The Design of Water Intake System and Analysis of Water Quality Conditions of the Regional Energy System of Complex River Water Source Heat Pump

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Abstract: As a realization of the energy cascade utilization, the regional energy system has the significant potential of energy saving. As a kind of renewable energy, river water source heat pump also can greatly reduce the energy consumption of refrigeration and heating system. Combining the regional energy and water source heat pump technology, to achieve cooling, heating and power supply for a plurality of block building is of great significance to reduce building energy consumption. This paper introduces a practical engineering case which combines the regional energy system of complex river water source heat pump, which provides a detailed analysis of the hydrology and water quality conditions of the river water source heat pump applications, and discusses the design methods of water intake and drainage system. The results show that the average temperature of cold season is about 23.5 ºC, the heating season is about 13.2 ºC; the abundant regional water flow can meet the water requirement of water source heat pump unit; the sediment concentration index cannot meet the requirement of river water source heat pump if the water enters the unit directly; the river water chemistry indicators (pH, Cl^-, SO_4^{2-}, total hardness, total iron) can meet the requirement of river water source heat pump, and it is not required to take special measures to solve the problem. However, the problem of sediment concentration of water must be solved.

Keywords: Distributed energy, district cooling, feasibility evaluation, energy and environment, the utilization of natural gas.

1. INTRODUCTION

Combined cooling, heating and power (CCHP) systems, which can also be referred to the trigeneration systems, are broadly employed in small-medium scale power systems in order to achieve economic efficiency and lower contamination [1, 2]. CCHP systems have been widely introduced into various kinds of buildings, such as office buildings, hotels and hospitals [2, 3]. Water-source heat pump (WHP) system refers to the use of a renewable, large body of natural water as a heat source-sink for space heating and cooling [4]. Water source heat pump composite CCHP system can further improve the efficiency of energy use by combining the advantages of the two kinds of energy systems.

The extensive literatures reported related research on CCHP systems [5-11] and water source heat pump technology [12]. However, there is little introduction for CCHP combined with river water source heat pump technology. The paper taking a practical engineering project in Chongqing area as an example, analyzed the conditions of hydrology and water quality of the project, and introduced the design methods of water intake and drainage. Through the study of water source heat pump, the paper analyzed the feasibility of the project and provided a reference for the implementation of the project.

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2. PROJECT PROFILE

The project is located in Chongqing, which is one of the southwest cities of China, located along the Yangtze River, and belongs to the hot summer and cold winter area. The summer demands large cold while the winter needs a lot of heating. At the same time, the territory is rich in natural gas, which provides energy security for the natural gas CCHP. The project is located in Chongqing City, providing the 15 buildings with energy supplies and serving the construction area of about 800,000 square meters.

The distance from the Yangtze River is 50 m, and the Yangtze River water conditions are good. Considering the economy and energy saving, the heat and cold sources of this project adopts river water source heat pump composite CCHP system. The operation principle of composite system of summer and winter is shown in Fig. (**1**). In transition season, according to the need of sanitary hot water consumption, the generator will be started to heat sanitary hot water suing waste heat.

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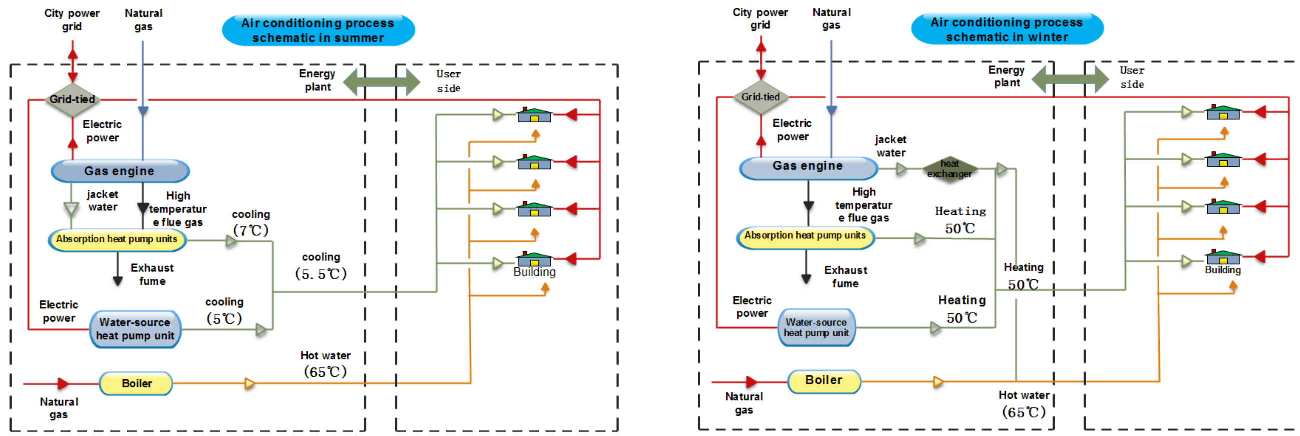

Fig. (1). Gas engine directly connected with CCHP and river water source heat pump composite system.

3. HYDROLOGY AND WATER QUALITY CONDITIONS

The suitable hydrology and water quality conditions are the bases for application of water source heat pump, which are important for the feasibility analysis of the project and the system design. In this study, part of hydrological and water quality data is from hydrological station test data. But in order to get the overall data of hydrology and water quality, the waters of the region were also measured, which provided detailed data for the system design and feasibility analysis of the project.

3.1. Water Temperature Conditions

The temperature of surface water system is an important factor influencing the operation effect of water source heat pump system. Fig. (**2**) shows the practical temperature measured values. As can be seen from the graph, cooling season of the district changes in water temperature are between 21.5-26 ºC, whereas the average cooling water temperature is about 23.5 ºC. The regional heating seasonal changes in water temperature are between 10.9-17.7 ºC, whereas the average heating season temperature is about 13.2 ºC, so the district has good temperature conditions.

3.2. The Water Flow and Water Level

According to the analysis of 1943-2008 data of hydrological stations, the annual average flow is 11,200 m^3/s, in which the average flow of 5-11 months (cooling period) is 16,300 m^3/s, and the average flow of 12-4 month (heating period) is 3,790 m^3/s. As can be seen from the data, the regional water flow is abundant and the water can be

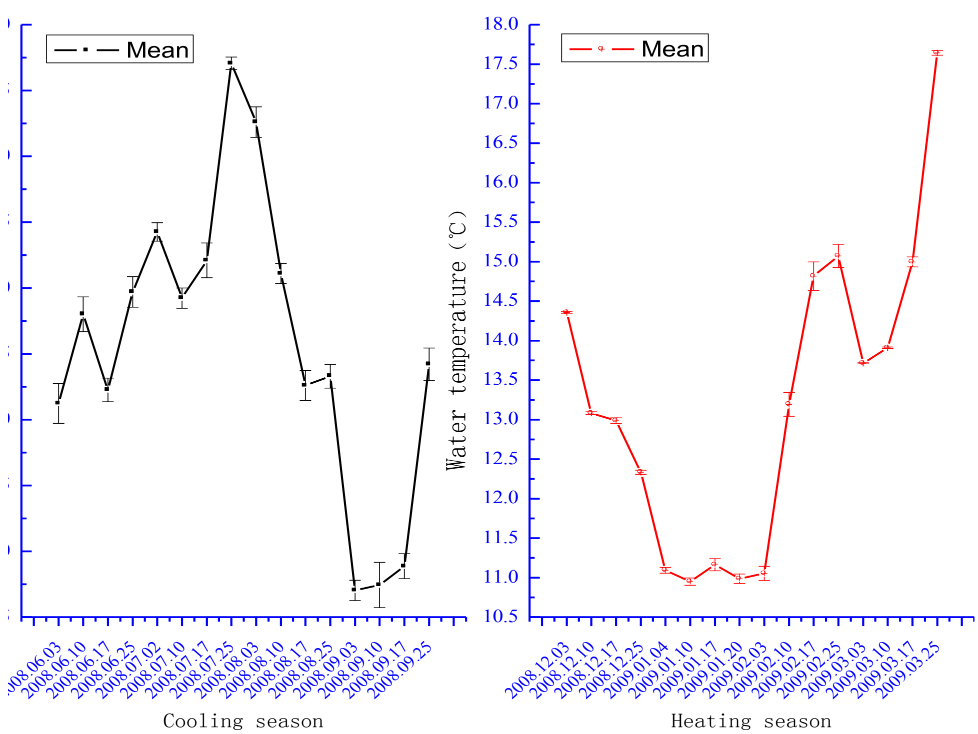

Fig. (2). Project areas water temperature measured values.

used to meet the requirements of water source heat pump (1 m^3/s water source heat pump can provide 20,000-25,000 kW air conditioning cooling capacity).

As Fig. (**3**) shows, the regional level changes in January 2008 to April 2009. As you can see from Fig. (**3**), before October 2008, the water level of summer is higher than winter for the rainy season; but after October 2008, the Three Gorges Reservoir began to store water in summer and released water in winter, leading to the significantly different water level during January to March of 2009 and 2008. So the water intake and drainage design was required to use the change rule of water level after October 2008.

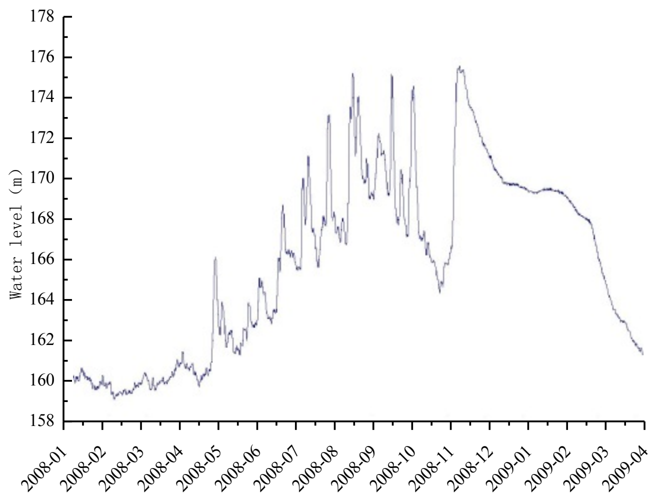

Fig. (3). Variation of water level line.

3.3. Water Quality Conditions

Water quality not only affects the heat transfer performance of heat pump units, but also has a serious impact on the service life of the heat pump units and its accessories.

So, the analysis of water quality conditions of the water area and the suitability of water source heat pump system can provide the foundation for the effective technical measures.

3.3.1. Sediment Concentration

As can be seen from Fig. (**4**), the annual maximum and minimum sediment concentration of the typical cross section of the water were 2.95 kg/m^3 and 0.022 kg/m^3 in June 2008 and March 2009 respectively. The average sediment concentration is about 0.48 kg/m^3, which cannot meet the limited 100 mg/L value of < surface water source heat pump units water quality standard. As can be seen from Fig. (**5**), suspended particles diameter vary from 0.004 mm to 0.012 mm; average particles size vary from 0.013 mm to 0.051 mm; the maximum particle size vary from 0.228 mm to 0.424 mm. Through the above analysis, the heat pump system design needs to take sand removing measures. The sand removal equipment to deal with about 0.005 mm to 0.05 mm sand should have high grade removal efficiency, and can remove the large particles of about 0.4 mm. If necessary, a multi-stage treatment is available.

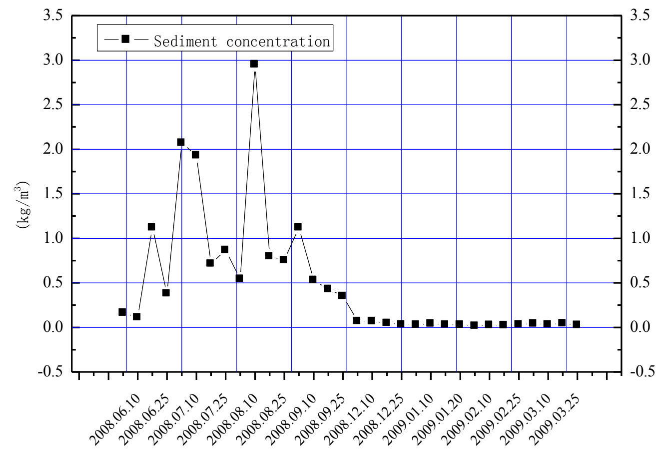

Fig. (4). Water sediment concentration.

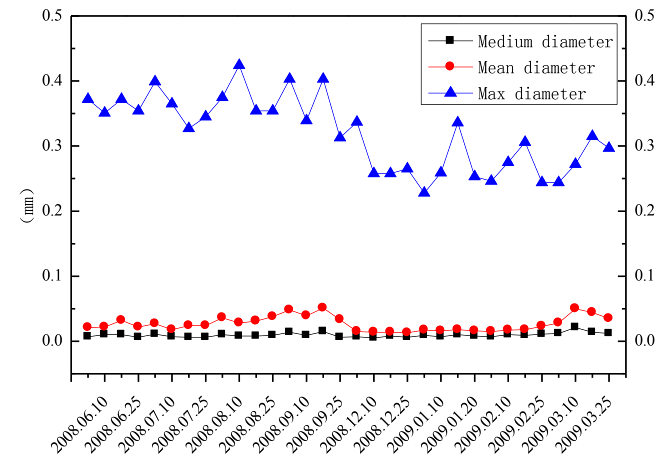

Fig. (5). Sediment particle size characteristics.

3.3.2. Chemical Index

The Fig. (**6**) shows the river water chemical indicators (pH value, the concentration of Cl^-, the concentration of SO_4^{2-}, total hardness, total iron). As can be seen from the graph, the monthly average pH value of the water varies from 7.7 to 8.4. The chloride ion concentration of the section between 5 ~ 25 mg/L and its maximum and minimum concentration appear in the flood season. The monthly average sulfate concentration is in the range of 15 ~ 100 mg/L, but it is lower at the flood season, about 20 ~ 40 mg/L. The average sulfate concentration in the non-flood season is greater than the value in the flood season for the non-flood season owing to higher values. Total hardness is in the range of 110 ~ 180 mg/L, it has obvious seasonal variation and it is higher in non-flood season but smaller in the flood season. Total iron concentration is in the range of 0 ~ 8 mg/L. The entire index mentioned above meets the relevant requirements of surface water source heat pump units water quality standard.

According to the analysis of hydrology, water temperature, water quality conditions, the water area of the Yangtze River is found suitable for application of low heat source water source heat pump. However, the sediment concentration cannot meet the feasibility requirement of the water source heat pump. Using the river water as water

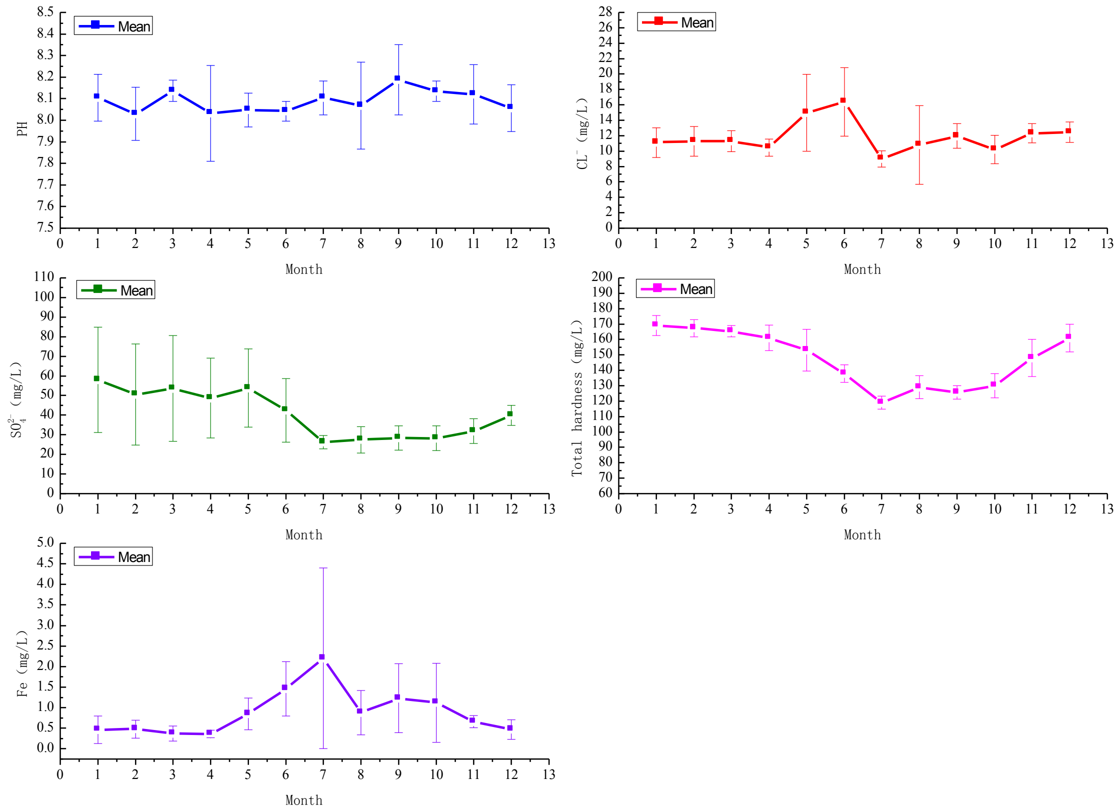

Fig. (6). Water chemical indexes.

source heat pump water, must solve the problem of the river sediment concentration. Especially in the summer, the lager sediment concentration can cause the water source heat pump ex-changer fouling easily. Effect of fouling on the heat ex-changer has two main aspects: on the one hand, the fouling growth affects the heat ex-changer and reduces the energy efficiency; on the other hand, the fouling growth increases the flow resistance when water gets in and out of heat ex-changer, increasing the energy consumption of the pump. Therefore, in the design and operation of the system, water treatment should be taken as corresponding measures.

4. WATER INTAKE AND DRAINAGE SYSTEM DESIGN

4.1. Water System Design

The main factors considered in the design of water intake are site, water level, water demand of units and water intake form. Location should be fully considered as bed forms, and it needs to have good bearing capacity, no landslide, sand, no weathering and karst phenomenon. The first level of water pump is difficult to adapt to changes, such as the water level, under the condition of meeting high efficiency. Therefore the scheme adopts the operation of two stage supply. The first level of intake water pump adapts to changing water level of the Yangtze River with different impeller cutting and conversion; second level of intake pump adapts to water demand of different energy station unit with grouped setting; the cyclone desander and regulating pond should be installed between the water intake pump house and feed pump room. Fixed structure has two types: the shore and river bed. The project is more suitable for the type of river bed of the slow river beach at the site of water intake. The specific process is: the water head will be set below 156 m (the Yellow Sea), water enters the suction end of the first level of water intake pump, lifted by the pumps, then enters the cyclone desander and regulation pool. The water will be transported to the energy station for further processing by a two-stage water intake pump, and finally goes into the heat exchanger.

Since the water level changes from tens of meters in summer, from the low water level to the normal water level even flood water level, so in order to ensure the raw water quality is always in a good state, the low and high water pipes are set up (as shown in the Fig. **7**). Low water diversion pipe head extends to the center of the river. Considering the low water level (157.80 m) and the lowest navigable water level (158.5 m) and ship draft, the head of the top elevation is 153 m. High water diversion pipe center design elevation is 164.5 m. The filtration treatment of source water takes multistage water schemes by water head coarse filter, cyclone desander and full water processor fine filtration filter. At the same time, the use of automatic online cleaning system of heat exchanger pipes for online cleaning, avoids deposit of the dirt on the surface of the heat exchanger and ensures the long-term efficient operation of change heat equipment.

4.2. Water Drainage System Design

The drainage port is arranged on the downstream side of intake and guarantee a certain distance, so the drainage will not affect the intake. In the design, the distance of high

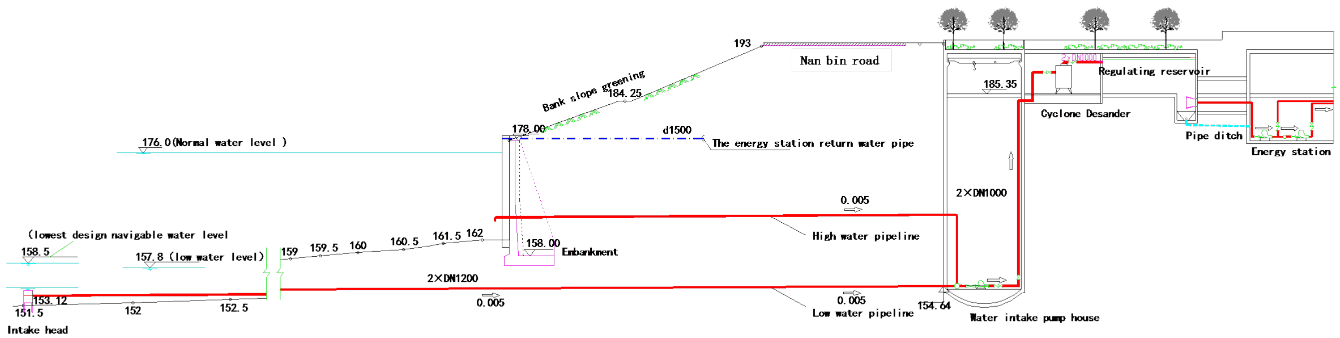

Fig. (7). Schematic diagram of water intake.

intake and drainage is about 110 m, whereas the distance of low intake and drainage distance is about 290 m.

CONCLUSION

Along with our country's energy structure adjustment and improvement, the West East gas pipeline project, the proportion of natural gas in the energy structure of China will be increasing gradually. With the rapid development of China's urbanization and the increase of building energy consumption, the construction of low carbon, energy saving and green city district is the only way of city development. The efficient energy-saving regional technology is an important technical means to build a green area.

This analysis shows that: in the cooling season, average temperature is about 23.5 ºC, in the heating seasonal average temperature is about 13.2 ºC, so the temperature conditions are good; regional water flow is abundant and can meet the requirements of water source heat pump unit; sediment concentration index directly used into the water source heat pump cannot meet the requirements of the host. River water chemistry indicators (pH, the concentration of chloride ion, sulfate ion concentration, total hardness, total iron) can meet the requirements of water source heat pump unit, so it does not need to take special measures to solve the problem. However, the problem of sediment concentration of water must be solved. The sand removal equipment selected in the engineering design should have high grade removal efficiency for the sand of 0.005-0.05 mm, and can remove the large particles about 0.4 mm. A multi-stage water treatment is available when necessary. The use of river water source heat pump and CCHP system can meet the energy saving, green and low carbon requirements, so they should be considered as a kind of energy conservation programs in the construction of similar projects in the city. Due to the less restrictions of energy station and pipe network layout in the new area, it is more suitable for the regional energy projects to carry out.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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