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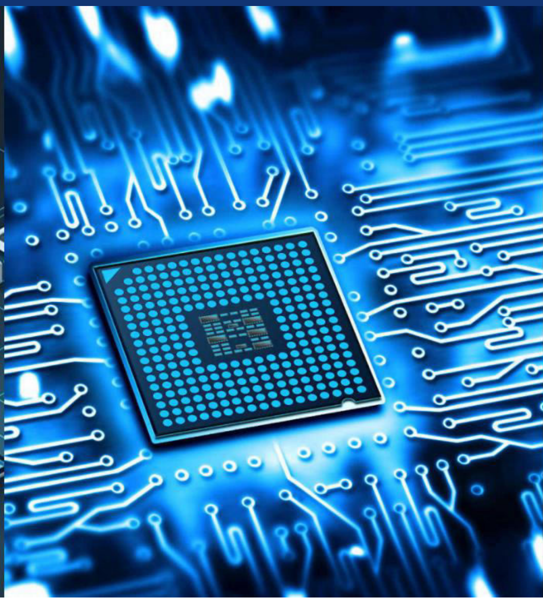


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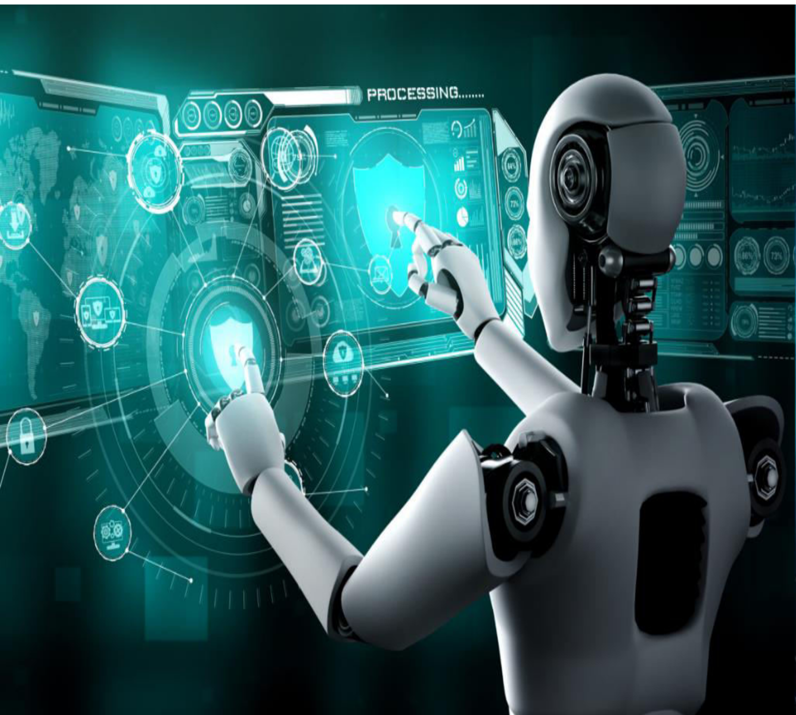

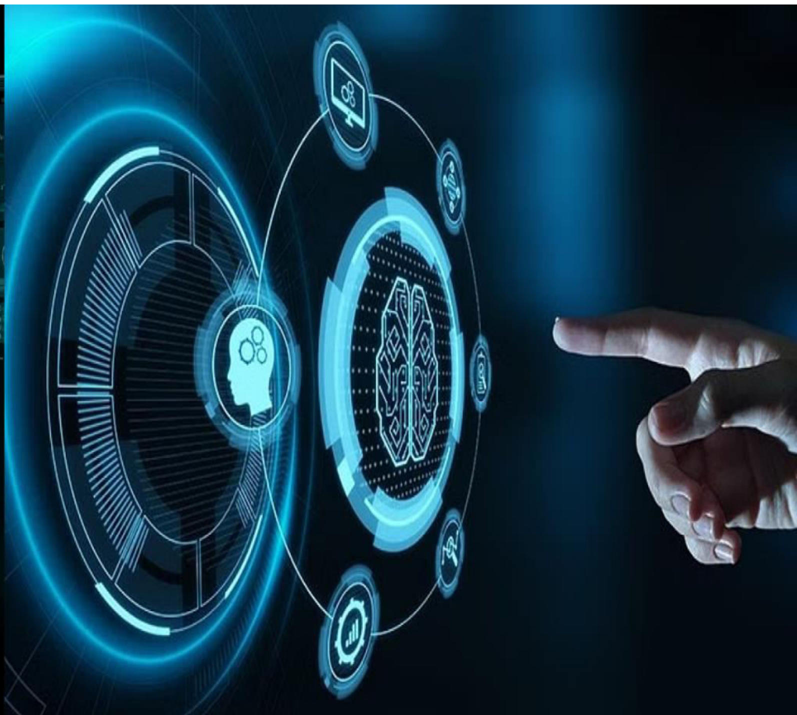

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Diagnosis of Rotor End-Ring Broken Fault of Three Phase Squirrel Cage Induction Motor

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ABSTRACT: The paper discusses development and practical implementation of a novel recent advanced digital signal processing technique (DSPT) for effective fault diagnosis and performance determination on rotor broken end-ring of three phase induction motor. The electrical signals are gained and processed digitally to obtain the machine status. This paper presents a reliable, advance and most accurate rotor fault diagnosis system using an ordinary hardware and LABVIEW software. The National Instruments DAQ used have 32 AI (16-bit, 2 Ms/s). This paper presents the system and results to monitor rotor winding faults using motor current signature analysis. The three phase current and voltage signals are acquired in healthy and faulty rotor conditions at load conditions. A number of tests carried out on small-size 415 V, 2.1 A, 1.00 HP, 1440 rpm three phase induction motor highlight the excellent promptness in detecting faults, and very good diagnostic performance. This paper present the digital signal analysis for rotor broken end-ring fault of the motor.

KEYWORDS: Rotor Faults, broken end-ring, Motor current signature analysis.

I. INTRODUCTION

Three phase induction motor is simple in construction, robust, cheap, minimum maintenance costs so it is economical for the industrial applications. While operating induction motor various stresses like thermal stress, mechanical stress, electrical stress etc are produced which are acting on the parts of the motor so it may fail. There are various on-line and off-line methods to detect the faults occur in three phase induction motor. In off-line method, the motor is switched off from the supply and in on-line method the fault is detected when the motor is operating. In off-line method there is a huge revenue loss and time consuming so the researchers are attracted to on-line condition monitoring and faults diagnosis. The induction motor transforms electrical energy to mechanical energy at high efficiency between 85 % - 97 %. There is no electrical connection between stator and rotor very small maintenance costs. As per IEEE literature review the various faults occur in the motor is as, Bearing faults 42 %, Stator faults 28 %, Rotor faults 8 % and other faults 22 %. The stator winding faults is one of the major faults in the motor so it essential to diagnose the stator winding faults.

A. Rotor Faults:

Squirrel cage rotor winding is in the form of aluminium or copper bars which are short circuits at both the ends by the end rings of same material. The bars are thicker in size, the rotor bar current enters in the end rings so end rings are bigger in size than the rotor bars.

B. Causes of Rotor Faults:

There are many reasons for which rotor faults may occur in an induction motor. The main causes of rotor broken bar of an induction motor are as below:

manufacturing defects, rotor asymmetry may occur during manufacturing process.

thermal stresses, in rotor bars and end ring the heavy current is flowing which produce thermal stress which can damage the rotor bar and if one rotor bar damage the other rotor bars may damage.

Mechanical stress, heavy rotor current produces more mechanical stress on rotor which can damage the rotor bars

Frequent starts of the motor at rated voltage, the frequent start of the motor overheat the rotor which can damage the rotor bars.

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Due to fatigue of metal of the rotor bar.

C. Broken End-Ring Fault:

The rotor bars are shorted at both the ends of rotor by the end-ring. The material for rotor bar and end-ring is same. So rotor current is very large as compared to stator current. All the rotor bar current are entering the end-ring. So, the end-ring current is very large than the rotor bars. To carry this large amount of current, the size of end rings is made bigger than the bars.

The broken bar fault produces a series of sideband frequencies in the stator current signature given by

$$f_{brb} = f\,(1 \pm 2\,k\,s)$$

where f = supply frequency, H_z

s = slip, p.u. and

k = integer, 1, 2, 3,

The lower side band frequency at f (1–2s) is the strongest which will cause ripples in torque, and speed at a frequency of 2sf and this in turn will induce an upper side band frequency at, f (1 + 2s) and this effect will continue to create the series of sideband frequency as per above equation. The magnitude of the lower sideband frequency is used as an indicator of rotor broken bar fault

D. Experimental Set-up

The 3- phase Current & voltages are sensed by current & voltage sensors. The signals from CT's & VT's are given to NI-DAQ for processing. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution. Data acquisition (DAQ) is the process of measuring an electrical quantities voltages, and currents. DAQ is interfaced with computer to obtain the signal in digital form. The experimental setup consists of:

1. Current Transformer: Ratio 120/0.2 A, 600 V, 50 H_z, Burden 2.5 VA, Class 0.5, Gilbert & Maxwell Make
2. Voltage Transformer Specifications: Ratio: 415/5 V, Burden: 0.5 VA, Class: 1.0/0.5, 1-Phase, 50 Hz. Gilbert & Maxwell Make.
3. AQ: 32 AI (16-bit, 2 Ms/s)
4. The motor nameplate specifications Volts: 415, HP/kW: 1/0.75, Hz: 50, Amp: 2.1, Pole: 4, Class of insulation: B, Duty: S1, Connection: Star, Frame: 80, Make: Link Servo-Systems Pvt. Ltd.

The highly sensitive three CT's and VT's are used to monitor the current input and supply voltage respectively.

II. RELATED WORK

H. Douglas, P. Pillay, et al, [1] proposed the technique centers around the ex-traction and removal of the fundamental component of the current and analysing the residual current using wavelets. The broken rotor bars faults are detected by the de-composition of the start-up current transient. This method is not load dependent and effective on small lightly loaded machines. There is no need for speed, torque, or vibration measurement. This method also detect the end-ring faults, bearing failures.

Irahis Rodriguez, Roberto Alves, et al, [2] "Analysis of air gap flux to detect induction motor faults" presents the Motor Flux Signature Analysis to the detection of stator winding failures, broken rotor bars and end ring faults in induction motors. The program developed in LabVIEW to perform data acquisition and analysis is presented. Data is read in real time form the working induction motor, and the program provides three fault indicators were found: rotor bar failure, rotor end ring failure and stator winding turn to turn short circuit.

A. Bracale, G. Carpinelli, et al, [3] the traditional diagnostic techniques are based on the stator current or torque spectral analysis by FFT-based methods. However, the spectral leakage phenomena of FFT cannot estimate accurate spectral components; and its frequency resolution problems limits a fast detection of the fault condition. To overcome these problems, author has presented a high resolution method, the ESPRIT method, to make the fault identification faster and accurate. The rotor bars broken faults are diagnosed using this method.

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Alejandro Ordaz-Moreno, Rene de Jesus Romero-Troncoso, et al, [4] presents the online detection of broken rotor bars in induction motors during the start-up current transient. The algorithm is based on the DWT analysis of the current transient to compute coefficients WC's and a further mean-square function is applied to a subset of those coefficients to obtain a simple weighting function WFBRB that, according to its value, clearly points the motor condition as either healthy or damaged.

Ioannis P. Tsoumas, George Georgoulas, et al, [5] introduces a technique for the detection of rotor faults based on wavelet analysis of the stator phase current. The measured stator phase current is filtered through a complex wavelet. The approach is based on the filtering of the phase current with the complex Morlet wavelet. The modulus of the transform is free from the fundamental supply frequency component, and the fault characteristics is highlighted This is advantages of this method, if the induction machine operates at low slip values, where the characteristic frequency components of the rotor fault are very close to the fundamental frequency component. At the same time, by matching the wavelet function to the frequencies of the faulty components, a narrow band-pass filter at the frequency region of the fault characteristic spectral components is obtained.

III. EXPERIMENTAL RESULTS

It is observed that the LSB and USB is 49.77 Hz and 50.298 Hz respectively. From the stator current frequency spectra LSB and USB are not visible. It is difficult to detect the broken end ring fault at no load condition. It is observed that the LSB and USB is 45.104 Hz and 54.97 Hz respectively. From the stator current frequency spectra LSB and USB are not visible. It is difficult to detect the broken end ring fault at half load condition. It is observed that the LSB and USB is 41.731 Hz and 58.344 Hz respectively. From the stator current frequency spectra LSB is visible and USB is not visible. It is difficult to detect the broken end ring fault at no load condition. The frequency spectra current obtained from the current signal for broken end ring at no load, half load and full load are given. At no load the side bands frequency is very close to fundamental frequency and the amplitudes of the sidebands is quite smaller.

Load conditions	Slip	Fault Frequencies							
		k = 1				k = 2			
		LSB (Hz)	Observation	USB (Hz)	Observation	LSB (Hz)	Observation	USB (Hz)	Observation
No Load	0.0026	49.77	Not Visible	50.298	Not Visible	49.51	Not Visible	55.24	Not Visible
Half Load	0.0493	45.104	Not Visible	54.97	Not Visible	40.17	Visible	59.9	Not Visible
Full Load	0.083	41.731	Visible	58.344	Not Visible	33.42	Not Visible	66.65	Visible

Table 1: The expected fault frequencies with broken end ring various load conditions

It can be observed that the detection of the searched slip frequency sideband at no load is too difficult, since the current in the end ring is small. At half load, only 40.17 H_z frequency is visible and other frequencies for the same side band fault frequencies may not be visible. Thus, it is slightly difficult to detect broken end ring fault at half loaded condition. The side band frequency depends on the speed of the motor with load.

It is observed that fault frequency side bands for end ring are visible only at load 80% or at full load. The faults frequency of 41.731 H_z and 66.65 H_z at full load are visible. So it is difficult to detect end ring broken fault. It is difficult to detect whether the fault is broken bar rotor or broken end-ring

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Frequency spectra for above results are as below:

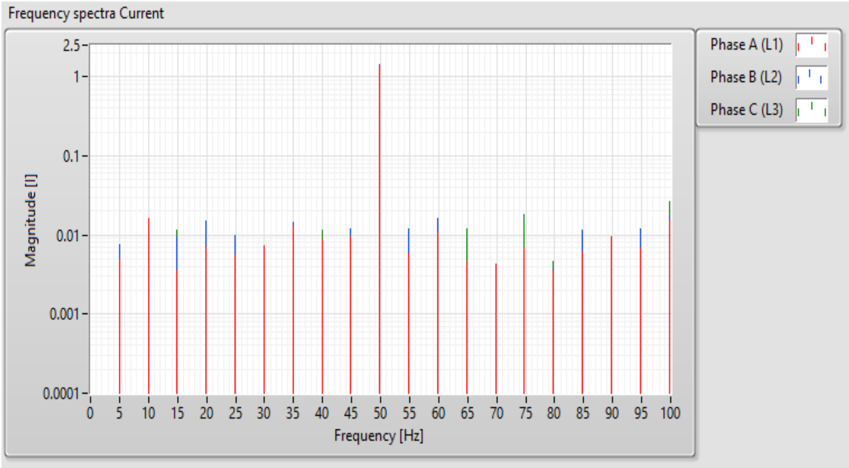

Fig.1. Frequency spectra at no load condition

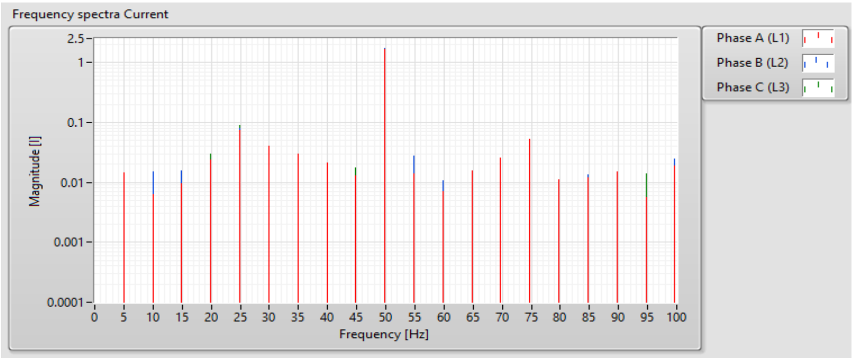

Fig. 2. Frequency spectra at half load condition

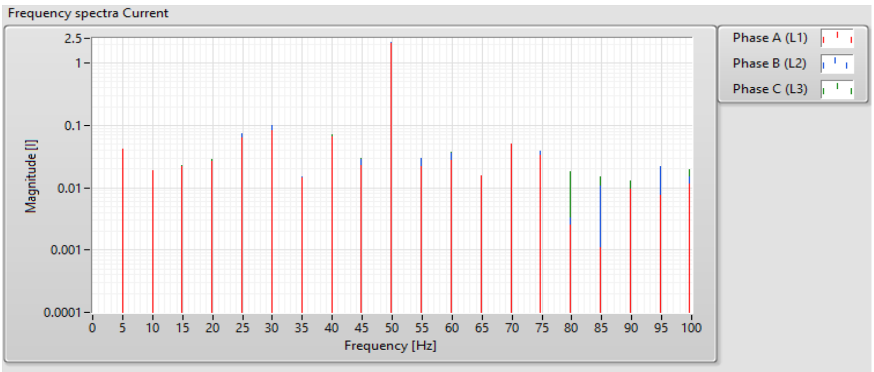

Fig. 3. Frequency spectra at full load condition

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IV. CONCLUSION AND FUTURE WORK

In three phase squirrel cage induction motor major faults are stator and bearing faults. As per literature review, rotor faults are about 8%. Though the faults are less in percent, it is essential to diagnose the rotor faults, as the production of the industry is depend on the induction motor operation. If the I.M. fails, the production chain gets disturbs and cause huge revenue loss.

The proposed system can be used to detect the rotor broken bar faults and the stator winding related faults. This technique gives more accurate results, which depends on accuracy of sensors. As the sensors are involved for the accuracy, it increases the system cost.

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