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Thermal characteristic research of associated power devices based on three-level inverters and power-loss calculation

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ABSTRACT

To reduce the size and improve the power density of three-level inverters, two or more associated power devices are assembled on the same heatsink, which, however, has a great influence on the thermal characteristics of heatsink because of heat accumulation, and is the main cause of thermal faults. The NPC (Neutral Point Clamped) three-level inverter was taken into this paper as a research target and platform. The dynamic power losses of two power devices were calculated firstly according to the working condition and then put into the solid model. Secondly, the thermal characteristics of heatsink with associated power devices on it were analyzed through finite element analysis, and the temperature rise of power devices were studied as well. Finally, the thermal characteristic experiment was conducted on a 1 MW NPC three-level inverter platform, and the results proved the effectiveness of the research method on thermal characteristics of heatsink with associated power devices.

1. Introduction

The power capacity of three-level inverters is becoming larger more and more. With the increases of power capacity and power density, the thermal stability of cooling system is required to be higher and higher. While, the heat accumulation generated by the associated power devices in one heatsink will bring in some possible thermal fault and its influence should be researched.

Firstly, as the premise to analyze the heatsink, the power-loss calculation of power devices in three-level inverters has been researched in recent years and got some achievements. The methods proposed in [1,2] are two kinds of conventional ones, which analyze the phase relationship between the output voltage and load current, and study the working condition of power devices to build the power device model to fit and calculate the power losses of power devices. The difference between these two methods is in power device models, which will affect the accuracy of calculation results. Several power-loss calculation principles of multi-level inverters were compared and analyzed in [3–6]. The power losses of NPC three-level inverter were obtained under SPWM (Sinusoidal Pulse Width Modulation) and SVPWM (Space Vector Pulse Width Modulation), but the neglect of the influence caused by the junction temperature of power devices on the power loss is their common disadvantages. The power-loss generation principle of IGBT module was illustrated in [7], and the mathematical model was built as well to calculate the power losses of NPC and ANPC (Active NPC) high-power three-level inverters based on SVPWM and analyze the junction temperature simulation. These methods above do not put power-loss calculation and thermal analysis of cooling system together to study the thermal characteristics.

Secondly, some researches on the design of forced-air cooling system in inverters have been made at present. Axial flow draft fan is a common style of cooling fans, which can be overhead type or knapsack according to the installation position. The both installation positions have their advantages in saving space. The overhead type is the research target of this paper, and the structure is

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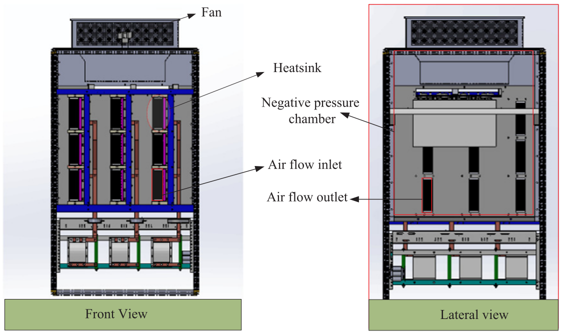
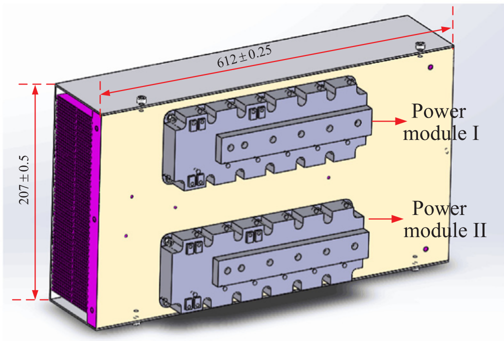
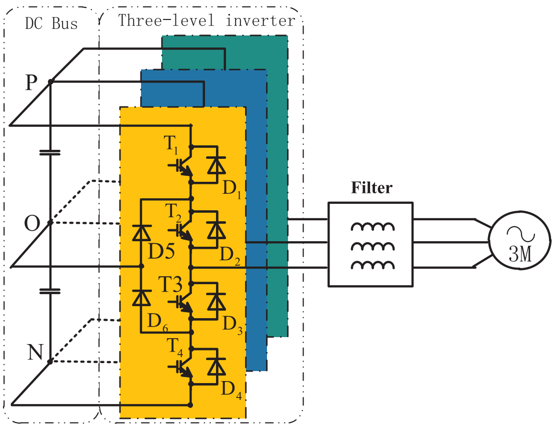


(a) Forced-air cooling system structure



(b) power modules on heatsink



(c) NPC three-level inverter circuit

Fig. 1. Cooling system, installation structure of heatsink and inverter circuit. (a) Forced-air cooling system structure. (b) power modules on heatsink. (c) NPC three-level inverter circuit.

shown in Fig. 1(a). The power module I and II in Fig. 1(b) are assembled together and composed of the associated power devices. The total number of power devices in one three-level inverter is can be figured out from Fig. 1(c). The power devices have different thermal characteristics in single state and associated state, and it is necessary to study it under two states. Some research has been obtained already. [8,9] indicates that the empirical formulas and analysis model has been an alternative method to describe different models accurately. What's more, the authors discussed the theoretical power limit of inverter system using water cooling, on which base the heatsink was optimized. A forced convection of fin type heatsink with average heat transfer efficiency was stated in [10]. A cooling fin type array with forced-air convection was introduced in [11]. [12] provided a practical guidelines for selecting heatsinks, and some recommends on design and development process were provided as well. In [13], the authors summarized the by-pass flow characteristic of the aluminum alloy heatsink, and put forward their own design model to calculate the by-pass flow path. These researches on heatsink are mature and comprehensive, but lack of the research of heatsink based on the power-loss calculation of the