Thermal Design of Photovoltaic Power Generation Inverter

Jian-Ping Wen

***Abstract*—Photovoltaic power generation inverter is key facility of photovoltaic power generation system. Its thermal characteristics effect the reliability of system directly. On the basis of PSIM, the power dissipation and temperature calculation models are established. Thermal analysis of DC/DC and DC/AC that is two main heat sources in 10kW photovoltaic power generation inverter are be carried out. Under full load, the thermal characteristics of inverter are assessed to optimize the design of heat sink. Finally, the temperature of prototype is tested. The results demonstrate the validity of the method.**

***Index Terms*—photovoltaic power generation, thermal design, inverter, PSIM**

I. INTRODUCTION

In recent years, as energy consumption soar and the threat of climate change, people pay more and more attention to the problem of energy and environment. Power generation making use of the clean energy, solar energy, has aroused more and more attention gradually in many countries around the world because of its advantages of sustainability and cleanliness. Development of Photovoltaic power technology is flourishing. The key part of photovoltaic power generation system is photovoltaic power generation inverter, which transforms the direct current to transform. There are many technical requirements about the solar energy inverter [1]. The thermal design of inverter influences the long service life and reliability of the generating electricity system.

The heat sources in inverter circuit include the DC/DC and DC/AC modules, which generates the amounts of heat at work. On the basis of PSIM, the thermal calculation models with heat sources are designed. The models are applied to calculate and analyze the temperature variation of the modules, the results of which are used to optimize the heat sink's flow and heat transfer performance. The temperature of inverter is calculated, the calculating results of the models is compared to the temperature measurement of prototype inverter. The experiment results verify the validity of the model.

II. INVERTER TOPOLOGY

photovoltaic power generation system consists of charging section and inverting section [2], including photovoltaic array, charging controller, discharging controller, storage battery, and photovoltaic power generation inverter, which is shown in Fig. 1.

When the photovoltaic power generation system is directed to connect the grid, the storage battery, charging controller, and discharging controller can be neglected, which simplifies the system.

In general, low voltage DC power is converted to high frequency AC power by high frequency chopping. Then the high voltage AC is obtained by using high frequency transformer boosting the low voltage AC power and is rectified to high voltage DC power. So, via the photovoltaic power generation inverter, the DC power of photovoltaic array is transformed into sinusoidal AC power, usually 50 hertz. In order to improve the conversion efficiency, some new topologies are proposed [3]. This paper adopts the DC/DC BOOST chopper circuit, which can pump up the low voltage DC power to high voltage DC power. Then, by applying the DC/AC inverting circuit, the sinusoidal AC power is be output. This topology type can save high frequency transformer and improve the efficiency. The frame is shown in Fig. 2.

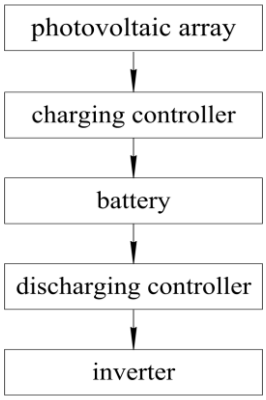

Fig.1 The block diagram of Photovoltaic power generation system

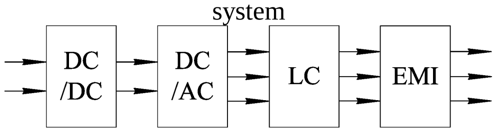

Fig.2 the main circuit of photovoltaic inverter

III. HEAT DISSIPATION MODEL OF INVERTER

A. Power dissipation model of the main circuit

In the main circuit, the DC/DC BOOST circuit and DC/AC three phase inverter are the main power dissipation sources.

The DC/DC circuit uses high power IGBT to constitute the boost chopping circuit, IGBT is voltage-controlled power switch, which synthesizes the merits of MOSFET and bipolar transistor with high pressure resistance, simple driving circuit, low turning on and off dissipation, wide security area, and high-speed switching. The power module in the BOOST circuit is powered by CM100DY-24A IGBT. The voltage and current of this type are 1200V and 100A, respectively. The maximum service temperature is 150ºC.

The DC/AC three phase inverter circuit adopts the modulation strategy of SPWM the frequency of the carrier wave is chosen as 10k. The power module in the inverter

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circuit is powered by PM75RLA120 IPM. The voltage and current of this type are 1200V and 75A, respectively. The maximum service temperature is 150ºC. The IPM is an integrated part of low power dissipation IGBT and driving circuits, which has overvoltage protection circuit, overcurrent protection circuit, and protective circuits for IGBT overheat check.

The SPWM is used to control power tube on or off. In the running process of the DC/DC and DC/AC circuit, the duty ratio is about change, it is difficult to calculate the power dissipations. On the basis of the PSIM, the power losses calculation model is established, which is shown in Fig. 3.

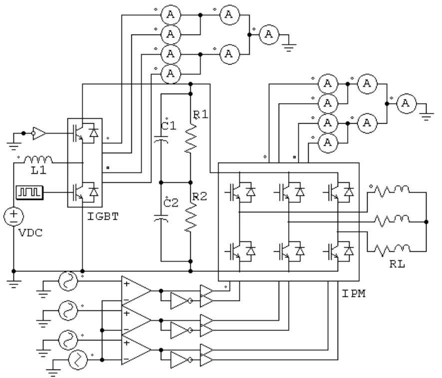

Fig.3 power losses calculation model under full load

B. Heat sink temperature computation model

In the process of the heat's propagation the thermal resistance exists at the border of the heat sink [4], which can be expressed as [5]

$$R_{th} = \frac{\text{temperature difference}}{\text{total losses}} \qquad (1)$$

Based on the power dissipations, the thermal resistances of the DC/DC and DC/AC heat sinks can be obtained. The heat sink temperature calculation model is established as Fig. 4

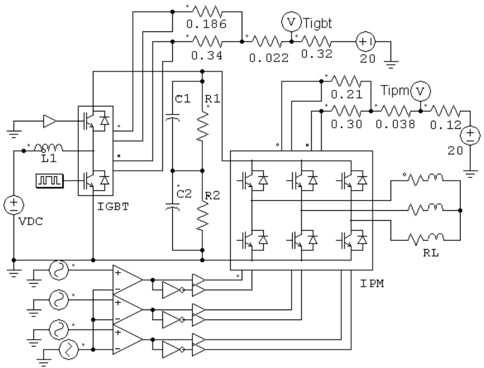

Fig.4 heat sink temperature computation model

IV. RESULT AND DISCUSSION

The experiments are made under full load, the ambient temperature is 20°C. The power dissipations of the two power modules as follows.

In the DC/DC circuit, the conduction losses and switching losses of the anti-parallel diodes are 24.06 W and 16.16 W, respectively. The conduction losses and switching losses of the transistors are 46.40 W and 68.21 W, respectively. The total losses of the IGBT is 108.43 W.

In the DC/AC circuit, the conduction losses and switching losses of the anti-parallel diodes are 9.71W and 68.89W, respectively. The conduction losses and switching losses of the transistors are 34.0 W and 192.69 W, respectively. The total losses of the IPM is 305.29 W.

The temperature difference between heat sink temperature and air temperature is set as 35°C, the thermal resistance of the heat sink for the IGBT as follows

$$R_{thIGBT} = \frac{35}{108.43} = 0.32°C/W.$$

The thermal resistance of the heat sink for the IPM is follow as

$$R_{thIGBT} = \frac{35}{305.29} = 0.12°C/W.$$

According to the models, the heat sink temperature in the DC/DC circuit is 54.3°C. the junction temperature of IGBT is 69°C. The heat sink temperature of the inverter circuit is 59.3°C. the junction temperature of IPM is 124°C. The results show that temperatures of IGBT and IPM are the allowable range.

The prototype is tested under the 20°C ambient temperature. When the heat sink temperatures stabilize, the heat sink temperatures of the main circuit is 52.9°C and 58.3°C, respectively. The actual temperature differences are 32.9°C and 38.3°C, respectively.

Comparison results demonstrate the validity of the models, which provides an effective method for optimal design of the heat sink.

V. CONCLUSION

Power modules are the main heat sources of the photovoltaic power generation inverter. Besides choosing the electrical parameters, the power dissipations of power modules need to be calculated to improve power modules' heat dispelling. This paper establishes the power dissipation model and temperature calculation model on the basis of PSIM. The experiment results show that the models are reasonable.

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