Research on Fault Diagnosis of Broken Rotor Bars of Squirrel Cage Asynchronous Motor

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Abstract: The squirrel-cage asynchronous motor is the main executive component in modern industrial production. Whether it works normally or not is directly related to the operating condition of the entire production process. Broken rotor bars are a common type of fault in motors, which are serious and difficult to detect. Therefore, to study the fault diagnosis technology of broken rotor bars in order to detect the faults in the early stage of the broken bars of the motor and prevent the further deterioration of the faults, which has important theoretical research significance and practical economic value. This article first describes the current status of the research on the fault diagnosis technology of broken rotor bars, and analyzes the mechanism of broken rotor bars, which lays a theoretical foundation for the detection of broken bar faults by the current spectrum method. The influence of the slight broken bar fault on the slip rate of the motor is analyzed through the finite element simulation model, and it is verified by the actual motor speed measurement. Realize the effective diagnosis of broken rotor bar fault

1. Introduction

The squirrel-cage asynchronous motor has become the main executive component in modern industry and agricultural production due to its simple structure, easy manufacture, low price, reliable operation, and suitable for various working environments. Whether the motor is running normally or not is directly related to the running condition of the entire production process.

Due to the unreasonable structural design of the motor itself, defects in the production and manufacturing, or human operation errors, the service life of the motor will be greatly reduced. The reason why the motor is prone to broken rotor failure is usually caused by frequent starting, braking and heavy load operation during the long-term operation of the motor. Especially at the time of starting, it is easy to cause the short-term winding current to be too large, causing the rotor conductor to overheat, the rotor electromagnetic stress changes sharply, and the rotor bears huge impact force, which causes the motor rotor to break the fault. For minor broken rotor bar faults, the fault generally does not immediately have a great impact on the operation of the motor, but as the running time of the motor continues to increase, the broken bar will easily cause other rotor bars around it to further develop. The fracture [1].

In summary, it is necessary to diagnose the broken rotor bar fault of the motor. [2] Through further theoretical research on the detection method of broken rotor bar fault, find the most reasonable signal processing algorithm for practical application. On the basis of its theoretical research, a set of real-time motor rotor broken bar fault diagnosis system was developed to meet the needs of production applications.

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2. Rotor Broken Bar Failure Cause Analysis and Failure Mechanism Research

2.1. Analysis of the Causes of Broken Rotor Bars

Under normal circumstances, the squirrel cage asynchronous motor is not easy to cause broken bars due to its sturdy structure and long service life. Due to the limitation of the production and manufacturing of the motor technology, the casting quality of the guide bar, the material and welding of the guide bar and the end ring are prone to problems, so that the guide bar cannot be fully tightened in the rotor groove, and finally the guide bar and end ring are caused by stress. The distribution is uneven and broken. If the overall foundation strength of the unit is not enough, excessive vibration of the motor will also cause serious wear of the cage. The load carried by the motor is large, and the electric power is large when starting [3]. The current and force passing on the squirrel cage bar during startup are quite large, causing the rotor conductor to fatigue. When the fatigue limit is reached, the weld between the rotor copper bar and the end ring is prone to fracture [4].

2.2. Mechanism Analysis of Broken Rotor Bars

The prerequisite for the fault diagnosis of squirrel cage asynchronous motor rotor broken bars is the extraction of broken bar fault characteristics. In the current spectrum method, compared to the normal motor, the rotor bar breaker motor has additional frequency components besides the power frequency f component. This article focuses on how to extract the broken bar fault characteristics of the rotor to carry out analysis and research. The fault diagnosis system consists of a lower computer system responsible for signal acquisition and an upper computer system responsible for signal diagnosis. The main control core of the lower computer system design, including its chip selection, sensor selection, hardware circuit design, and system program debugging. Apply the previously studied fault diagnosis algorithm to the host computer system. Finally, the data communication between the upper computer and the lower computer is realized through the serial bus, so as to realize the detection and diagnosis of the broken bar fault of the motor rotor[6] .

For a squirrel-cage asynchronous motor with the number of pole pairs p, under the condition of power supply frequency f, the stator winding generates magnetomotive force during operation, and the expression of the fundamental wave is (1)

$$M_1 = K_1 N_1 I_1 \sin(\omega t - p\theta) \quad (1)$$

Where: K1 is a constant related to the number of pole pairs and winding coefficients of the motor; N1 is the effective number of turns of the stator winding; I1 is the stator current; ω is the grid angular frequency; θ is the initial phase angle expressed in mechanical angle (2).

$$\phi = \theta - \omega_r t \quad (2)$$

Under the action of the stator's rotating magnetic field, the rotor winding will induce an electric potential and generate a current to establish a rotor magnetic potential that is balanced with the stator at this time. The fundamental wave of the rotor magnetic potential is expressed as (3):

$$M_2 = K_2 N_2 I_2 \sin\left[\omega(-\omega_r)t - \phi\right] \quad (3)$$

Where: K2 is a constant related to the number of motor pole pairs and rotor winding coefficient; N2 is the number of turns of the rotor winding; I2 is the rotor current.

It can be derived from the above formula that in the magnetomotive force, the second magnetomotive force component contains a component that is 2sω lower than the angular frequency of the power supply, so the electric potential and current of the corresponding frequency must be induced in the stator winding.

2.3. Rotor broken bar fault signal source selection

The effective and reliable diagnosis of motor faults must rely on the correlation analysis of motor

faults and their corresponding symptoms. At the same time, the selection of motor operating parameters and advanced signal processing technology are decisive factors for motor fault diagnosis [7-8]. Based on the analysis and research of the current research status of the rotor broken bar fault diagnosis technology, combined with the development direction of the fault diagnosis system, the corresponding fault diagnosis system is designed scientifically and reasonably. First, select those signal sources that are sensitive to faults and easy to obtain, and secondly, combine appropriate signal processing techniques to analyze the fault characteristic components in the motor parameters to determine whether the fault has occurred. After comprehensive consideration [9].

In this paper, the stator side current signal is selected as the research object to diagnose the broken bar fault of the rotor [10]. Current signals have low requirements for signal acquisition and processing devices, and a series of operations on their signals can be completed through simple circuit design and programming. This article only needs a high-precision AC current transformer and supplemented by a peripheral circuit to complete the acquisition of the current signal on the stator side of the motor. The current signal can obtain high sampling accuracy and is not susceptible to interference from other signals, and its signal has a high signal-to-noise ratio [11].

3. Simulation Analysis of Broken Bar Fault Based on Notch Filter

According to the characteristics of the current signal on the stator side when the squirrel-cage asynchronous motor has a broken bar fault, an IIR digital notch filter with the notch frequency of the actual power frequency is designed to filter the power frequency component to the broken bar fault characteristic frequency component. interference.

IIR notch filter is a typical application of infinite impulse response digital filter. The IIR notch filter can be expressed by the following constant coefficient linear difference equation (4):

$$y(k)=\sum_{i=0}^{M}a_i x(k-i)-\sum_{i=0}^{N}b_i y(k-i) \tag{4}$$

Where: x(k) is the current input value, y(k) is the output value of the extremely narrow band notch filter; ai and bi are the filter coefficients.

Based on the above analysis of the characteristics of the current signal on the stator side of the motor, we can build a dynamic simulation model of its signal, and verify the reliability and accuracy of our signal processing method through experimental simulation. Assume that the input signal s(t) of the stator side current of the motor is composed of the power frequency signal: x(t) and the broken bar fault characteristic signal d(t), f is the power frequency, here it is assumed that the power frequency is the standard power frequency 50Hz; n Is the number of sampling points, here is 2048; fs is the sampling frequency, here is fs=500 Hz; s is the slip rate of the motor (usually 0<s<0.05) [12], here is 0.01; A1 and A2 are respectively The amplitude of the power frequency signal component and the amplitude of the broken bar fault component.

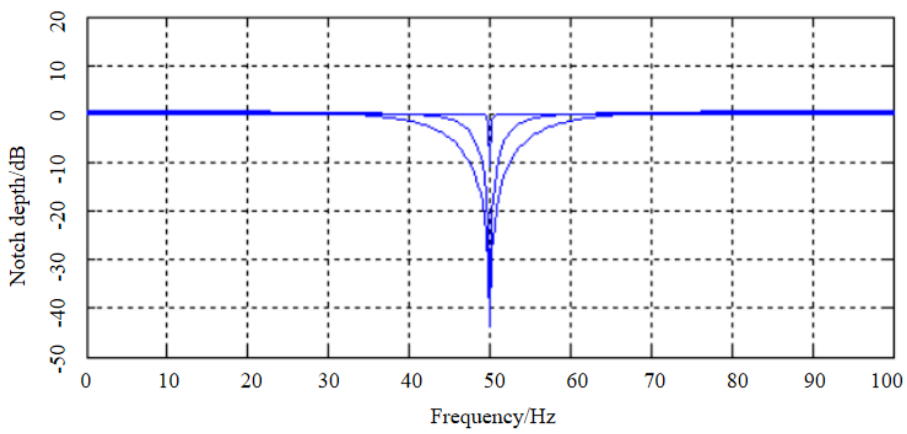

Figure 1 Notch width and depth characteristics

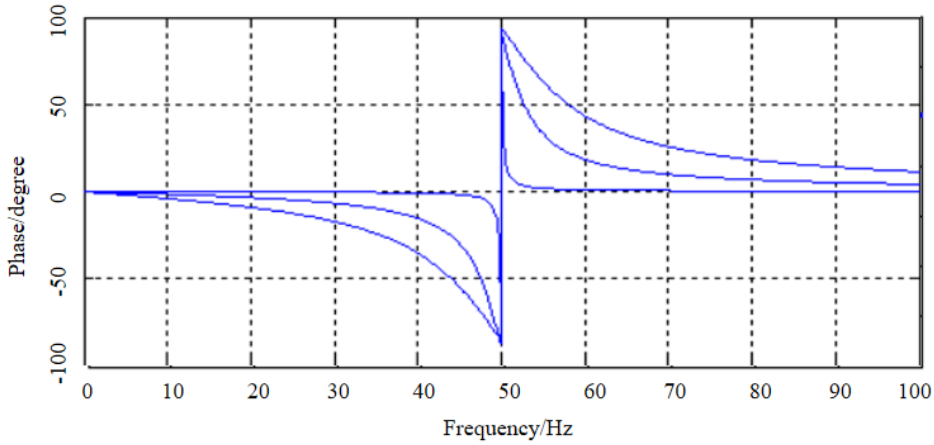

Figure 2 Phase characteristics of the notch filter

In view of the above-mentioned signal expansion, the performance analysis of the IIR notch filter is to find the control parameters of the IIR suitable for the rotor broken bar signal, as shown in Figure 1 and Figure 2.

Since the value of u directly affects the change of the depth and width of the notch, the notch depth and the notch width have a contradictory relationship, which cannot be satisfied at the same time. In Figure 1, the curves from top to bottom are the depth and width characteristics of the trap when u = 0.998, u = 0.962, and u = 0.900. In Figure 2, the curve from bottom to top is the phase characteristic effect of the notch filter when u=0.998, u=0.962, and u=0.900.

When the IIR notch factor μ is 0.962, the fault characteristics of the broken bar are analyzed. The simulation stator side current signal (in order to facilitate the observation of the simulation current waveform, take the first 300 sampling points), the FFT spectrum analysis results, as shown in Figure 3.

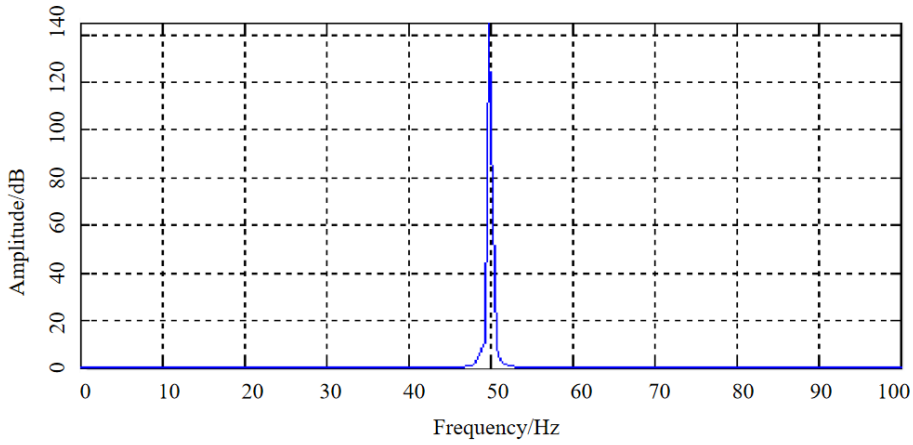

Figure 3 Spectrum diagram of simulated stator current

The FFT spectrum analysis of the current signal on the stator side can not identify the broken bar fault characteristic component) f, and the analysis result after the IIR notch filter can clearly identify the frequency component of f at 49 Hz.

The simulated stator side current signal after passing through the IIR trap (in order to facilitate the observation of the current waveform, the first 300 sampling points are taken), as shown in Figure 4.

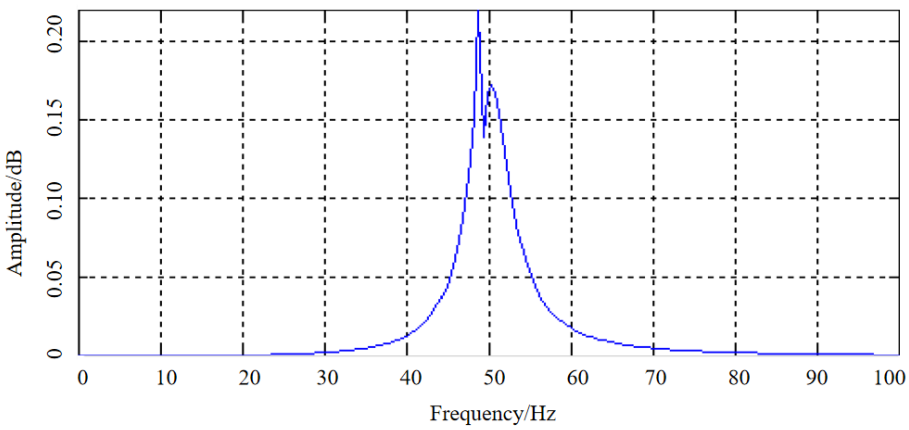

Figure 4 Spectrogram after IIR notch

According to the analysis of the failure mechanism of the motor bar breakage in the previous chapter, when the motor has a bar breakage fault, the current frequency component of f is very close to the frequency component of the power supply, and it will modulate the stator current, resulting in a frequency component of f. Here we use a finite model to verify it. When the motor runs under rated load conditions, the speed is close to 1420r/min, and its slip rate s=0.05, so the characteristic component f of the broken bar fault should be 55Hz.

Since the operation of the motor is affected by the original components of the motor, the installation environment, the power supply, the operating mechanism, the nature of the load and other factors, any abnormality of any link may bring about a series of failure chain reactions. For the motor itself, the types of motor faults are also diverse, and there are also complex relationships between them [13].If you want to realize an effective analysis of a certain kind of fault, you must adopt the corresponding reasonable fault diagnosis technology.

Through the analysis, we can also get the following conclusion: as the number of broken bars increases, the amplitude of the characteristic components of the broken bars also increases, which shows that the amplitude of the characteristic components of the broken bars reflects the occurrence of the broken bars. severity. The larger the characteristic component of the broken bar fault, the more serious the broken bar fault.

4. Conclusions

Cage asynchronous motors occupy an extremely important position in the field of transmission due to their simple structure, low price, reliable operation and long service life. The fault diagnosis of squirrel cage asynchronous motors is an important measure to ensure the safe and reliable operation of the production system, reduce the motor failure rate and reduce economic losses. Among the many faults of the motor, the broken rotor bar fault is serious and difficult to identify, accounting for about 10% of all faults in the motor. Therefore, the research on the rotor fault diagnosis of squirrel cage asynchronous motor is of great significance.

Starting from the actual detection of broken rotor bars, this paper studies the fault diagnosis technology of broken rotor bars and analyzes the reasons that lead to broken bars in the motor rotor. Theoretically deduced the fault diagnosis mechanism of broken rotor bars, it is concluded that the broken bars of the motor occurs. When a fault occurs, based on the study of the basic structure and working principle of the squirrel-cage asynchronous motor, the main fault forms of the squirrel-cage asynchronous motor are analyzed. The rotor broken bar fault is selected in this paper based on the stator current analysis method to collect, analyze and process the motor signal. Extract the fault feature quantity. The test of analog signal and actual fault diagnosis under experimental conditions shows that this method can effectively extract the fault characteristic frequency that is often submerged by the fundamental frequency signal in traditional current spectrum analysis. There will be an additional frequency component f basis in the stator side current. It is verified that

when the motor has a slight broken rotor bar fault, it has only a small effect on the motor slip rate s.

References

[1] Wang Zhen, Li Cheng, Chen Xu, et al. Asynchronous motor rotor broken bar fault diagnosis using dual HTLS parameter estimation under short-term data[J]. Electric Power Automation Equipment, 2017, 37(1): 5.

[2] Qiao Weide. Firefly-particle swarm optimization neural network based fault diagnosis of asynchronous motor rotor broken bars[J]. Electric Machines and Control Applications, 2017, 44(1):6.

[3] Liu Xinzheng, He Shenghua, Gao Lin, et al. Features of LMS filtering method in the diagnosis of broken rotor bars in cage asynchronous motors[J]. Journal of Electrical Machines and Control, 2017, 21(5):1.

[4] Wang Jianying, Dong Weiguang, Gao Fengyang, et al. Asynchronous motor rotor broken bar fault signal separation based on SPIN algorithm[J]. Journal of Lanzhou Jiaotong University, 2018, 037(005): 57-61.

[5] Shi Liping, Wu Wenjun, Ma Xiaowei, et al. Broken bar fault detection of asynchronous motor based on MUSIC and FOA[J]. Micro & Special Motor, 2017, 45(8):5.

[6] Liu Xinshang, Xie Chen. The establishment and simulation study of the broken bar model of the doubly-fed generator[J]. Shaanxi Electric Power, 2018, 046(002):83-86,92.

[7] Yang Mei, Sun Hongqiang, Hao Jing. Rotor broken bar fault detection of induction motor based on RMO[J]. Electric Drive, 2020, 50(8):6.

[8] Song Xiu, Wei Yu. Fault diagnosis of asynchronous motor rotor broken bar based on short-time fractional Fourier transform[J]. Journal of Wuhan University of Science and Technology, 2016, 39(2): 5.

[9] Xu Yunzhi, Xu Zhiying, Fang Lei, et al. Research on Asynchronous Motor Broken Bar Fault Diagnosis Method Based on Chaos and Fractal Theory[J]. Coal Mine Electromechanical, 2016, 000(005): 27-32.

[10] Dong Aihua, Min Tianwen, Li Zhichao, et al. Research on rotor fault diagnosis algorithm of asynchronous motor[J]. Measurement & Control Technology, 2016, 35(3): 4.

[11] Bian Ning, Xu Yunzhi. BP neural network motor broken bar fault diagnosis based on ARMA and genetic algorithm optimization[J]. Coal Mine Electromechanical, 2017, 000(003): 23-26, 30.

[12] Hao Xiaohong, Wang Huimin. Simulation of the faulty operation state of asynchronous motor based on Matlab[J]. Research and Exploration in Laboratory, 2017, 36(2):4.

[13] Xie Ying, Shan Xueting, Guo Jinpeng, et al. Research on the correlation between field changes and failure degree of motors caused by the fracture of cage rotor bars [J]. Proceedings of the Chinese Society of Electrical Engineering, 2017, 37(14): 10 .