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Open-Transistor Fault Detection and Diagnosis Based on Current Trajectory in a Two-level Voltage Source Inverter

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Abstract

Even though technological developments in the area of control of voltage source inverter (VSI) have reached a relatively matured state, advances in improving the reliability of VSI is still a developing area. In order to improve safety as well as reliable operation, an effective fault detection and diagnosis method has to be integrated along with the control of inverter-fed systems. In this paper, implementation of open-transistor fault detection and diagnosis in VSI is presented. The current trajectory of phase currents is employed to detect the fault condition and identify the faulty switch. Implementation of this method in a three-phase two-level VSI with the aid of data acquisition card and LabVIEW software is presented with the experimental result.

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Keywords: Current trajectory; Fault detection; Fault diagnosis; Open-transistor fault, Voltage source inverter.

1. Introduction

Voltage source inverters (VSI) found a wide range of applications in variable speed drives (VSD), reactive power compensation, high-voltage direct-current transmission (HVDC), railway traction, renewable energy integration, to name a few. In all these applications, the inverter serves as the key constituent; therefore, reliability and availability of the inverter plays an important role in the consistency of the overall application. A fault in an inverter actuates the

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protection systems such as fuses, relays and circuit breakers, resulting in the immediate shutdown of the operated process, which leads to a loss in terms of human resources and wastage of raw materials. In this scenario, incorporation of a fault detection and diagnosis (FDD) method ensures the monitoring, protection, safety, reliability and reduced maintenance cost and time [1]. It is reported that power semiconductor faults contribute about 38% of the faults in inverter-fed drives [2]. As the power semiconductor switches such as IGBTs, MOSFETs are the basic building blocks of inverter; any malfunctioning affects the normal operation of the inverter. Often modulation of inverter concentrates on delivering the required speed or torque demand of the load. In order to ensure isolation of fault, avoid fault propagation and restoration of the highest degree of normal operation, an effective FDD method has to be incorporated along with the control scheme [3].

Fault detection and diagnosis in VSI found its significance towards the beginning of the nineties. Many FDD methods over the years have investigated fault detection of 3-phase VSI using current trajectory tracking. In the current trajectory tracking method, Concordia transform was first applied to the three-phase currents and then the trajectories tracked by the transformed currents were plotted. For fault-free condition, the transformed currents tracked a perfect circle. For each fault, the transformed currents track a different trajectory that was used for fault diagnosis. The use of transformed currents for trajectory tracking required a better controller or processor that adds to the cost and complexity of the system. This method was found to be especially true in the cases where FDD of VSI was implemented to an existing system without changing the original firmware [4-7]. A few methods based on artificial intelligence based methods have also been introduced for the open-transistor fault detection and diagnosis. These methods utilized the fuzzy logic controller, neural network and clustering Adaptive Neural Fuzzy Inference System (C-ANFIS) for fault detection and diagnosis [9-11].

Even though a number of techniques have been introduced in the area of fault detection and diagnosis based on current trajectory, with the advances in the area of digital controllers, software tools and artificial intelligence techniques, research in this area is in continuous development. In this paper, implementation of open-transistor fault detection in a three-phase two-level VSI with the aid of data acquisition card (DAQ) and LabVIEW software is presented. This paper is organized as follows. Section 1 gives the introduction and the existing literature background and Section 2 deals with the various aspects of faults in inverters-fed systems. In Section 3, the detection and diagnosis method based on current trajectory is detailed, followed by the implementation of the fault detection and diagnosis method with the results in Section 4 and 5, respectively. Finally, conclusions are given in Section 6.

2. Fault in inverter-fed systems

Many industrial applications are employing variable speed drive (VSD) and a typical block diagram of VSD is shown in Fig. 1 (a). The major components of drive systems are electrical machine, sensors, control logic and power circuit. Majority of the applications use induction motors to drive the load. The sensors are for measuring the mechanical and electrical quantities for the purpose of monitoring, protection and control. Control logic achieves the desired load requirement based on the control input and sensed parameters. The control action is established through the power circuit by controlling the power input to the electrical machine. The power circuit consists of rectifier, DC-link and inverter. All these components of the drive systems are vulnerable to fault [12].

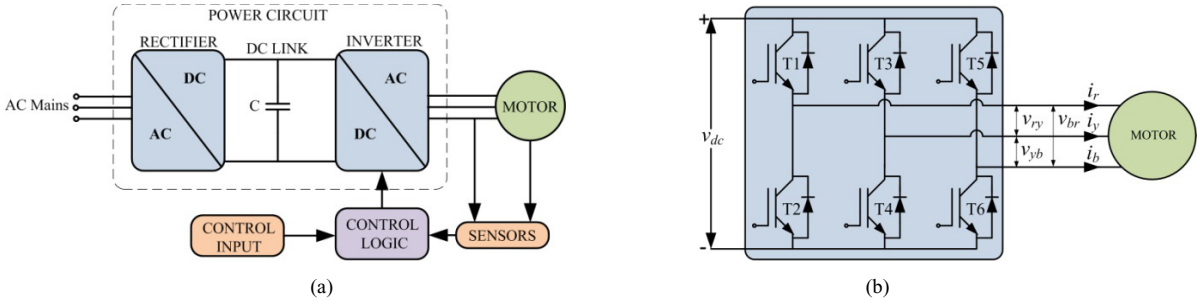

Fig. 1. (a) Block diagram of VSD; (b) Power circuit of V three-phase two-level VSI.