Stator Winding Fault Diagnosis Method Based on Dc Side Current of Inverter

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Abstract. This paper analyzes the influence of the fundamental negative sequence component of the grid voltage on the output voltage of the variable frequency power supply, and points out that the fundamental negative sequence component of the grid voltage will not generate the fundamental negative sequence current component in the stator current of the induction motor, so when the stator winding fault is diagnosed, the influence of the negative sequence voltage of the grid does not need to be compensated. Based on the characteristic that the fundamental negative sequence current component in the stator current is converted into two times of the inverter output frequency component in the DC side current of the inverter, a stator fault diagnosis method based on the DC side current of the inverter is proposed. The method of connecting the short-circuit resistance between the two phases of the motor is used to simulate the non-metallic short-circuit fault of the stator coil. The experimental results show that this method does not need to compensate the negative sequence voltage, and only needs to collect one current signal, and the algorithm is relatively simple, which is a simple and effective method.

1 Introduction

The stator winding short-circuit fault of induction motor is one of the main causes of motor failure, and the incidence of this kind of fault is as high as 40% [1]. It is very important to detect and diagnose the early stator short-circuit fault of asynchronous motor from the point of view of safety and economy. Most of the existing researches are aimed at induction motors with direct power supply from power grid. For the need of speed regulation, induction motor is driven by variable frequency power supply in many applications. There is a big difference between frequency conversion power supply and direct power supply [2,3,4]. A large number of switching devices are introduced into the rectifying and inverting circuits of the variable frequency power supply. The harmonic components in the output voltage increase sharply, which makes a large number of harmonic components be introduced into the stator current. In particular, the negative sequence component of grid voltage has different forms in the output voltage of variable frequency power supply. This is of great significance to the diagnosis of stator winding short-circuit fault with the fundamental negative sequence current component as the fault characteristic. Firstly, this paper analyzes the influence of the fundamental negative sequence component of the grid voltage on the output voltage of the variable frequency power supply, and points out that the fundamental negative sequence component of the grid

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voltage will not produce the fundamental negative sequence current component in the stator current of the induction motor\[^5\], so it is not necessary to compensate the influence of the negative sequence voltage of the grid when the stator winding fault is diagnosed. Based on the characteristic that the fundamental negative sequence current component in the stator current is converted into two times of the inverter output frequency component in the DC side current of the inverter, a stator fault diagnosis method based on the DC side current of the inverter is proposed, and a fault severity factor measuring the severity of the stator winding short circuit fault is defined from the perspective of impedance. This definition has the concept of "impedance" in the physical sense, and the calculation is relatively simple at the same time. The method of connecting short-circuit resistance between two phases of motor is used to simulate the non-metallic short-circuit fault of stator coil. The experimental results show that this method does not need to compensate the negative sequence voltage, and only needs to collect one current signal, and the algorithm is relatively simple, which is a simple and effective method.

2 Performance of negative sequence component of grid voltage in output voltage of variable frequency power supply

The simulation model of induction motor driven by variable frequency power supply is established. It is found that the frequency component of 2-fold frequency in the output voltage UD of the rectifier, that is, the frequency component of 2fs, is caused by the fundamental negative sequence component of the three-phase grid voltage\[^6\]. Specifically, the generation of 2fs frequency component comes from two aspects: first, the negative sequence component of fundamental wave in the three-phase grid voltage affects the switching sequence of the upper and lower tubes of three bridge arms, so that the negative sequence component is generated in the switching function of three bridge arms, and the positive sequence component of fundamental wave in the grid voltage is modulated by the negative sequence component of fundamental wave in the switching function to generate 2fs frequency component. Secondly, the negative sequence component of the fundamental wave in the grid voltage is modulated by the positive sequence component of the fundamental wave in the switch function to generate the 2fs frequency component. Compared with the line voltage, these harmonic voltages of the input phase voltage of the induction motor have changed in amplitude and initial phase, but not in phase sequence. The voltage of these frequency components in the phase voltage will generate corresponding harmonic current components in the stator current. The reason why 55Hz component (2fs-f0 component) appears in the frequency spectrum of stator current. In fact, the fundamental negative sequence component of three-phase grid voltage always exists to some extent\[^7,8,9\].

3 Orders experimental verification and result analysis

The output frequency of the inverter is 25kHz. Short circuit resistance is connected between A and B phases of the experimental motor to reduce the insulation of the coil, simulate the non-metallic short circuit of the stator coil, and limit the short circuit current of the coil to ensure that the motor is not completely damaged. The circuit schematic is shown in Figure 1.
Figure 1. Equivalent circuit of stator winding fault.

It is shown the measured current spectrum of motor phase a. It can be seen from the figure that in addition to the fundamental component with a frequency of 45Hz, there are 55Hz and 145Hz frequency components in the stator current. These two frequencies correspond exactly to the frequency of 2F +. There is always a negative sequence component in the grid voltage to some extent. The negative sequence voltage component of the power grid will generate 2F ± frequency component in the output voltage of the inverter and corresponding current component in the stator current.

Simulate the stator short circuit fault of the motor, connect the resistance between a and B phases of the motor, and compare it with no fault of the motor. Figure 4 shows the spectrum of measured DC side current of inverter. According to the previous analysis, the component of 100Hz frequency in the figure is caused by the negative sequence component of grid voltage, while the component of 90Hz (2f₀) frequency is caused by the negative sequence current component of stator current. Through comparison, it is found that the amplitude of 90Hz frequency component is more than three times of that without fault. It can be seen that it is feasible to use the frequency component of 2f₀ as the fault characteristic frequency component to diagnose the stator fault.

Change the resistance value, and let the motor run under different load levels, collect the DC side current of inverter under various conditions, and calculate the corresponding. The change of amplitude with load change is shown in Table 1. The unit in the table is Ma, the fluctuation amplitude is defined as the ratio of the maximum difference between each element in each row and the mean value, and the fault severity factor λ is defined as the ratio of the sum of the mean value. At this time = 520v. It can be seen from table 1 that when the amplitude is constant, the fluctuation amplitude is about 10% with little change. With the decrease, the trend is gradually increasing, the smaller, the larger, the smaller the fault severity factor λ, the more serious the short-circuit fault.

4 Summary
The current negative sequence component is detected to diagnose the motor stator fault. The existing methods need to collect at least two current signals (assuming that there is no zero sequence component in the three-phase stator current). The method proposed in this paper can reduce the hardware cost of detection equipment for induction motor driven by variable frequency power supply, which only needs to collect one circuit of DC side current signal of inverter. Through the analysis, it is found that the negative sequence component of the power grid voltage is fed back to the DC side current of the inverter through the influence of the variable frequency power supply on the stator current, and its frequency component is not at the same frequency point as the characteristic frequency component of the stator fault. Therefore, it is no longer necessary to compensate for the negative sequence component of the grid voltage, which greatly simplifies the algorithm and further reduces
the hardware cost of the detection equipment. A fault severity factor is proposed to measure the severity of stator fault. The ratio of the output DC voltage of rectifier to the amplitude of fault characteristic component in inverter current is taken as the fault severity factor, which has the concept of impedance and good physical significance. Moreover, the output DC voltage of the rectifier can be directly measured by the multimeter, and the fault characteristic component of the inverter reverse current side current can also be detected by the general spectrum analyzer, without the need to design special test equipment.

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