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Performance analysis and improvement of air-to-water chiller for application in wide ambient temperature range

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Abstract

Some air-to-water chillers can work well in summer but meet problems in low temperature ambience. When the ambient temperature decreases into a certain level, the cooling capacity of the chiller drops rapidly or in severe situation the compressor stops running. In order to expand the applicable condition, performance variation of an air-to-water chiller in a wide range of ambient temperature is analyzed based on simulation, and a new type air-to-water chiller is presented, in which an auxiliary capillary tube is installed parallel to the thermostatic expansion valve (TEV) as well as variable number condenser fans are used. A suitable control strategy of the chiller is proposed, and the performance of the chiller across an assorted range of ambient temperature range is also predicted. The operation of the capillary tube and the cooling fans are found to be a function of the coolant temperatures and the unique chiller operation has been tested for a period of more than a year.

Keywords: Air-to-water chiller; Auxiliary parallel capillary tube; Variable condenser air flow; Control strategy

1. Introduction

An air-to-water chiller uses ambient temperature air to condense refrigerant and employs water to deliver its cooling capacity. The ambient temperature influences the performance of such chillers obviously. Some of the chillers operate under a narrow ambient temperature range, for example, the chillers for air-conditioning purpose. Normal running of chillers is ensured for most

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Nomenclature

T_{amb}	ambient temperature (°C)
$T_{out,c}$	outlet temperature of condenser (°C)
$T_{w,in,e}$	inlet chilled water temperature of evaporator (°C)
t_{fan}	least fan running time (s)

application rating conditions but off-design conditions may pose difficulty for smooth chiller operation. It is difficult to ensure chillers to operate in such a wide ambient temperature range. In the development and application of air-to-water chillers, we find that some chillers operate well in summer but the cooling capacity drops rapidly or even the compressor fails when the ambient temperature is low.

In order to develop a suitable operating strategy for wide working conditions, we should understand the characteristics of chillers operating under these conditions. In this paper, we present the types of faults that could be encountered and propose practical solutions. As experiments can be time consuming and costly, analysis on the theoretical chiller behaviours are checked using simulations.

There have been a lot of literatures on simulation of chillers [1–8]. We have conducted research in chiller simulation and developed suitable simulation software for different kinds of chillers, where the predictions are within ±10% of the experiments [9,10]. The chillers described in this paper are similar to the type modeled in Ref. [10]. The performance variation of such an air-to-water chiller is simulated. Based on the analyses, a new structure chiller and its control strategy is proposed. The performance of the new type chiller is discussed.

2. Characteristic analysis of air-to-water chiller under wide working condition

2.1. Description of the chiller and its simulation software

The structure, the mathematical model and the verification of the model of a heat pump are described in Ref. [10]. In this paper, the structure of the chiller is similar except that the four-way valve of the refrigerant circuit is not used. Thus, the verified model presented in Ref. [10] is suitable for the chiller described in this paper. Fig. 1 shows the schematic of the chiller. A thermostatic expansion valve (TEV) is used as the throttling apparatus, which would respond appropriately with the superheat of the evaporator.

2.2. Characteristic analysis of the chiller under variable ambient temperature and variable airflow rate through condenser

Many users of chillers believe that a decrease of the ambient temperature can lead to an improved performance of a chiller because the condensing pressure is reduced. Is such a notion