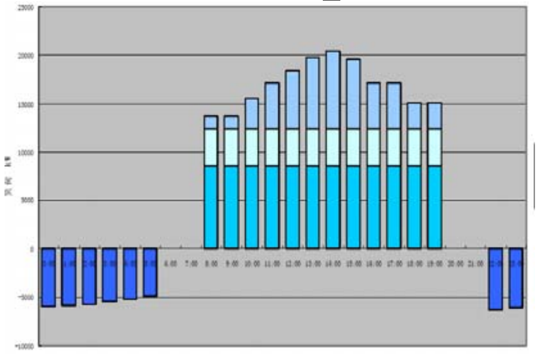

Figure 3. The ice-storage operating strategy of the project

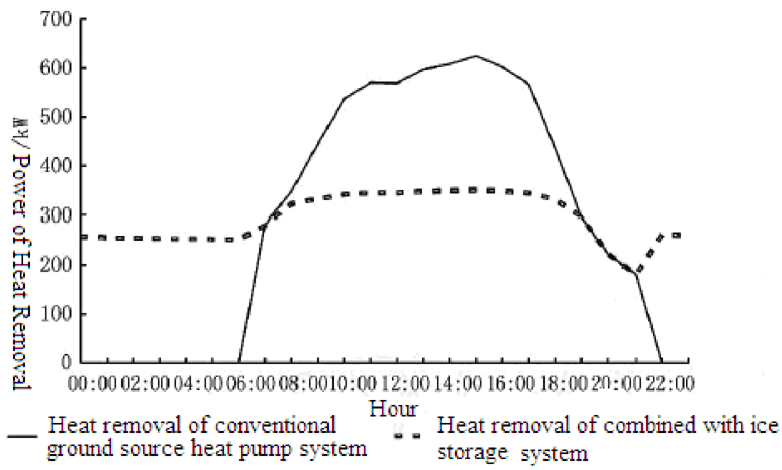

Figure 4. The comparison of gradual heat extraction values which is applied in regular air condition system and water source heat pump coupling storage ice cooling system

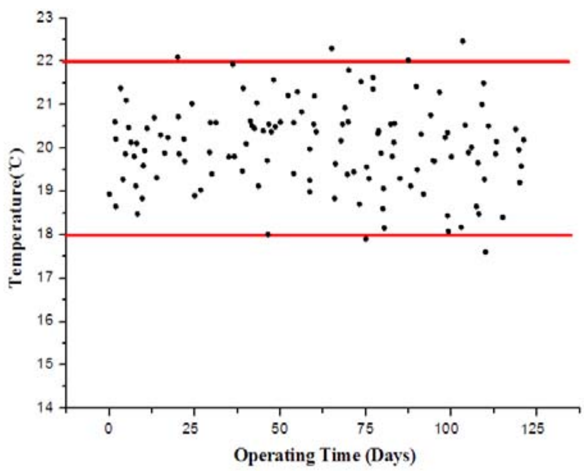

Figure 5.The temperature variation for 120 days

6 ENERGY EFFICIENCY EVALUATION

In order to analysis the economical property of combination running, comparing with regular project (centrifugal water chilling units and boiler heating) would be necessary. In regular project, centrifugal water chilling units are used for cooling in summer, cold water is 7℃/12℃, cooling water is 32℃/37℃, COP=5.1; the fuel gas boiler heating is used in winter and the hot water is 40℃/45℃.

Table.3 Funding and life cycle analysis

Iterms	Case1		Case2	
	Cooling	Heating	Cooling	Heating
Technical Charateristics	Watering chilling unit+gas bolier		Water source heat pump+ice storage	
Initial investment	1009		2021	
Annul operation cost	396	286	296	158
The operation cost for 5 years	3412		2282	
Payback period (years)	--		4.5	

According to the calculation above, compared with regular project, combination running the river water source heat pump and ice storage centrifugal water chilling units can recycle investment balance in 4.5 years because of the cheap running expense, although the ice storage tank and river process equipment are expensive investments (Li YG et al. 2009). Whereas, in the 15 years age limit of the units, project two can save more than 33800 thousand yuan than project one, which means the saving-energy effect are really remarkable.

7 CONCLUSION

(1) The cultural center of Shanghai World Expo is aiming at load features, besides the surroundings take reasonably advantage of river water heat pump and ice storage cooling technology. With all the measures the air condition system can make a great difference on saving-energy and saving running expense.
(2) The high running efficiency of the water source heat pump can supply heat in winter and refrigeration in summer at the same time. Ice storage cooling can reduce lading capacity to create a peak clipping and valley filling effect. Combination of the two technology is easy to have complementary advantages and create good economic benefit and energy-saving benefit.
(3) During the specific designing process, the architecture features and conditions , cooling load distribution, local electricity prices should be considered so as to choose fit devices and operation ways. What’s more, it is advisable to take investment and energy-saving rate of return into consideration.

8 ACKONWLEDGEMENTS

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