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A DC Converter Based on the Modular Redundancy Design

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Abstract: A high reliability DC converter what can transform DC high voltage power supply into DC low voltage power supply was introduced in this paper. Its technical parameters, functional requirementsmodular structure designmodule connection mode and the Reliability realization method are illustrated for the DC converter, focusing on. The circuitous philosophy of the switching power supply module and its load sharing, charging management were emphasized. The reliability redundancy design of the DC converter and its corresponding protection was summarized in this paper.

Key words: High reliability, DC converter, modular structure, load sharing

INTRODUCTION

Some electrical equipments and control systems with high security and reliability requirements, use high reliability DC low-voltage power supply and generally are in parallel with the load on the battery to ensure that in case of a system failure or power off, the power can provide electrical energy of a certain time for the control system or other safety system (Song, 2006). Therefore, it is particularly critical that how to convert the DC high-voltage power to a low-voltage DC power, and charge and manage the battery (Wei and Zhou, 2010). This paper describes a high reliability DC converter. The converter can convert 3-way isolation DC high voltage into a 24 V low-voltage DC power supply which can charge to the 24 V battery connected to the converter output, and also charge to the power consumptions equipment in parallel with the battery which are connected with security requirements (such as a 24 V battery fan) and the control equipments which require a higher reliability for its power supply (such as operation and control system).

Main technical parameters and functional requirements of the DC converter: The main technical parameters of the DC converter are shown in Table 1.

The DC converter changes 3-way 380 V DC power grid potential isolated into the 24 V DC power supply isolated and ungrounded and monitors the asymmetric insulation fault of the 24 V power supply and supplies power for the 24 V battery fan and monitors its working condition and monitors the working condition of the DC converter and protects for over current or overvoltage.

Table 1: The main technical parameters of the DC converter

Parameters	Values
Input Voltage (V)	DC 380 (300 400)
Input under-voltage protection value (V)	280
Input over-voltage protection value (V)	420
Starting surge current (A)	120
Output voltage (V)	DC 24 (27~29)
Ripple factor (%)	<2
Maximum output current (A)	100
Rated power (kW)	1.8
Efficiency (%)	>90
Switching frequency (kHz)	≥100

Modular structure of the DC converter: The DC converter takes slot type modular structure to be convenient in repairing and maintenance (Wei and Qi, 2011). The converter is made of nine switch power modules and a back veneer of protection function; the back veneer has the protection function of asymmetric insulation fault monitoring, and switching power supply module working condition monitoring; the output wire takes copper bar which is exported to the output interface connector by the cord (Wei *et al*., 2012).

The block diagram for DC converter functions is shown in Fig. 1. Every 380 V power grid feeds to three switch power supply modules which is connected to the high voltage fuse in the input terminal to ensure that the damage of a single switch power supply module does not affect the normal work of the 380 V power grid. The output of the nine switching power supply module is in parallel to supply for 24 V battery and other load power. In normal work case, three switch power supply modules can satisfy the system power supply and the control system supplied by three isolated 380 V power grid and nine switch power module, greatly improves the reliability of power supply. Even if two of the 380 V power grid break down or power off, the control system can work

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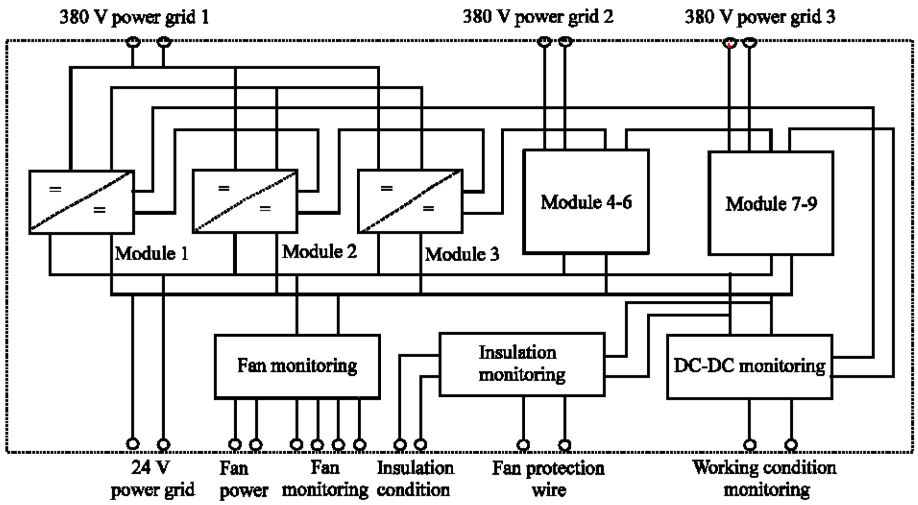

Fig. 1: Diagram for the relationship of the DC converter switching power supply modules

normally and make protection control timely; The DC converter separately provides 24 V power supply to 24 V battery fan and limits the maximum current of the fan, so, when the fan is fault, it can also cut off the fan load in order to protect the 24 V power grid to supply the power normally. The converter can determine fan's working condition according to the fan feedback signal and feedback to grid diagnosis system; The converter detects the working condition of the nine switching power supply module. The detection signal is connected in series. When any one of the switching power supply module output is not normal, the fault signal will be issued to the diagnosis system by the converter working condition detection circuit which suggests the fault existed in some switching power supply module of the converter (Wei *et al*., 2011). At the same time, the symmetrical insulation condition to the ground of the 24 V power grid can be detect and upload by each DC converter to ensure 24 V power grid load on the safety to human body.

Switching power supply module: The switching power supply module is the core components of DC converter. The total output power of nine switching power supply module is 1.8 kW and the rated output power of a single switch power supply module is 200 W. The input terminal of the module takes two stage LC filters to eliminate the conducted interference on 380 V power grid and uses the strike circuit to restrain the maximum input impact current of the module when it is power supplied. The main circuit of the module is realized by half bridge topology. In this way, the switch tube which voltage stress is the single times input voltage, can use 500 V mosfets (Wei and Hao, 2011) and the driving circuit that takes the transformer isolation drive way to insulate the drive signal is simple (Wei and Jun, 2012). The loop control mode used voltage loop control is simple and efficient (Wei and Ma, 2012). The switch frequency is a constant for 100 kHz, using optical coupling isolation feedback; The output end uses decoupling diode to ensure that the failure of a single switch power supply module can not affect the normal work of the 24 V power grid. The working condition detection of switching power supply module is to detect output voltage in the positive pole of the decoupling diode and the output voltage module in the normal range shows that the module working properly. At the same time, switching power supply module has the protection function of input and output voltage overvoltage. The overall module block diagram as shown in Fig. 2.

Equalizing current control and charging management: When more than one module output is in parallel to supply power for the load, it's best to share the load current for all parallel module and is not the case that some module output larger current, or some modules output smaller current, even the extreme situation that some module output maximum current, or some module output no current. Load sharing can lead to the thermal equilibrium in the box and can equalize the loss in whole module (Lin *et al*., 2009) and can avoid that the load imbalance leads to the electrical stress of some module device so as to increase the damage probability (Bo and Zhang, 2009). The switching power supply module equalizing current control and charging management control circuit diagram as shown in Fig. 3.

The switching power supply module outputs current through the mΩ resistance detection module and then

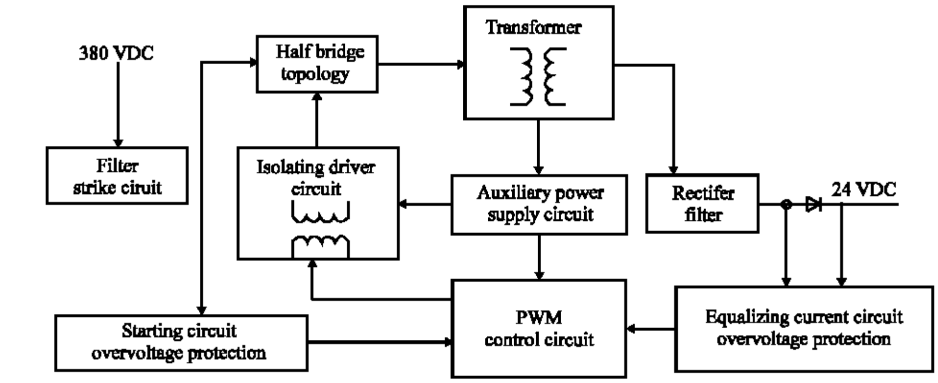

Fig. 2: Block Diagram for the switching power supply module function

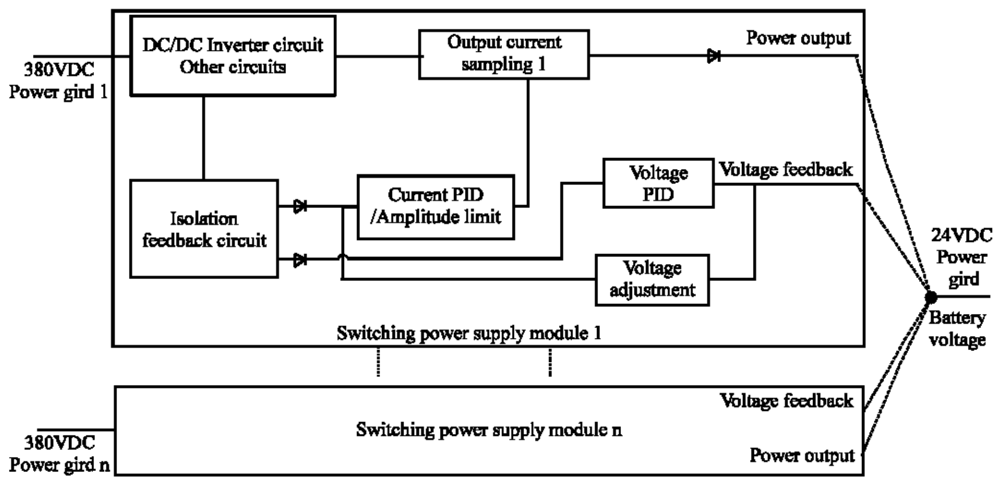

Fig. 3: Diagram for the equalizing current charging circuit

sets a maximum output current value through the op-amp to ensure that the module will not output over-current. The maximum output current of each module is 11A and the output current restriction of a single module also determines the total output current of the DC converter. The switching power supply module takes the decoupling diode cathode as its output voltage test point, that is to test battery voltage. In the wiring of PCB layout, all modules set a voltage telemetry end in order to remove the influence of wire pressure drop and then connect to the point of common coupling of the parallel module through the backplane, and have this point as the battery voltage test point to ensure that the voltage passed on to the point by each module output is the same. At the same time, the output current signal of the switching power supply module affects battery voltage feedback signal inverse ratio, i.e., if the output current increases, the output voltage expected value of module will be adjusted small and vice versa.

The output current of the battery and the voltage of the switching power supply module determine the three work mode of converter. Three kinds of mode which are constant current charging, equalizing current charging and constant voltage floating charging, as shown in Fig. 4. When the battery voltage is too low to reach the minimum adjusting voltage V_{min} of module internal, the converter goes into constant current charging work mode. Until the module output current signal takes part in the duty ratio adjustment of module switch tube, and the battery voltage feedback signal is shielded by current signal, all module output the largest setting current constantly to supply power for the battery and the other load, and the battery voltage rises. When the battery voltage rises to the minimum adjusting voltage V_{min}, the converter goes into equalizing current charging work mode. At this point, the battery voltage feedback signal starts to participate in the duty ratio adjustment of module switch tube and the module output current signal participates in the duty ratio adjustment of module switch

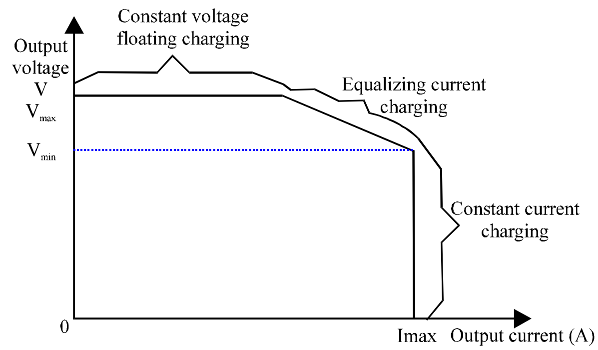

Fig. 4: Diagram for the output curve of switching power supply module

tube through fine adjusting the battery voltage feedback signal and the battery voltage rises, the module output current drops. When the battery voltage rises to the highest adjusting voltage V_{max} set in module, the converter goes into constant voltage floating charging work mode. At this point, the output current signal of the module exits loop adjustment, the duty ratio of module switch tube depends on the battery voltage feedback signal absolutely and the battery voltage keep constant, the battery charging current decreases gradually and the module specific output current value is determined by the other load.

CONCLUSION

The loads on 24 V power grid are all the key control equipment of the control system, so they have higher requirements for the reliability of DC converter. The DC converter considers the possibility of reliability design for structure and protection function and other aspects to improve its reliability. One is to make full use of the redundant system, for example , there are 3-way 380 V power input, 9 switch power supply modules output in parallel to form a 24 V power grid. The second is the protection function of the system. The 24 V power grid parallels with battery and battery fan with protection function and the switching power supply module is equipped with charging management control and equalizing current charging control and the module output end is cascaded with a decoupling diode and it has working condition monitoring and protection functions. These measures greatly improve the reliability of DC converter.

This kind of DC converter can be applied to all kinds of control ystems requiring for high reliability to ensure the safe power supply of control system and has a high application value.

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