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Research Article

Modelling and performance prediction of an integrated central cooling plant for HVAC energy efficiency improvement

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Abstract

The aim of this paper is to explore methods to reduce the energy consumption of a central cooling plant. To achieve this, we have developed a new design for heating, ventilating and air conditioning (HVAC) efficiency improvement. A storage tank together with an immersed heat exchanger is installed in the discharge line between the compressor and condenser. The heat exchanger uses the make-up water of the cooling tower to reduce the refrigerant temperature entering the condenser. To investigate the potential of energy savings, we used a real-world commercial building with a central cooling plant, located in a hot and dry climate, for our case study. The energy consumption and relevant data of the existing central cooling plant were acquired over the course of a typical week in summer. The integrated system has been modeled and analyzed to achieve energy conservation. The performance of the proposed cooling system was simulated using a transient simulation software package. Comparison of the proposed system with existing cooling plant is included in this paper to demonstrate the advantages of our new configuration. Results show that up to 18% power saving can be obtained by using our design.

Keywords

central cooling plant,
design improvement,
energy saving,
modelling,
performance prediction

Article History

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Building Systems and Components

1 Introduction

Heating, ventilating and air conditioning (HVAC) systems consume significant amounts of electricity. The building sector represents 20%–40% of final energy consumption in developed countries (IEA 2008). As reported by U.S. Department of Energy (DoE), 31.2% of energy use by U.S. residential buildings is by HVAC equipment (DoE 2001). In addition, it has been accounted by DoE that energy use in the built environment will grow by 34% in the next 20 years at an average rate of 1.5% (DoE 2006). Therefore, finding novel ways to reduce energy consumption in buildings without compromising comfort and indoor air quality is an ongoing research challenge. In recent years, different control and optimization strategies have been used to improve the energy consumption rates of air conditioning systems (Beghi and Cecchinato 2011; Kusiak et al. 2011; Mossolly 2009; Lin and Yeh 2007; Huang et al. 2009); however, these approaches are either expensive or very complicated to implement and require constant monitoring. While optimizing the mechanical design of the traditional HVAC system results in extra upfront costs, these modifications can actually provide substantial savings in the long term by reducing ongoing maintenance costs associated with control and optimization strategies.

One proven way of achieving energy efficiency in HVAC systems is to design systems that use novel configurations of existing system components (Schoenfeld 2008). Recent research has demonstrated that a combination of existing air conditioning technologies can offer effective solutions for energy conservation and thermal comfort. A 6.5 kW prototype CO_2 heat pump unit was constructed and equipped with a counter-flow tripartite gas cooler in order to reject heat by cooling of CO_2 at supercritical pressure (Stene 2005). The gas cooler was also used for preheating of the domestic hot water. Their results showed that the integrated heat

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