Motor Broken-bar Fault Diagnosis Based on Park Vector and Wavelet Neural Network

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Abstract. In the technology of motor fault diagnosis, current monitoring methods have become a new trend in motor fault diagnosis. This paper presents a motor fault diagnosis method based on Park vector and wavelet neural network. This method uses the stator current as the object of study. Firstly, it uses Park vector to deal with the stator current and filter out fundamental frequency component, thus the characteristics component of motor broken-bar will be separated from fundamental frequency component; Secondly, it uses five layers wavelet packet decomposition to pick up fault characteristic signal; Finally, we distinguish the fault by BP neural network, and use the simulation software of MATLAB to realize it. The test results show that: This method can detect the existence of motor broken-bar fault, and has a good value in engineering.

Introduction

Asynchronous motor has been widely used in modern industrial system, which is the important electrical equipment to achieve energy into mechanical energy. Among variety of motor faults often occurred, about 10% of the motor fault is caused by broken rotor bars and rotor end ring fracture fault. Therefore, timely detection of rotor faults, and take appropriate measures to reduce losses to a minimum have great significance.

When the asynchronous motor rotor fault , the stator current will produce \((1 \pm 2s) f_0\) frequency components, which is close to the fundamental frequency component and have smaller amplitude value, the frequency components can be easily drowned by fundamental frequency component and ambient noise, so that reduced detection accuracy. In this paper, the park’s vector process has been used on stator current that we collected; the fundamental frequency AC component of the current can be filtered out easily. Then, fault signal is extracted by wavelet packet decomposition. Finally, recognize whether the motor rotor broken bars faults occurs by using the BP neural network. The experimental results show that the method can recognize rotor broken bars faults perfect.

Acquisition of the Current Data and Preprocessing

When the asynchronous motor rotor bars are broken, the stator current will produce \((1 \pm 2s) \ast f\) frequency components, because it is very close to the fundamental frequency component, and the faults component amplitude values is less, so that it can be easily drowned by the fundamental frequency component and the ambient noise. Lead to less accuracy of the detection. Thus, we firstly transform the stator current with Park 3 / 2, which the basic idea is to transform the stator three-phase current from the (A, B, C) three-dimensional coordinate to (D,Q) two-dimensional coordinates, namely

\[i_D = \frac{2}{3}\sqrt{\frac{2}{3}} i_A - \frac{1}{\sqrt{6}} i_B - \frac{1}{\sqrt{6}} i_C\]

\[i_Q = \frac{1}{\sqrt{2}} i_B - \frac{1}{\sqrt{2}} i_C\]  \hspace{1cm} (1)

\[i_D = \frac{1}{\sqrt{6}} i_B - \frac{1}{\sqrt{6}} i_C\]  \hspace{1cm} (2)
When the motor rotor broken bars fault occurs, the stator phase current has the following form:

\[ i_a = I_0 \cos(wt - \alpha) + I_1 \cos((1 - 2s)wt - \beta) + I_1 \cos((1 + 2s)wt - \gamma) \]  

\[ i_b = I_0 \cos(wt - \alpha - \frac{2\pi}{3}) + I_1 \cos((1 - 2s)wt - \beta - \frac{2\pi}{3}) + I_1 \cos((1 + 2s)wt - \gamma - \frac{2\pi}{3}) \]  

\[ i_c = I_0 \cos(wt - \alpha + \frac{2\pi}{3}) + I_1 \cos((1 - 2s)wt - \beta + \frac{2\pi}{3}) + I_1 \cos((1 + 2s)wt - \gamma + \frac{2\pi}{3}) \]  

Where, \( I_s \) is the maximum value of the stator current fundamental frequency component; \( w = 2\pi f_0 \) is Fundamental angular frequency; \( I_1 \) is the maximum value of the Current low-side component; \( I_h \) is the maximum value of the Current high-side component; \( \alpha \) is the initial phase angle of the fundamental frequency component; \( \beta \) is the initial phase angle of the low-side component; \( \gamma \) is the initial phase angle of the high-side component;  

According to the Eq. 1~Eq. 5, \( i_d \) and \( i_q \) can be obtained as follow:

\[ i_d = \left(\frac{\sqrt{3}}{2}\right)(I_s \cos(wt - \alpha) + I_1 \cos((1 - 2s)wt - \beta) + I_1 \cos((1 + 2s)wt - \gamma)) \]  

\[ i_q = \left(\frac{\sqrt{3}}{2}\right)(I_s \sin(wt - \alpha) + I_1 \sin((1 - 2s)wt - \beta) + I_1 \sin((1 + 2s)wt - \gamma)) \]  

We suppose the current park’s vector is \( \bar{I}(t) \), and \( \bar{I}(t) = i_d + ji_q \). Stator current Park’s vector modulus square function is \( I_s(t) \). According to Eq. 6 and Eq. 7, we obtain that

\[ I_s(t) = |i_d + ji_q|^2 = \frac{3}{2}(I_m^2 + I_1^2 + I_h^2) + 3I_m I_1 \cos(2swt - \alpha + \beta) + 3I_m I_h \cos(2swt + \alpha + \gamma) + 3I_1 I_h \cos(4swt + \beta - \gamma) \]  

According to the above, among the park’s vector spectrum, there are two variable frequency AC components of \( 2sf_0 \) and \( 4sf_0 \) corresponding to DC component and broken bars fault, which power source current fundamental frequency component hold the main ingredient. Thus, fault feature variable frequency AC component is far beyond the power source fundamental frequency component, so that the adverse effects caused by the fundamental frequency component are eliminated.

**Feature Extraction of Rotor Broken-bar Fault**

Currently, there are many methods of fault feature extraction, Wavelet transform is a local transform of space and frequency, which can analysis carefully the function and signal by the operation function of compressing or expanding and moving, so wavelet transform can pick up characteristic signal effectively from signal. However wavelet packet transform is the development of wavelet transform, relative to wavelet transform, wavelet packet transform can decompose the high frequency part of signal and image. So wavelet packet transform can deal with all sorts of time-varying signal. Wavelet packet decomposition tree is shown in the Fig. 1:

![Three layers wavelet packet decomposition tree](image1)

![The waveform graph of normal signal and fault signal](image2)
The normal current signal waveform and fault signal waveform are showed in the Fig. 2 from motor monitoring system, which are only processed by Park vector. In each of the measured data contains a total of 4096 data, the two groups of signal waveform are superposition of different frequencies and different amplitudes, so it is difficult to finish the work of the extraction of the failure information. Firstly, this article uses the principle and method of wavelet packet analysis to respectively do five layers wavelet packet decomposition with the measured motor stator current of normal signals and the fault signals, as shown in Fig. 3. Then we reconstruct the coefficients of wavelet packet decomposition. Fig. 4 is a reconfiguration coefficient waveform graph about portion of each node of wavelet packet decomposition, by contrast we can find that the waveform of the normal signal and fault signal have some differences at some frequency bands, and can judge the frequencies of the fault characteristic, in order to extract the fault feature.

When the motor rotor is broken, the motor stator current will fluctuate drastically in the fault points. So, we find the standard deviation about the reconstruction coefficient, and select the nodes which standard deviations have a larger difference each other as the failure nodes, as shown in Fig. 5. The most obvious nodes are the eighth node in the fourth layer, the second, the third, the seventh, the eighth, the fifteenth in the fifth layer, a total of six nodes, then as the input of BP neural network, in order to test whether have motor broken-bar.

**Recognition of Rotor Broken-bar Fault**

For the analysis of fault feature vector which is extracted by five layers wavelet packet, we determine that the number of input note of BP neural network is six, and the number of the output node is one, according to the experience to determine the number of hidden layer are four–thirteen, and separately for training, and select eighteen groups of training data, each group of 4096 data. There are 9 group of normal data and 9 group of fault data, and training step is 1000, and allowable error is 1.00e-20. Verified by numerous experiments, finally, the simulation results are shown in fig. 6 when the optimal number of hidden layer nodes are 10, the training results reach the permissible error range in the designated training step number. And the training curve is very ideal, and the error is smaller.
between network detection output and requirements, the simulation results are basically consistent with the expected output, the accuracy of fault detection is higher than 94.4. Therefore, this method can be applied to completely in fault diagnosis system.

**Fig. 5** The difference of standard deviation of reconfiguration coefficient between normal and fault signal

**Fig. 6** The training curve of achieving the desired output by BP neural network training

**Conclusion**

This article uses Park vector to analysis and pre-process with the collected rotor current signal, and separates the weak component of broken-bar fault characteristics and fundamental frequency component, makes the former received the highlight, so as to more accurately and effectively capture the fault feature. Then it uses five layers wavelet packet decomposition to pick up fault characteristic signal. Finally, we distinguish the fault by BP neural network. The experimental results show that the method is correct and effective, and can be extended to the motor fault diagnosis system research and application.

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