Analysis of Problems in Soil Source Heat Pump

Jie Li*, Pei-yao Xiao, Guo-feng XV, Long-tao Zhai and Fan-shuo Meng
School of Energy and Architectural Engineering, Harbin University of Commerce, China
*Corresponding author

Keywords: Soil source heat pump, Thermodynamic equilibrium, Hydraulic balance, Economy.

Abstract. The soil source heat pump system is characterized by high efficiency, energy saving, environmental protection, and full use of renewable energy. And today, when excessive energy consumption puts tremendous pressure on the environment, it has increasingly become the focus of attention. Most of the research aimed at it so far has focused on heat exchange, but there is almost no water balance problem. And many studies only draw some conclusions based on some theoretical calculations or numerical simulations. As a result, there have been many studies on the problem of heat transfer, and the research has deviated from the actual focus on theory and hydraulic balance. For the entire system, there is almost no comprehensive consideration of thermal balance, hydraulic balance, and economics. Therefore, this paper discusses the problems existing in the above three aspects of the soil source heat pump system, and then has some reference value for the actual project.

The Background and Significance of Soil Source Heat Pump

Geothermal resources has the characteristics of stability and efficiency, and has total proven reserves of 2.6 times the coal, the annual mined 69 billion m³ [1] and almost without geographical and resource constraints, and therefore known as unlimited renewable energy. The soil source heat pump is a new energy technology that utilizes geothermal energy resources [2]. Due to its unique advantages, it has developed rapidly in recent years. It can completely replace equipment such as boilers with serious air pollution. And in some areas with harsh climatic conditions or more extreme weather can play a significant advantage.

Introduction of Soil Source Heat Pump System

Advantages of the Soil Source Heat Pump System

High Control Flexibility

By using a multi-stage manifold [4], multiple units in the soil source heat pump control the ground tube loop of the area. When the total load is relatively large, each unit operates together to maintain...
the supply of cold heat; and when the total load is relatively small, the energy loss can be reduced by opening or closing the underground buried circuit and some of the units therein.

**Environmental Pollution Free**

The soil source heat pump system uses heat as a circulating medium to obtain heat from the underground soil. In the summer, it can replace the cold water tower as a cold source for cooling indoors. In winter, it can be used as a heat source for indoor heating instead of the conventional heat source. A small amount of electrical energy is required to maintain its normal operation and has significant energy saving features. In the process of operation, the system does not occupy an excessive area, and at the same time, there is no water consumption, and thus there is almost no damage to the environment, achieving environmental protection effects. Therefore, in terms of long-term benefits, this technology has great development potential and broad market prospects [5].

**Disadvantages of Soil Source Heat Pump System**

**Destruction of Soil Temperature Field**

Due to the long-term process of heat absorption and release in the soil, the underground heat exchange system will cause large fluctuations in the soil temperature field, and the local underground temperature field will be destroyed. Wei-bo Yang et al. analyzed the soil thermal imbalance problem in the soil source heat pump system where there is uneven temperature and heat load, and proposed that the soil thermal imbalance problem is a key problem that must be solved [6]. Rui-rui LI explained the effects of intermittent operation and auxiliary cold and heat sources on the thermal imbalance of soil from various angles [7]. Li BAI et al. observed and studied the soil temperature field of actual projects in severe cold regions. The factors that influence it and the laws of change. Finally, it is inevitable that the thermal imbalance of the soil will occur under the condition that the thermal load of the cold load is not balanced [8]. The above documents [6] to [8] all point out that the problem of soil source heat pump system damage to soil temperature field cannot be ignored. At the same time, the thermal imbalance of the soil will result in low summer temperature and high heating temperature in winter, or excessive heat from the soil in winter to produce frozen soil phenomenon, which will affect the normal operation of the system [9].

**Initial Investment Is Very High**

Because there are many heat exchange processes between underground and soil, the total heat resistance of heat transfer is large. Moreover, the efficiency of heat exchange between the circulating medium and the soil in the underground buried pipe is very low. Therefore, the buried pipe generally increases the heat exchange area or increases the buried depth of the buried pipe in order to increase the heat exchange efficiency. Therefore, it is necessary to dig a lot of soil and deep drilling, which leads to a large investment in the early stage.

**Problems with Soil Source Heat Pump**

**Thermal Balance Problem**

Through long-term research, the heat stored by the soil source heat pump in summer is generally not equal to the heat taken away in winter. When the heat exchange area is a relatively large tube group, the soil temperature around it will be out of balance, causing a slight fluctuation of the temperature field. Over time, the soil temperature field will evolve from a slight fluctuation to a constant increase or decrease in temperature, which will result in less heat exchange in the tube group. At the same time, due to the accumulation of cold (heat) in the vicinity of the tube group, the temperature gradient of the soil changes, and the magnitude of the soil heat flux changes, causing the surface temperature of the earth's crust to change, and heat unevenness occurs in some areas. Will destroy the natural environment [10].
For this reason, many scholars at home and abroad have conducted research. The main research focuses on the heat exchanger research, the numerical simulation of soil temperature field, the improvement and optimization of heat transfer model, the selection of buried pipe backfill material, the development of simulation software, and different equipment in the system. Mutual matching and switching of different modes of operation, system thermodynamics and systems economics research [11,12,13,14]. There are also many studies on this aspect of the problem of thermal equilibrium at home and abroad. For example, the thermal properties of soil, the spacing and depth of buried heat exchange tubes, the thermal properties of backfill materials, the ratio of cumulative load in winter and summer, and the increase of auxiliary cold source heat sources [15,16,17,18,19].

**Causes of Thermal Balance Problems**

1. There is no standard operating procedure in the process of construction, and there is no regulation in the process of operation.
2. Since the initial investment of the system is relatively large, the number of heat exchange tubes used is reduced, and no auxiliary equipment is added.

**Hydraulic Balance Problem**

The circulating medium in the outdoor underground heat exchanger in the system is fluid, and due to the complicated arrangement of the piping system, the slight influence will affect the system operation. In some practical projects, problems will arise shortly after use. The main reason is caused by the imbalance of water in each loop in the whole system. At the same time, when the system runs for a long time, the flow Q of some loops is not high, which will make the pipeline full of lowness, so that the sediments are more likely to gather in these lower flow pipelines to reduce the life. Since the outdoor underground heat exchanger system is buried underground all the year round, it is impossible to know in time when problems occur, so hidden dangers are buried. In order to reduce the adverse effects of hydraulic imbalance on the heat exchanger system, it is necessary to analyze the hydraulic stability of the entire system [20]. It can be used to scientifically determine the layout of the entire system, pipe flow, pipe diameter, fluid flow rate, and so on.

**Causes of Hydraulic Imbalance** [21]

1. The constructor did not follow the design drawings during the actual construction process.
2. In order to save costs, the loop valve is not closed according to the specifications.
3. The system equipment changes the original pipeline direction during maintenance, or changes the original number of valves.

**System Initial Investment Problem**

The initial investment in the soil source heat pump includes: equipment purchase cost, civil construction fee, installation fee and replacement cost [22]. However, civil construction fees account for a large proportion of the initial investment, because drilling operations are required in the early stage. According to the actual investigation, underground drilling is about 120 yuan/m in China. An ordinary heat pump system needs at least 100 holes, and each hole is about 65m. At least 780,000 yuan is spent on drilling, which will increase the cost in actual projects due to many factors. However, the maintenance cost of this system is very low [23]. In the long run, the soil source heat pump is still a good choice compared to other systems. However, it is necessary to optimize the construction process, reduce the cost of drilling, and develop new materials for pipes [24].

**Conclusion**

In summary, in order to reduce the footprint of the soil source heat pump, most of the vertical buried pipe is adopted, and the impact on the environment is small and the heat exchange efficiency
is high. Although the initial investment is high, the soil source heat pump is still a good choice in
the long run. In the actual project, the problem should be considered comprehensively, and the
hydraulic balance analysis and calculation should be done in the system design stage. For the
thermal balance problem, choose the mode of operation and other methods to avoid changes in the
soil temperature field. In the construction process, it is necessary to reduce the initial investment
caused by drilling due to the actual situation.

References

[1] Zhou Yiya. On the Utilization and Development Prospect of Geothermal Energy[J].Science &
Technology Prospect, 2015, 25(30):117.

[2] Du Shimin, Liu Yefeng, Ai Yongjie, Li Xu, Ma Junlin. Simulation and experimental study on
heat transfer characteristics of buried tube heat exchanger[J].Fluid Machinery, 2015, 43(01):1-6.

[3] Yang Weibo, Wang Songsong, Liu Guangyuan, Zhang Susu. Experimental study on heat
transfer enhancement and control of underground source heat pump underground buried pipe[J].Fluid Machinery, 2012, 40(10):62-68+32.

[4] Yang Yong, Han Dongtai, Hu Bin. Design of soil source heat pump system in a residential
building in Xuzhou[J]. Industrial Design, 2011(10): 138-139.

[5] Huang Wugang. Design of ground source heat pump system for Nantong station premises[J].
HVAC, 2010, 40 (05): 28-31.

[6] [7] Yang Weibo,Zhang Susu. Research status and key issues of soil heat pump imbalance in soil
heat pump in non-equilibrium areas[J].Journal of Fluid Mechanics, 2014, 42(01):80-87.

[7] Li Yurui. Analysis of underground soil thermal imbalance in soil-source heat pump system in
severe cold area[D]. Jilin University of Architecture, 2015.

[8] Bai Li, Li Yang. Study on the variation characteristics of soil temperature field of soil source
heat pump in severe cold area[J].Building Energy Ventilation and Air Conditioning, 2015,
34(06):19-22.

[9] Yang Weibo. Analysis of underground heat balance problem of soil source heat pump system
[A]. The Chinese Association of Refrigeration. Proceedings of the 2009 Annual Conference of
China Refrigeration Society[C]. The Chinese Association of Refrigeration Refrigeration): China
Refrigeration Society, 2009: 6.

[10] Zhu Hongfen, Du Zhenyu. Influence of heat balance problem of soil source heat pump system
on ecological environment[J]. Energy and Energy Conservation, 2011(07): 4-6.

[11] Ma Zhiliang, Lv Yue. Ground source heat pump system design and application [M]. Beijing:
Mechanical Industry Press, 2006: 13-25, 135-143.

[12] Chiasson A D, Spitler J D, Rees S J, et al. A model for simulating the performance of a
pavement heating system as a supplemental heat rejecter with closed-loop ground-source heat pump
systems [J]. Journal of Solar Energy Engineering, 2000, 122 (4): 183-191.

[13] Ping Cui, Hongxing Yang, Jeffrey D. Spitler, Zhaohong Fang. Simulation of hybrid ground-
coupled heat pump with domestic hot water heating systems using HVACSIM+[J]. Energy &
Buildings, 2008, 40(9).

[14] Yan Fucheng. Study on soil temperature field around heat exchanger of soil source heat pump
hot water system [D]. Hunan University, 2012.

[15] Lubis L I, Kanoglu M, Dincer I, et al Thermodynamic analysis of a hybrid geothermal heat
pump system [J] Geothermics, 2011, 40 (3):33-238.
[16] Zhai X Q, Yu X, Yang Y, et al Experimental investigation and performance analysis of a ground-coupled heat pump system [J] Geothermics, 2013, 48 (Complete): 112-120.

[17] Liu Jiali, Ma Neng. Study on the Influence of Soil Physical Properties on Soil Source Heat Pump[J]. Building Materials & Decoration, 2018(17): 162.

[18] Yu X, Wang R Z, Zhai X Q. Year round experimental study on a constant temperature and humidity air-conditioning system driven by ground source heat pump [J] Energy, 2011, 36 (2): 1309-1318.

[19] Han Xiaohong, Chen Guangming. Analysis of Several Factors Affecting Hydraulic Stability of Thermal Network[J]. HVAC, 2004, 34(9).

[20] Gao Wei, Jiang Xingwang. Discussion on the imbalance of hydraulic balance in heating pipe network [J]. China New Technology and New Products, 2009 (14): 48.

[21] Pei Qingqing. Economic Analysis of Soil Source Heat Pump Air Conditioning System in Hot Summer and Warm Winter Zone[A]. China Refrigeration Society: China Refrigeration Society, 2005:5.

[22] Qu Yunxia. Model and simulation of ground source heat pump system [D]. Xi'an University of Architecture and Technology, 2004.

[23] Wu Boqian. Experimental study and economic analysis of soil source heat pump [D]. Huazhong University of Science and Technology, 2006.