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Diagnosis of Rotor Fault of Three Phase Squirrel Cage Induction Motor

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ABSTRACT: During the operation of three phase induction motor, there are slight changes in supply and motor winding parameters, the abnormality condition if occur then the motor may deviate from its expected performance. During operation, the parts of the motor are under various stresses such as mechanical stress, electrical stress, and thermal stress. These stresses produce the bad effect on the motor parts. Due to these stresses the motor faults get initiated and if not detected and corrective action is not taken, then the fault progress and induction motor gets fail. The operators of motors are under continual pressure to reduce maintenance costs and prevent unscheduled downtimes, which result in loss of production and financial income. This arises the need for monitoring the condition of motors and planning the maintenance based on an indication that a problem is about to occur. Rotor fault diagnosis implies monitoring various parameters of a machine in order to assess the health of the machine.

During past twenty years there has been huge amount of research into the creation of new rotor fault diagnosis techniques. New methods have been developed by the researchers which are now being used by the operators and research is continuing with the development of new and alternative online diagnostic techniques. To diagnose the different types of motors faults, generally the technique often called "Motor Current Signature Analysis" is used. The rotor current fault frequencies are reflected into the stator currents. From the stator current, the fault frequencies are detected to confirm the faults.

The objective of the rotor fault diagnosis techniques is to detect fault frequencies for various faults and predict the faults in early stage and take corrective action before the motor complete shut down and revenue loss. The project work is carried out by developing the real time online rotor fault diagnosis technique based on MCSA technique. The rotor fault diagnosis system is generally based on MCSA technique. From outcome of MCSA technique, it is found that this system is more effective and able to detect various faults in early stage in induction motor.

KEYWORDS: Rotor fault diagnosis, Motor current signal analysis (MCSA), rotor broken bar, fault frequencies

I. INTRODUCTION

The detection of motor condition prior to a complete failure provides an opportunity for maintenance to be performed on a scheduled routine. Safety, reliability, efficiency and performance are some of the major concerns of induction motor applications. Due to high reliability requirements, and cost of breakdown, the issue of rotor fault diagnosis of induction motors and diagnosis is of increasing importance. There are two types of rotor fault diagnosis systems for the fault diagnosis, off-line and on-line schemes. Online condition monitoring system requires sensors which are expensive that increases the cost of online technique. Also expert is required for online diagnosis. The requirement of sensors is deduced which reduces the cost of offline diagnosis system making it useful for under knowledge persons.

Objective of the work is to develop rotor fault diagnosis technique. The squirrel cage induction motor is chosen as rotating machine for the fault study and monitoring applications.

Sometime it is difficult to monitor the conditions of three phase induction motor by using the traditional system as fault frequencies and symptoms are very close to one another for some faults. The MCSA based method is most accurate method for rotor fault diagnosis.

II. BROKEN ROTOR BAR

The experimental setup is prepared to detection in broken rotor bar. Generally broken rotor bars do not cause immediate induction motor failure but if it is not detected at initial stage then the serious mechanical damage to insulation and winding of motor may take place. To avoid the heavy repair cost and breakdown time, it is required to detect the rotor faults at initial stage. The broken rotor bars or end rings may be due to following reasons:

1. Imperfections in rotor manufacturing process. The uniform air-gap along the axial length of the rotor the bars should place uniformly. If there is imperfection in the rotor manufacturing process then the rotor winding may damage. Direct on-line starting or frequent switching.
2. The DOL starting is applied to motor having rating up to 5.00 hp. The big rating motors started by some other means to reduce the starting inrush current. In DOL start method, the rotor current is very high so the rotor may heat up which may damage the rotor bars or end rings.
3. Pulsating mechanical loads if applied to the motor the high mechanical stress act on the rotor which may fail the motor.

The researchers have developed various techniques to detect the motor faults as the failure rate is more. The researchers are less attracted towards the diagnosis of rotor faults. Since last decade, researchers have developed the various techniques to diagnose the rotor faults. The various signal processing techniques that can be used for diagnosis of rotor bar faults are given below:

- Fast Fourier Transform (FFT)
- Short Time Fourier Transform (STFT)
- Wavelet Transform (WT)

The success of these techniques depends upon locating by spectrum analysis with specific harmonic components caused by faults. Due to broken rotor bars, the side band frequencies appears near the fundamental frequency.

Generally, a decibel (dB) versus frequency spectrum is used to detect the current signature patterns that are characteristic of different faults. The three phase supply connected to the stator, produce a rotating magnetic field which rotate at synchronous speed. The rotating magnetic field induces rotor voltages and currents at slip frequency, and this produces an effective three phase magnetic field rotating at slip frequency with regard to the rotor. If rotor asymmetry occurs then there will be negative sequence backward rotating field at slip frequency with respect to the forward rotating rotor. This backward-rotating field induces a voltage in the stator at the corresponding frequency. Thus, a related current, which modifies the stator-current frequency. Under three phase balanced supply conditions, the synchronous speed of forward rotating magnetic field is produced in induction motor which rotates at synchronous speed.

$$N_s = 120 p / f_s, \text{ rpm}$$

$$\text{Slip, } s = (N_s - N_r) / N_s$$

$$\text{Slip speed} = N_s - N_r$$

$$\text{Rotor speed, } N_r = N_s (1 - s)$$

The backward rotating magnetic field speed produced by the rotor due to broken bars and with respect to the rotor is: $= N_r - s N_s$

$$N_{sb} = N_s (1 - 2 s)$$

Above equation in terms of frequency, $f_{brb} = f_s (1 - 2s)$

Therefore, twice slip frequency sidebands occur at $\pm 2s f_s$ both side of the supply frequency

$$f_{brb} = f_s (1 \pm 2s).$$

The lower side band and upper side band frequency produce oscillations in speed and torque so more mechanical stress on the bearings. The sequence of side band frequency can be observed by following relation

$$f_{brb} = f_s (1 \pm 2k s) \quad \text{where, } k = 1, 2, 3$$

III. LITERATURE SURVEY

Tabatabaei-Yazdi, and C Grantham, [1], the author has developed a scheme based on Digital Signal Processor (DSP) for the on-line real time monitoring performance and the real time parameter determination of three phase induction motors. A software based algorithm is used to measure the performance and calculate the parameters of the three phase induction motor in real time. Giovanni Betta, Consolatina Liguori, et al, [2] used a DSP-based measurement system to the vibration analysis on rotating machines. The Vibration signals are on-line acquired and processed to obtain a continuous monitoring of the machine status. The author presented in detail the approach followed to built up fault and unfault models together with the hardware and software solutions. Behrooz Mirafzal, Richard J. Povinelli, et al, [3] the proposed technique is approach based on the concept of magnetic field pendulous oscillation, which occurs in induction motors under faulty conditions. It is a robust inter-turn fault detection technique. Author has shown that the from the experimental results if circulating current level in the shorted loop increases beyond the phase current level, an inter-turn fault can be easily detected using the proposed approach. Jose Antonino Daviu, Selin Aviyente, et al, [4] present a novel algorithm for the automatic diagnosis or rotor bar failures in induction motors. The developed algorithm is based on a transient based diagnosis methodology. The algorithm relies on the ex-traction of fault related DWT based features from the original start -up current signals. A single phase current, which can be measured in a non-invasive way, is enough for its application. S. M. A. Cruz and A. J. M. Cardoso, [5] the proposed system developed to the diagnosis the rotor faults in closed-loop induction motor drives. Different control strategies used are the direct torque control and the indirect rotor field oriented control. A de-tailed analysis of different motor/controller variables enlightens about the behaviour of these systems under the presence of rotor faults

IV. METHODOLOGY

The 3-phase induction motor of specifications is:- 415 Volt, 1 HP, 50 Hz, 1440 rpm, 4 pole, 2.1 Amp., 80 turns per coil, 2 coils per phase (160 turns per phase) with suitable stator winding turns are taken out for making the winding faults is used for the experimentations.

1. Motor under test with loading: 415 Volt, 1 HP, 50 Hz, 1440 rpm, 4 pole, 2.1 Amp., 80 turns per coil, 2 coils per phase (160 turns per phase)
2. Voltage Transformers: Single phase 600 V, 50 Hz, Ratio- 415/5 V, burden-0.5 VA, Class-1.0/0.5
3. Connecting board
4. Power Quality Analyzer: Hioki 3198
5. DAQ: 32 AI (16-Bit, 2 MS/s)
6. Clamp-on Current sensors: Hioki 9694 Clamp-on sensor, 5A, 300V, output 10mV/A

The motor current signal analysis (MCSA) and its measurement is processed with various devices and the acquired data can be retrieved with the help of Lab-VIEW software. To obtain the sample current value in the data acquisition card NI-DAQ is used, that gets the value from the motor under various loading conditions. NI-DAQ is a data acquisition (DAQ) device that gives the ability to measure and analyse on-line signals. 32 AI (16-Bit, 2 MS/s), 4 AO (2.86 MS/s), 48 DIO USB Multifunction I/O Device-The USB 6363 offers analog I/O, digital I/O, and four 32 bit counters/timers for PWM, encoder, frequency, event counting, and more. On board NI STC3 timing and synchronization technology delivers advanced timing functionality, including independent analog and digital timing engines and retriggerable measurement tasks. The USB 6363 is well suited for a broad range of applications, from basic data logging to control and test automation. The included NI DAQ mx driver and configuration utility simplify configuration and measurements. The speed is measured by digital tachometer.

V. EXPERIMENTAL RESULTS

ROTOR ONE BROKEN BAR FAULT

The expected fault frequency current obtained from the current signal by calculation for one bar broken at free running, 1/2 load and 4/4 load are given in table below. At no load the side bands frequency is very close to fundamental frequency and the amplitudes of the sidebands is quite. It can be observed that the detection of the searched slip frequency sideband at no load is too difficult, since the current in the rotor bars is small. It is also observed that even at 1/2 load side band fault frequencies may not be visible because again their magnitude is low. Thus, it is slightly difficult to detect broken rotor bar fault at half loaded conditions also. The side band frequency is depend on the speed of the motor with load. The rating of the motor used for the experimentation is low, its speed with load is dropped considerably so at 1/2 load the side band frequencies are visible. It is observed that fault frequency side bands for one broken bar are visible only at load 80 % or at full. The faults frequency observations for one broken bar rotor are shown in table below:

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	50.55	Not Visible
1/2 Load	0.0493	45.104	Visible	54.97	Visible	40.17	Visible	59.9	visible
4/4 Load	0.083	41.731	Not Visible	58.344	Visible	33.42	Visible	66.65	Visible

By the calculation rotor fault current frequencies are shown in above table at various conditions. It is observed that at free running speed is 1496 rpm and the LSB and USB is 49.77 Hz and 50.298 Hz respectively. These LSB and USB fault frequencies may not be visible. It is difficult to identify the one rotor bar broken fault at free running condition. At ½ load speed measured is 1426 rpm and the LSB and USB is 45.104 Hz and 54.97 Hz respectively. These LSB and USB fault frequencies are visible. It is easy to identify the broken one rotor bar fault at 1/2 load condition. It is observed that at 4/4 load speed is 1380 rpm and the LSB and USB is 41.731 Hz and 58.344 Hz respectively. These LSB is not visible and USB is visible. It is difficult to detect the broken one rotor bar fault at 4/4 load condition.

Frequency spectra for above results is given below:

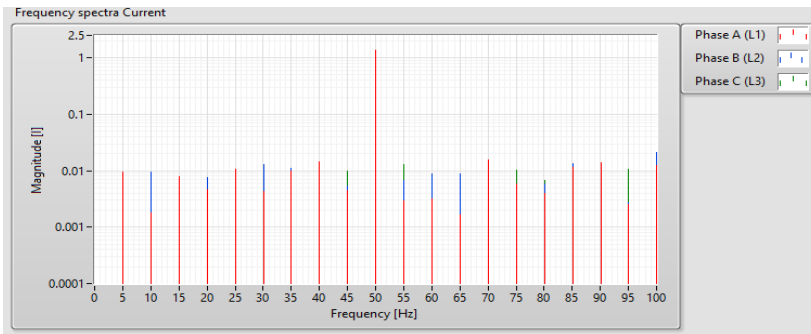


Fig. 1. Frequency current spectra for no load broken rotor bar fault

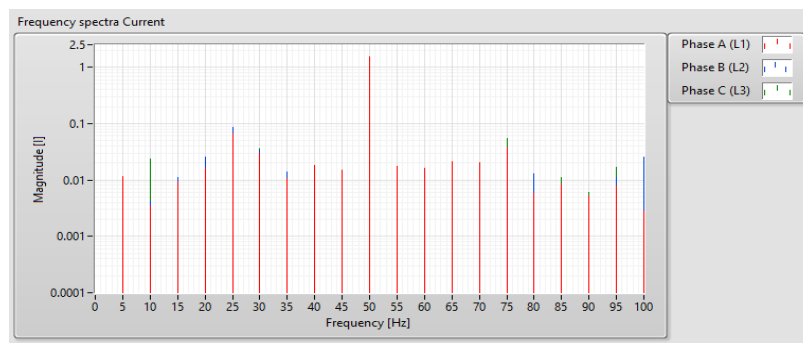


Fig. 2. Frequency current spectra for 1/2 load broken rotor bar fault

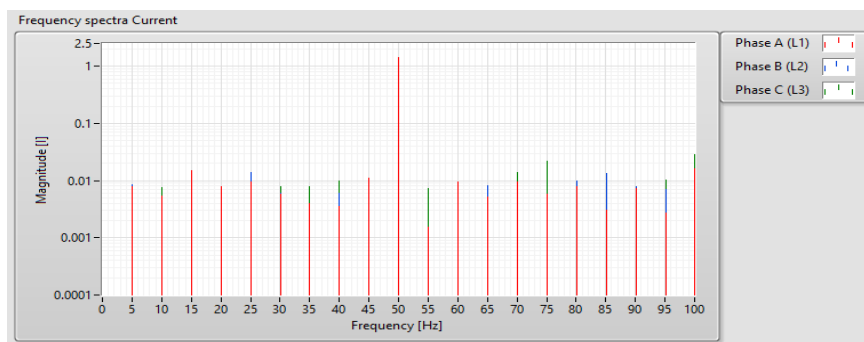


Fig. 3. Frequency current spectra for 4/4 load broken rotor bar fault

VI. CONCLUSION

The sideband frequency reflected in stator current due to, rotor broken bar, depend on speed. At free running, the speed is 1496 rpm is measured by digital tachometer. So, slip is nearly equal to zero. Therefore, no side-band frequency is observed in stator current at free running condition. As load increases, the speed decreases and slip increases. So, sideband frequency is observed in stator currents of all the three phases.

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