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Free cooling technologies for data centers: energy saving mechanism and applications

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Abstract

Air conditioning and cooling systems account for about 40 % of total electricity usage in data centers. Free cooling is a novel and promising technology that can decrease the load ratio of electrical chiller and save cooling energy consumption accordingly, through making full use of natural free cooling source. In this paper, four typical free cooling systems are analyzed and compared, to show their mechanisms, main features, energy saving effects and applicable situations respectively. (1) Direct fresh air cooling is of the highest free cooling potential. However, it is hard to meet indoor air quality demand due to the indoor-outdoor air mixing. (2) Rotating wheel heat exchanger can be used for indirect free cooling, since indoor and outdoor air flow in different paths for heat exchange. While its power usage effectiveness (PUE) increases inevitably under the same climatic conditions. (3) Heat pipe can be integrated with rack back plate to enhance heat transfer with free cooling sources. Its cooling efficiency can increase by 3-5 times compared to traditional heat exchangers. (4) In water-based free cooling system, a heat exchanger is installed in parallel with electrical chiller and the system can work under three modes according to different outdoor temperature. Increasing the load ratio of free cooling can decrease PUE and save electricity usage. In practical applications, the cooling system design for data centers depends on various factors, such as indoor air quality requirement, local climatic conditions, energy saving demands, room space, capital investment and operation costs.

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Keywords: Data center; Refrigeration; Air conditioning; Free cooling; Energy efficiency

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1. Introduction

During recent years, information communication and internet technologies are undergoing a dramatically fast development [1]. Thus the increasing demand for data processing caused a rapid growth in the data centers containing IT equipment, rack servers and related devices. It is reported that the total energy consumption in data centers doubled from 2005 to 2010 [2]. The IT devices are often of huge heat emissions and show high demands for temperature and humidity control in data centers, so that the cooling and air conditioning system is indispensable. According to a recent survey, the refrigeration and air conditioning system accounts for about 40 % of total electricity usage for data centers [3]. Therefore, in order to reduce the energy consumption of air conditioning is of great importance in energy efficiency for the whole data center.

There are many effective ways to save cooling energy usage in data centers, such as indoor air distribution optimization, heat transfer enhancement for rack servers, thermal performance improvement of chillers and so on [4]. Zimmermann [5] applied the hot water system to refrigeration system in IT rooms and established the energy model. Ebrahimi [6] introduced different cooling systems according to working conditions and found that energy efficiency could be increased substantially through low grade energy recovery. Marcinichen [7] proposed the two phase cooling technologies and put forward the method to evaluate heat recovery ratio. In addition, free cooling is a novel and promising technology that can decrease the load ratio of electrical chiller and save cooling energy consumption accordingly, through making full use of natural free cooling source [8]. Because of the high efficiency and low emissions, free cooling technologies utilized in data centers causes more and more attentions during recent years.

In this paper, four typical free cooling technologies and corresponding air conditioning systems are analyzed and compared, to show their mechanisms, main features, energy saving effects and applicable situations respectively. This work is of significance in guiding the design of refrigeration system with free cooling technologies for practical data centers.

2. Air Conditioning Systems in Data Center

IT devices always show high necessities in working conditions, especially the indoor temperature (22±2 ^{o}C) and humidity (50±5 %) control. Therefore, the air conditioning system is of great significance in space cooling for such data centers, considering the huge and consecutive heat emissions [9]. Fig. 1 shows the typical refrigeration system for data centers. The electrical chiller is used to produce low temperature water in its evaporator and then the chilled water is delivered to the terminal air handling units to take away the emission heat from racks. On the other hand, the condensation heat of the chiller is exhausted to the ambient through the cooling tower.

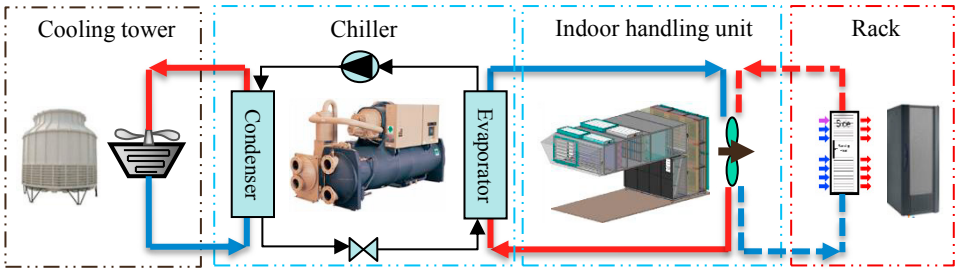

Fig. 1. Typical refrigeration system in data centers.

Such refrigeration system constitutes the dominant part of energy consumption in data centers, except for the IT devices themselves. Power usage effectiveness (PUE) is often used to evaluate the energy consumption level for data centers [4].

$$PUE = \frac{PU_{total}}{PU_{IT}} = \frac{PU_{IT} + PU_{AC} + PU_{else}}{PU_{IT}} \tag{1}$$