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Design Issues of Redundant Protection and Supervision System for the Special Purpose Power Converters

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Abstract. This paper addresses problems related to the design and implementation of a fault detection and protection system for high-voltage (HV) NPT IGBT-based converters. An isolated half-bridge power converter topology is investigated, which seems to be very attractive for the high-power electronic converters due to its overall simplicity, small component count and low realization costs. This converter is to be applied in rolling stock with its demanding reliability and safety requirements. Clearly, the robust control and protection system is essential.

Keywords

Protection and supervision system, high-voltage IGBT, DC/DC converter, fault detection, reliability, safety

1. Introduction

The IGBT transistors with the blocking voltages of 4.5 kV and 6.5 kV are becoming increasingly popular in the medium- to high-power applications, especially in railway transport. These transistors open up a whole new prospective area in power electronics, aimed at more simple and, consequently, reliable power circuit topologies to be implemented. For instance, in the present paper the half-bridge DC/DC topology will be examined as a candidate topology for an auxiliary power supply (APS) to be used in 3.0 kV DC commuter trains. The APS is responsible for the conversion of high DC voltage from the catenary (3.0 kV) to some intermediate DC voltage level (350 V) to supply secondary systems of a rail vehicle, such as lighting, braking, passenger announcement system, etc. The half-bridge DC/DC topology was implemented because of its simple construction and high overall reliability. With the new state-of-the-art high-voltage NPT IGBTs (Eupec/Infineon 200 A/6.5 kV FZ200R65KF1 IGBT modules with integrated freewheeling diode) the APS could be realized just by using only two switches (Fig. 1). The output DC voltage of the converter was selected upon the end-user aspirations, as a rule, being 300...350 V DC. It is obvious that a failure within this system would render the whole vehicle non-operational, resulting in a financial loss, operational problems to the commuter train system and discomfort to passengers. The fault detection and protection system developed (Fig. 2) should minimize the risk of serious failures.

Conditions on railways and railway applications are rugged: widely changing operating voltages, temperatures, vibration, electromagnetic interference, etc. In this highly unfriendly environment a variety of failures can occur. To guarantee smooth and proper operation of electrical devices, an effective failure detection and protection system is needed.

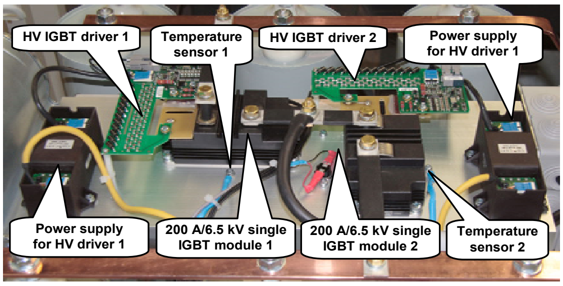

Fig. 1. Hardware side of the half-bridge high-voltage IGBT-based inverter.

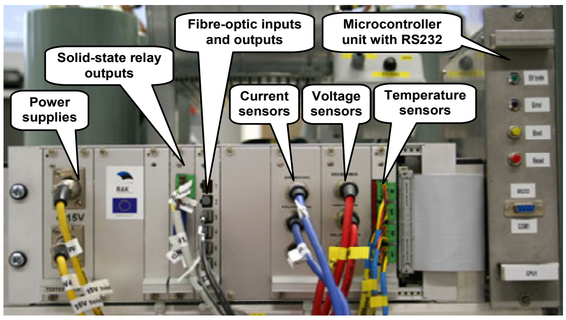

Fig. 2. Control, fault detection and protection system developed for the rolling stock auxiliary power supply.

2. Protection System

In principle, the control and protection system is divided into two parts: hardware and software. The software part includes the control algorithm with PWM generation and all the protection algorithms. The hardware part consists of some additional protections, like cross conduction protection and dead time generation, fiber optical links to separate power part from the control part. In general, hardware serves as a second level protection against software errors. All software errors and some of the hardware errors will be saved in the error log and also displayed on the screen of the user personal computer (PC). The APS has a built-in user interface to connect the user PC with the power supply.

3. Fault Detection and Actions

In general, any failure or inadmissible operating conditions always create a warning and/or alarm message, which will be displayed in the user PC. The APS is provided with various sensors: three voltage and two current transducers, four temperature sensors. Errors are divided into two groups. The faults in the first group terminate the control program. For recovery, manual reset of the controller is needed. The second group errors do not terminate the program and automatic recovery is possible after the error has been eliminated. The output (load) current is measured to determine the overload situation. In the case of overload the system will be switched off and manual reset is required for recovery. The temperature is constantly observed in the primary transistors, output rectifier and isolation transformer. An overheated system will be automatically switched off and also needs manual reset. The input and output voltage is sensed to discover over- or under-voltages. In the case of over- or under- voltage in the input, the system will be switched off and automatically restored after the voltage has returned in the nominal area. Similarly, the output voltage is regulated but once the output is switched off, no automatic recovery is possible. One serious problem can be the saturation of the transformer core. Therefore, the middle point voltage is constantly observed. The middle point voltage shift greater than 5 % results in an immediate blocking of IGBTs. The recovery is only possible after manual reset of the control system.

4. Fault Observation and Logger Systems

Although the APS is able to operate completely autonomously, it still has a built-in user interface, which can be connected to a PC. Data exchange between the PC and the test bench is realized via serial communication interface (RS232). With the standard Windows communication program HyperTerminal, the entire information from the APS can be observed and also changed to some degree. The user interface will be displayed in the HyperTerminal window. It is based on a menu system. The sub menus can be entered just by pushing the corresponding number on the keyboard. There are seven choices in the menu (Fig. 3): current sensors, voltage sensors, temperature, error code, manual pulse width adjustment, regulator parameters adjustment, and a logger. The current, voltage and temperature sub-menus display the sensor values. Error code gives information about the faults that may occur. The fifth menu allows manual change of the pulse width of IGBTs. PI regulator was used in the current project. To make regulator adjustment easier, the parameters (the proportional and integral gains) can be changed via the user interface. In the latter, sub-menu logger can be started. The logger stores readouts of all sensors in 5-minute intervals.

Recording of electrical and physical parameters during test-operation allows the analysis of faults and malfunctioning modes of converter operation. For that purpose the data logger function was developed. Data is recorded to the PC hard disk in the tabular form. Suitable output interval can be set for data output. All the variables that are viewable in the diagnostic menu can also be recorded on the hard disk. The recorded values can be viewed and processed in spreadsheet programs, such as Microsoft Excel, Calc, etc. Spreadsheet software allows values to be converted to a suitable form and printed out as tables or charts.

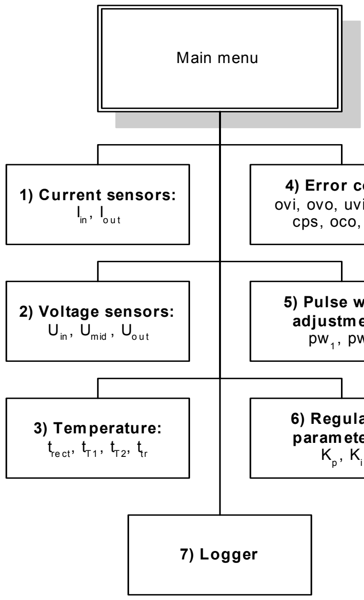

Fig. 3. Organization chart of the developed user interface.

5. Conclusions

A half-bridge DC/DC converter seems to be very attractive topology for power electronic converters due to its overall simplicity and low realization costs. However, there are many technical details to be considered during the development routine, especially in the case of high voltage applications. A half-bridge HV inverter must be developed with supreme accuracy and can be characterized by a high level of redundancy, especially in the hardware control and protection circuits. The keyword here is a multilevel protection system. The most vital protections in the HV converter should be doubled.

The performance of such HV IGBT inverters can be increased substantially by using modern HVI drivers. As explained in the full paper, modern HVI drivers incorporate various built-in protection and diagnosis functions. Using these functions will increase the reliability of the control system and reduce the load of the main control unit.

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