Fault Detection Method Research of Three-phase Asynchronous Motor

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Abstract—Three-phase asynchronous motor has been widely used in industrial automation fields for the advantages of simple structure, reliable operation,and convenient use, etc, In this article, first of all, the mechanical properties of three-phase asynchronous motor are analyzed. On this basis, fault detection methods of three-phase asynchronous motor are research, and the early fault detection method three-phase asynchronous motor is analyzed. Finally, the SATI method is studied in the fault diagnosis applications on the basis of basic principle of wavelet transform for the three-phase asynchronous motor, and the application of data fusion technology is carried out to explore.For improving the efficiency of fault detection of the three-phase asynchronous motor that plays an important role.

Key words-three-phase asynchronous motor; mechanical properties; fault diagnosis; wavelet transform; data fusion

I. MECHANICAL BEHAVIOR ANALYSIS OF THREE PHASE ASYNCHRONOUS MOTOR

A. Mechanical behavior of three phase synchronous motor

The mechanical characteristic refers to the relationship of three-phase asynchronous motor's between the speed of the motor n and the electromagnetic torque T, and torque T and the slip s is corresponding relationship , the form is T = f (s) or n = f (T). Three-phase asynchronous motor electromagnetic torque has three expressions: physical expression, practical expression and parameter expression, the three expressions in different forms, reflecting the mechanical characteristics of asynchronous motors from different directions[1].

Relational expressions that three-phase asynchronous motor electromagnetic torque *T* and the motor parameters, as shown in formula (1) :

$$T = \frac{m_1}{\omega_0} \cdot \frac{U_1^2 r_2^{'} / S}{\left(r_1 + r_2^{'}/S\right)^2 + \left(X_1 + X_2^{'}\right)^2} \quad (1)$$

In formula: m_1- stator winding phases;

U_1- added to the stator winding of the phase voltage;

ω_0- asynchronous motor synchronous speed.

S- slip of Induction motor;

The electromagnetic torque is a function of the slip when the stator phase voltages U_1 and the stator current frequency f_1 are constant in formula (1), and the motor parameters r_1 , r_2 ', X_1 and X_2 ' are constant too. Paint on the axis, *T-S* curves can be received. the three working states of motor are reflect by the mechanical characteristic curve , Induction motor is primarily used as a motor in the actual production. Parameter expressions reflect the parameters of the relationship between torque and power parameters [2]. With parameter expression can easily analyze effects of parameters on electromagnetic torque and effects of various artificial features.

B. Mechanical characteristics curve of three-phase asynchronous motor

Three-phase asynchronous motor's mechanical characteristic curves can be drawn, the torque that has effect on mechanical properties can be analyzed[3].

Slip-relationship that torque and power voltage of three-phase asynchronous motors, common forms as shown in formula (4):

$$T = K\frac{SR_2U_1^2}{R_2^2 + \left(SX_{20}\right)^2} = K\frac{SR_2U^2}{R_2^2 + \left(SX_{20}\right)^2} \quad (4)$$

In formula: K- structural parameters of frequency

and power of the motor-related constants;

X_{20}- leakage inductance of each phase winding;

R_2- resistance of each phase winding when rotor has a rest;

Mechanical characteristic curve can be obtained by the formula $T= f (S)$, as shown in figure 1.

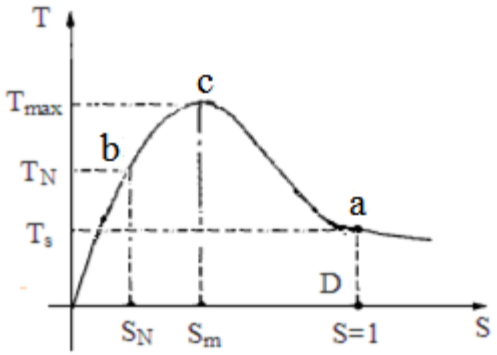

Figure 1 . Asynchronous motor T-S curve

T=f(s) curves turn 90° in a clockwise direction. Abscissa represent speed n, ordinate represents the torque *T*, another mechanical characteristic curves are obtained, as shown in Figure 2.

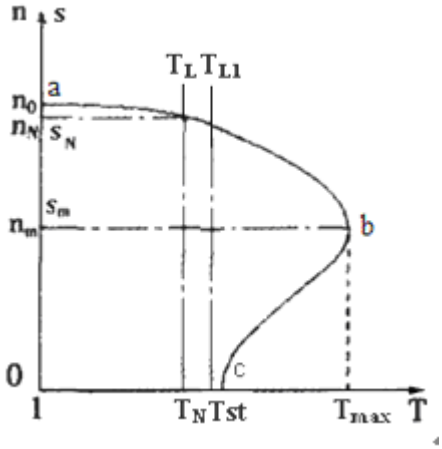

Figure 2 . Asynchronous Motors n-T curve

The mechanical characteristic of motor is a nonlinear curve that can be seen by Figure 2. Under normal circumstances, the maximum torque is a cut-off point. Its linear segment is stable operation area, and the nonlinear segment is unstable running area.

II. THREE-PHASE ASYNCHRONOUS MOTOR FAULT DETECTION METHOD RESEARCH

The study of three-phase asynchronous motor of the short circuit of stator winding interturn and rotor broken barsb , and bearing fault detection and diagnosis methods which can effectively improve the sensitivity and reliability of fault detection and diagnosis methods.

By combining the Multi-Loop model and Finite Element Method together, the ML-FEM mathematical model of induction motors is established. And the numerical simulation of RBB, SWITSC fault are performed, as paves the way to investigate the corresponding detection and diagnosis methods.

The simulation of RBB fault has been completed successfully for motors in induction , as well as the corresponding experiments. Based on thorough analysis of the simulation and experiment results, a novel method to detect RBB, which perfectly blends subdivision fourier transform, self-adaptive filter, rotor slot harmonics based slip estimation and detection threshold self-tuning techniques, and it is proposed. Fault detection instances that the presented method is effective in laboratory demonstrate , even taking into account the intrinsic asymmetry, rotor disalignment and air-gap eccentricity for induction motors. At the same time, tyhe novel criterion to estimate the number of broken rotor bars is deduced which possesses better performance than those presented previously.

The simulation of SWITSC fault has been completed successfully, and the corresponding experiments have been carried out. According to that, the novel detection method of SWITSC that blends perfectly the spectrum correction and self-adaptive filter techniques, which is proposed. Simulation and experiment results demonstrate that the novel method is immune to RBB fault and thus more reliable than those presented previously. Andthen, by taking the stator winding apparent impedance angle as the feature, the method to locate the stator winding faulty with inter-turn shorts is proposed.

The joint detection necessity of RBB and SWITSC fault that induction motors is clarified in squirrel cage, and the corresponding joint detection method, valid and practical which is put forward successfully. The simulation of RBB and SWITSC double fault motors has been completed successfullyin squirrel cage induction, as well as the corresponding experiments [4]. The double fault features have been generalized, and moreover, the appropriate detection strategy is recommended.

By thoroughly analyzing the mechanism and features of bearing fault in induction motors, the vibration signal based and stator current signal based methods to detect and diagnose bearing fault have been proposed respectively. The Motor Incipient Fault Online Detector that possesses the capability of detecting and diagnosing all the RBB. SWITSC and bearing fault that has been developed successfully and utilized widely on-site in induction motors.

III. THE ANALYSIS OF EARLY FAULT DETECTION METHOD OF THREE-PHASE ASYNCHRONOUS MOTOR

The incipient fault characteristic of the induction motor is usually very weak [5]. The induction motor is driven by frequency converter for speed regulation and energy saving requirements. The soaring harmonic component in converter and the noise is produced by peripheral equipment make it more difficult for the incipient fault detection. Aiming at the broken rotor bar, inter-turn short circuit, and bearing fault of the induction motor, the dissertation focuses on detection and incipient fault characteristic extraction in heavy noise. Because of

being blanketed by fundamental component, in the spectrum analysis when induction motor has the incipient broken bar fault, the new added fault characteristic component is difficult to be discriminated. To solve this problem, the improved correlation algorithm is proposed . According to the truth that the voltage and the fundamental component of current have the same frequency, reference signals whose frequency are equal to the one of stator voltage are constructed.

The amplitude and phase of the fundamental component in stator current that can be obtained by the improved correlation algorithm. After the fundamental component is removed accurately, and the rotor broken bar fault signal will be emerged . When broken rotor bar fault occurs in induction motor with variable frequency power, the fault characteristic centred on the carrier frequency is distributed in the input-side current spectrum of inverter with specific frequency interval. And it is easy to be covered with neighbouring components, and the condition gets worse as the inverter runs in low frequency or under light load. The reference signals are constructed according to output, input and carrier frequency of inverter. With improved correlation algorithm, the the diagnosis result of components confusing that is removed，and the fault characteristic can emerge from the spectrum.

With the three-phase improved correlation algorithm, the fundamental component can be got accurately in stator current [6].In the stator current signal, since there are a lot of harmonics and noise , especially when induction motor is fed with variable converter, the inter-turn short circuit fault diagnosis should be greatly influenced. This paper presents the detection method based on the anti-synchronous-speed coordinate transformation. Via this transformation, the positive sequence component is turned into the second harmonic. The negative one is transformed into DC component that can be extracted by the mean algorithm, and the amplitude of synthetic vector of the negative sequence component which can be derived in new coordinate. A sensitivity factor is defined to evaluate the severity extension of the inter-turn-short-circuit faults, which takes into account the manufactured asymmetry of the induction motor. Because of being obscured by noises of the peripheral equipment, the incipient bearing fault characteristic is so weak that it is very difficult to be discriminated. The filter used to extract weak signal is presented to extract weak fault signal based on spectral kurtosis in heavy noise . Via short-time Fourier transform to the vibration signals, and the estimation of the spectral kurtosis is given [7]. Taking microprocessor as a core of motor parameters collection，via the Labview software platform of data analysis and fault diagnosis，an incipient fault diagnosis system for the induction motor is constructed. According to the spectral kurtosis, the filter controlled is constructed automatically to remove the noises and harmonic components for signal-to-noise ratio. By means of the envelope analysis, the incipient bearing fault characteristic information could be very obvious . Experiment results indicate that the system is feasible in the broken rotor bar, inter-turn short circuit, and bearing fault diagnosis.

IV. Research on the Fault Diagnosis Methods of the SATI of three-phase asynchronous motor

Because to its excellent performance and low price , three phase asynchronous motor is used widely. The pros and cons of the rotor bar performance which directly affect the quality of motor engine.

To the SATI (a squirrel eageAluminum rotorofThree phaseInduetion one motor) fault diagnosis and studies the intelligent device which is to strictly control asynchronous motor rotor aluminum from production source.

With the views of basic electromagnetic and electrical machine theory, the interpretation, fault-character and its causation of the faults on SATI are give.

The common inductance computational formulae is suited for the normal condition.These formulae is used for fault condition. The previous methods to analysis the spectrum of line current always cannot highlight.

This thesis gives out computational formulae for the stator and rotor inductance parameters in the induction motor under both normal and fault conditions according to the winding function and the expression of air ga. The simulation results tally with that of experiments which indicates correctness of the modelsand the parameters computation [8]. The characters of the broken bar since the frequency of the fault component is very close to the power frequency.

so this research proposes three different fault diagnose method : the method based on vector control, the method based on Hilbert mode spectrum analysis, and the method based on spectrum analysis of instantaneous power. In the research, the choose method based on spectrum analysis of instantaneous power . Harmless-diagnosis based on ultrasonic that can show the fault of the the SATI visualized. All the fault of SATI such as crack,air bubble and others that are noticed by the way of practice.

V. Study on Induction Motor Fault Diagnosis of three-phase asynchronous motor

In various nonmilitary applications, the multi-sensor data fusion technology is an emerging interdisciplinary technology and that has received significant attention. The new method has introduced to solve the problem which the inherent uncertainty of traditional motor fault diagnosis technology. The data fusion technology could reduce the inherent uncertainty for the traditional fault diagnosis technology of induction motor. The researche on how to use data fusion technology which has done in the induction motor fault diagnosis , and the cage induction motor model to simulate the results of the feasibility of the data fusion technology is set in motor fault diagnosis [9]. The method use the multi-sensor data

fusion technology based on special methods for deal with uncertainty, and for increase the effectiveness of fault diagnosis. The data fusion technology and the characteristics of the fault diagnosis have concluded [10]. And the feasibility and reliability of the theory is verified by running the model of the system. The simulation results was got by combined the law of D-S theory whit running the system, and the advantages and weaknesses of this method is analyzed. The Multi-sensor data fusion technology has more advantages than the traditional motor fault diagnosis technology, and it could greatly increase the accuracy of the system of motor fault diagnosis.

VI. CONCLUSION

Three-phase asynchronous motor is widely used in the field of industrial automation, and the use of the motor performance has higher requirements. In this article, the mechanical properties of three-phase asynchronous motor are analyzed. On the basis of mechanical properties are analyzed, fault detection methods of three-phase asynchronous motor are research, and the early fault detection method three-phase asynchronous motor is analyzed. Finally, the SATI method is studied in the fault diagnosis applications on the basis of basic principle of wavelet transform for the three-phase asynchronous motor, the application of data fusion technology is carried out to explore.To improve the efficiency of the three-phase asynchronous motor fault detection and reduce the probability of failure, and improve the production efficiency and economic benefit is very important guiding significance.

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