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Research on the control laws of the electronic expansion valve for an air source heat pump water heater

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ABSTRACT

Compared to the conventional air conditioner, the air source heat pump water heater (ASHPWH) possesses wider operating ranges and more dramatic changes in working conditions. Conversely, traditional throttle devices, such as the thermostatic expansion valve (TEV) and capillary tube, are restricted by narrow regulating ranges in refrigerant mass flow rate and lagging response to the superheat. This article incorporates a novel dual-fuzzy-controller to regulate the electronic expansion valve (EEV) specialized for the ASHPWH system. The study analyzes the effects of the EEV initial opening and the target superheat on the performance of the ASHPWH. Moreover, this research proposes a fuzzy control method of selecting the initial opening and the target superheat on the basis of the ambient temperature and water temperature, and employs superheat error (e) and the derivation of superheat error (ec) as the input variables of the fuzzy controller B to regulate the opening of the EEV during steady running process. To improve self-adaptability of the fuzzy controller, a rule modifier and a gain scheduler are introduced. In order to quantitatively reflect the difference in the performance between the TEV-controlled system and EEV-controlled one, experimental comparison between the EEV and the TEV is presented. Results demonstrate that both the stability and efficiency of the ASHPWH can be improved significantly by the EEV.

1. Introduction

Recently, the air source heat pump has found more and more applications due to its obvious advantages such as environmental protection, high efficiency and energy saving [1]. The air source heat pump water heater (ASHPWH) is a device that yields hot water by condensing heat. As the fourth generation of water heaters, the ASHPWH has shown strong market potential. The ASHPWH can be classified as the instant type and the circulate type. For the latter, the circulating water pump transfer condensing heat to the water tank. In this way, water temperature (T_w) in the tank rises gradually from the initial value to the terminal value (which is normally defined as 55–60 °C) [2].

The performance of the ASHPWH depends largely on the ambient temperature (T_a). For subtropical climate, the system refrigerant circulating mass flow of the air conditioner in winter is 20–40% less than that in summer [3]. But for the ASHPWH system, the varying range in the evaporating temperature is much larger since the unit always operates in heating mode. In addition, a wide varying range in the water temperature also leads to a wider varying range in the condensing temperature. If the evaporator load is assumed to be approximately proportional to the refrigerant circulating mass flow, the ASHPWH refrigerant mass flow in winter is less 25–73% than that in summer based on the experimental formulas proposed by Morrison et al. [4]. The analysis above demonstrates that the required refrigerant mass flow regulating range for the ASHPWH system is much wider than that of the air conditioning system, and working conditions of the ASHPWH system varied more intensely than that of the air conditioner.

In order to improve the adaptability of system to various working conditions, variable capacity control technology has been applied in air conditioners and heat pumps. This technology is mainly used in moving components of refrigeration systems, such as compressors and throttles.

Variable capacity compressor can improve system efficiency, extend the life of components and reduce the indoor temperature fluctuations, since it eliminates frequent stop–start cycles [5–7]. But for a complete heating process of the circulate type ASHPWH, water is gradually heated from the initial temperature to the target value. Thus, unlike the air conditioning system, there are no frequent start-stop cycles during the operation of ASHPWH even if a fixed-frequent compressor is used, since the water tank possesses

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