Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 428 – 431

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Performance analysis on hybrid system of thermosyphon free cooling and vapor compression refrigeration for data centers in different climate zones of China

Hainan Zhang[a,b], Shuangquan Shao[a,]*, Huiming Zou[a], Changqing Tian[a]

[a] *Beijing Key Laboratory of Thermal Science and Technology，Technical Institute of Physics and Chemistry，Chinese Academy of Sciences, 29 Zhongguancun East Road, Beijing100190, PR China*

[b] *University of Chinese Academy of Sciences, No.19A Yuquan Road, Beijing 100049, PR China*

Abstract

Free cooling is one of the most potential ways of reducing the energy consumption of data centers. Thermosyphon has superior heat transferability thus it is suitable for application in free cooling. However, a separate thermosyphon free cooling system usually cannot provide sufficient cooling capacity in warm seasons. In order to overcome this weakness and avoid two sets of equipment, hybrid system of thermosyphon free cooling and vapor compression refrigeration for data centers has been developed by researchers. The cooling performance of this kind of system depends greatly on the climate outside therefore its applicability in different time and zones needs to be studied. In this paper, the climate data from five cities of different climate zones in China is collected. The performance model of the hybrid system is built up. Based on the climate data and performance model, the annual energy consumption is then calculated and compared with traditional air conditioner. The result shows that the energy-saving potential of the hybrid system varies in different climate zones, and when the mode switching temperature is relatively high, it is distinct in most climate zones of China.

Peer-review under responsibility of the Organizing Committee of ICAE2014

Keywords: thermosyphon; free cooling; data center; energy consumption; climate zone

1. Introduction

In recent years, increasing energy consumption comes with the development of data centers. Electricity used by data centers worldwide increased by 56% from 2005 to 2010.As one of the main facilities of data centers, cooling equipment takes up approximately 50% of the total energy consumption of data centers

* Corresponding author. Tel.:+86-10-82543433; fax:+86-10-82543433.
E-mail address: shaoshq@mail.ipc.ac.cn (S. Shao).

Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.11.1141

[1]. Traditional cooling equipment of data centers is a computer room air conditioner (CRAC) based on mechanical vapor compression refrigeration, which consumes a lot of energy mainly due to continuously operation all the time regardless how cold outside. Free cooling, which means using natural climate to cool data centers, is thought to be one of the most potential ways of dealing with this issue. Up to now, several free cooling methods have been put forward by researchers including airside and waterside economizers, heat pipe, thermosyphon and so on. Among these methods, thermosyphon free cooling shows great potential for its superior temperature control features and ability to transfer heat at small temperature difference without affecting indoor humidity and air quality. However, a separate thermosyphon free cooling system usually cannot provide sufficient cooling capacity in warm seasons. Hybrid system of thermosyphon free cooling and vapor compression refrigeration (HSTV) is an ideal way to overcome this weakness and avoid two sets of equipment. Han et al. [2] proposed a HSTV and applied it in cooling of data centers.

The performance of HSTV depends greatly on the environment therefore analysis of its operating performance in different climate zones is necessary. Few studies in this field have been conducted. This paper builds up an energy consumption model of HSTV and analyzes its annual operating performance in different climate zones of China.

2. Performance model

Several HSTVs have been proposed in recent years. This paper chooses one of them as an example and focuses on evaluating the design rather than the certain equipment developed by researchers. The HSTV proposed by Han et al. is chosen as the prototype of performance model, as shown in Fig. 1 [2]. When the outdoor temperature is lower or the load is small, it works in the thermosyphon mode (a), otherwise in the vapor compression mode (b).

In this paper, it is assumed that the fan and compressor are variable-speed so that the energy consumption is minimum. For the thermosyphon mode, the cooling capacity and energy consumption are calculated in a simplified method [3]. For the vapor compression mode, a simulation model is built to calculate the performances under different operating conditions. To investigate the energy-saving effect, the performance of traditional air conditioner (TAC) is also calculated for comparison and the same model with the vapor compression mode is used.

The input power of the HSTV and TAC changing with outdoor temperature is shown in Fig. 2. The cooling capacity is set to 5kW and the indoor temperature is set to 27 ^{o}C. The temperature for mode switching is set to 12 ^{o}C and 17^{o}C in 2 (a) and 2 (b), respectively.

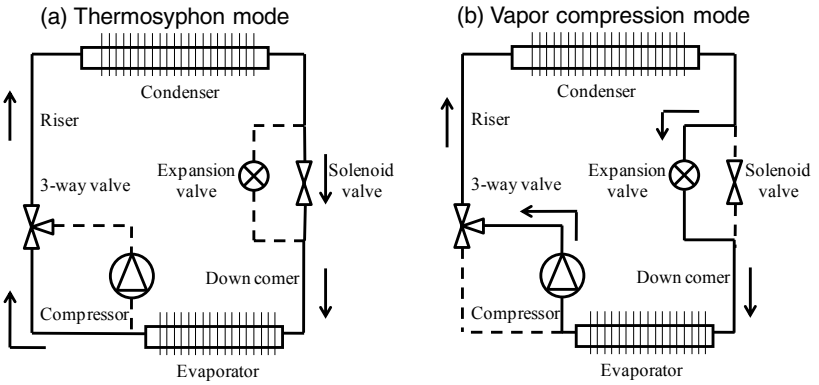

Fig. 1 The scheme proposed by Han et al. [2]

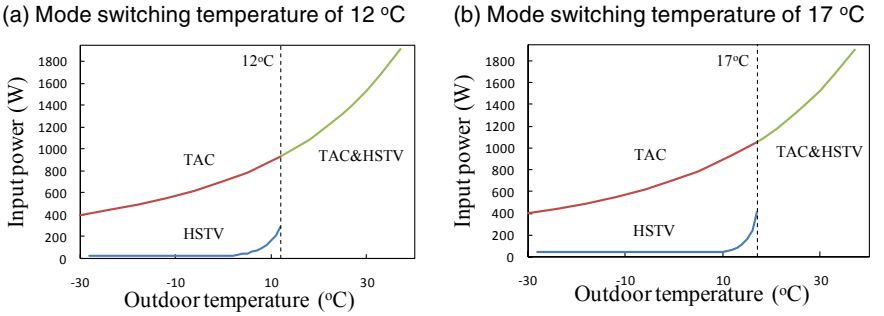

Fig. 2 The performance of the hybrid system and traditional air conditioner

3. Analysis of the annual performance

The hourly temperature data is obtained from weather monitoring stations across China from 1971 to 2003 [4]. These weather monitoring stations are located in five main cities of China: Harbin, Beijing, Shanghai, Chengdu and Guangzhou. Table 1 gives a summary of the locations of weather monitoring stations considered.

In this paper, we focus on the energy consumption of the cooling system for a single rack in data centers, therefore the cooling load does not change with the outdoor temperature. The cooling load of the rack is set to 5kW and the indoor temperature is set to 27°C. The mode switching temperature is set to 12 °C and 17°C, respectively.Based on the energy consumption model and the climate data, the annual energy consumption (AEC) is calculated and compared in Table 1.It can be seen that the energy-saving effect is greater in cold zones and seasons, and itis notable in most cities of China except Guangzhou when the mode switching temperature is 12 °C. When the cooling capacity of the thermosyphon mode is improved and the mode switching temperature increases to17°C, the energy saving rate increases due to the longer running time of the thermosyphon mode. The energy-saving effect will be distinct even in Guangzhou when the mode switching temperature is 17 °C. However, improving the cooling capacity of the thermosyphon mode is limited by the equipment size therefore optimized design considering both equipment size and energy saving rate is needed.

The annual performance of HSTV and TAC in Harbin with the mode switching temperature of 12°C is shown in Fig. 3.The hourly energy consumption changes with the outdoor temperature and is significantly reduced in colder seasons.

Table 1. Summary of weather and annual energy consumption in five typical cities in China

Station number	City	Latitude	Longitude	Time with T_{out} below 12 °C/17 °C (h)	AEC of TAC (kWh)	AEC of HSTV(kWh) (12°C/17°C)	Energy saving rate (12°C/17°C)
1	Harbin	45.75N	126.77E	5294/6409	7394	4267/3299	42.3%/55.4%
2	Beijing	39.80N	116.47E	4048/5210	8799	6046/4976	31.3%/43.4%
3	Shanghai	31.40N	121.45E	2932/4234	9545	7424/6185	22.2%/35.2%
4	Chengdu	30.67N	104.02E	2754/4249	9439	7429/6007	21.3%/36.4%
5	Guangzhou	23.17N	113.33E	772/2072	10924	10378/9186	5.0%/15.9%

4. Conclusion

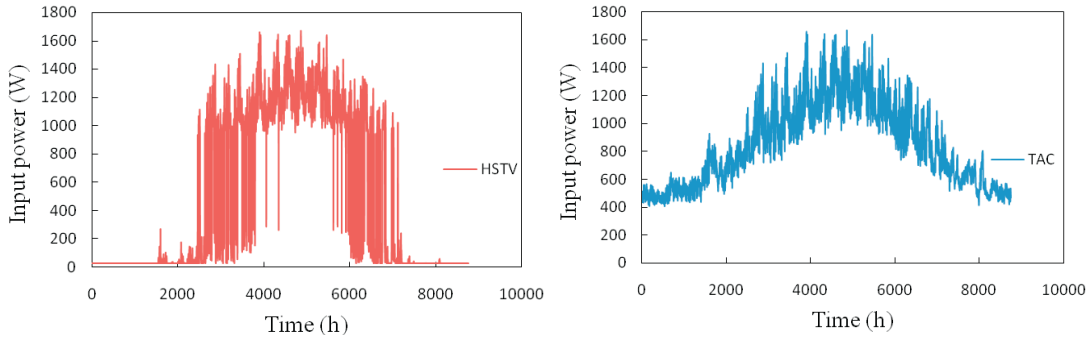

Fig. 3The annual energy consumption of HSTV and TAC in Harbin

The performance models of a hybrid system of thermosyphon free cooling and vapor compression refrigeration and a traditional air conditioner are built in this paper. Based on the climate data of five cities in China, the annual performances are calculated and compared. The result shows that the energy-saving effect of the hybrid system is notable in most cities of China except Guangzhou when the mode switching temperature is relatively low. By optimizing the control strategy for mode switching (improving mode switching temperature is the simplest method) or improving the performance of vapour compression mode and thermosyphon mode, the energy-saving effect will be distinct even in Guangzhou. Therefore, we speculate that in most zones in the world, hybrid system of thermosyphon free cooling and vapor compression refrigeration has a great potential in energy conservation of data centers.

Acknowledgements

The authors gratefully acknowledge the financial supports from National "Twelfth Five-Year" Plan for Science & Technology Support of China (2012BAA13B03) and the Joint Project of Foshan City and Chinese Academy of Sciences (No. 2012HY100082).

References

[1] Meijer GI. Cooling energy-hungry data centers. *Science* 2010; 328: 318-9.

[2] Han L, Shi W, Wang B, Zhang P, Li X. Development of an integrated air conditioner with thermosyphon and the application in mobile phone base station. *Int J Refrig* 2013; 36: 58-69.

[3] Zhuang J, Zhang H. *Heat pipe technology and engineering application*. Beijing: Chemical Industry Press; 2000 (in Chinese).

[4] Song FT, Zhu QF, Wu RH, Jiang Y, Xiong AY, Wang BM, et al. Meteorological data set for building thermal environment analysis of China. In: Proceedings of the 10th International Building Performance Simulation Association Conference and Exhibition, Beijing, China, pp. 9-16, 2007.

Biography

Changqing Tian was born in 1965. He received his Ph.D. in 2003 from Tsinghua University. He is now a professor of the Technical Institute of Physics and Chemistry, Chinese Academy of Sciences. Prof. Tian's research interests include heat pump, automotive air conditioning, refrigeration compressor and thermal management.