Fault Diagnosis Method for Joint Motor Inverter Power Tube of Live Working Robot

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Abstract. The joint motor of live working robot adopts brushless DC motor system. Because of the interference of unstable factors in working environment and the vulnerability of power electronic devices, inverter power tube is the most vulnerable link in the system. Based on the model of brushless dc motor system and simulation analysis of the open circuit fault mode of inverter power tube, this paper summarizes the distortion characteristics of the three-phase current waveform of inverter power tube output. An open circuit fault diagnosis method for inverter power tube based on the variation of three-phase current waveform is presented, and the correctness and feasibility of the method are verified.

1 Introduction

With the advantages of high safety factor, less time-consuming and high efficiency, live-working robot has become a hot research topic\cite{1}.Because the robot is in a strong electromagnetic field, accidental contact, shell clearance, switches and antenna holes will cause strong electric field penetration\cite{2}, resulting in the impact on the robot drive system .Its direct consequence will cause short circuit, open circuit or breakdown fault for inverter power tube\cite{3-5}. For open-circuit failure, it will not only lead to immediate shutdown, but also make the robot work ability decline, and bring safety risks\cite{6-7} .In this paper, an open circuit fault diagnosis method for inverter power tube based on the variation of three-phase current waveform is presented, and the correctness and feasibility of the method are verified.

2 Driver system

The control of the brushless dc motor system is shown in Fig.1 and the working circuit of inverter power tube is shown in Fig.2.
3 Open circuit fault analysis of inverter power tube

3.1 Open circuit fault mode of inverter power tube

The BLDCM adopts three-phase star connection mode, there are six working modes in one electric cycle. The open fault of the power tube is divided into the following four types:

1. Single tube open circuit fault F1: VT₁, VT₂, VT₃, VT₄, VT₅, VT₆;
2. Single phase open circuit fault F2: VT₁&VT₄, VT₃&VT₆, VT₅&VT₂;
3. Cross-phase dual-tube open circuit fault F3: VT₁&VT₆, VT₁&VT₂, VT₃&VT₂, VT₃&VT₆, VT₅&VT₂, VT₅&VT₆;
4. Two arms same side double tube open circuit fault F4: VT₁&VT₃, VT₁&VT₅, VT₃&VT₅, VT₃&VT₆, VT₂&VT₆, VT₂&VT₃.

3.2 Open circuit fault simulation of power tube

Simulate the open circuit fault of inverter power tube. After the system runs stably, stop sending the break over signal to the target power tube, at 0.3s, simulate single tube open circuit fault F1, the single-phase open circuit fault F2, the cross-phase double-tube open circuit fault F3 and fault F4 of the two bridge arms on the same side. The three-phase current waveform are shown in Fig.3-Fig.6.

Figure 3. Three-phase current waveform of fault F1.  
Figure 4. Three-phase current waveform of fault F2.
4 Open circuit fault diagnosis method for inverter power tube

4.1 Diagnosis method of open circuit fault for inverter power tube

According to the analysis in section 3, the three-phase current waveform of inverter power tube changes obviously under different open circuit fault states. Therefore, an open circuit fault diagnosis method for inverter power tube based on the variation characteristics of three-phase current waveform is proposed. When the power tube fails, the current waveform of the fault phase is always in the upper or lower half axis, assuming that the ratio of the upper / lower half axis waveform to the total waveform data is "1". The ratio of upper / lower axis waveform to the total waveform can be extracted to diagnose power tube fault.

4.2 Verification of the fault diagnosis methods

In Fig.7, The $T_{2A}$ is closest to 1, VT$_1$ open circuit; $T_{1C}$ is equal to 1, VT$_2$ open circuit.

In Fig.8, $T_{1A}$ is equal to 1, $T_{2A}$ is closest to 1(about 1), then A phase is open; $T_{1B}$ is equal to 1, $T_{2B}$ is closest to 1(about 1), and the phase B is open.
In Fig. 9, $T_{1B}$, $T_{2A}$ are equal to 1, VT1 & VT6 are open; $T_{1A}$, $T_{2C}$ equal 1, VT5 & VT4 are open too. In Fig. 10, VT1 & VT3 are open; VT4 & VT6 are open too.

**Figure 8.** Simulation of fault F2.

**Figure 9.** Simulation of fault F3.

**Figure 10.** Simulation of fault F4.
The above characteristic quantity simulation verification results prove that the open circuit fault diagnosis method of inverter power tube based on three-phase current waveform is correct and feasible.

5 Conclusions

In this paper, the open circuit fault of the inverter power tube of the joint motor of the live working robot are discussed, the four fault modes of the inverter power tube, such as single-phase open circuit, cross-phase double-tube open circuit, two-bridge arm and two-side double-tube open circuit are analyzed. According to the brushless DC motor system model built by the matlab and the simulation of the current condition in different fault states, an open circuit fault diagnosis method based on three-phase current waveform is presented. The simulation verifies the correctness and feasibility of the method. At the same time, it provides an idea for the further application of the fault diagnosis method and lays a foundation for the input of redundant system.

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References