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MCSA BASED MECHANICAL FAULT ANALYSIS OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

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***Abstract*—This paper deals with mechanical fault analysis of three phase induction motor using Motor Current Signature Analysis. This is a reliable technique that can be used to monitor the health of three phase induction motor. Three phase induction motor is used to find the Current Signature before and after the fault occurs. The FFT of Current signal is analyzed using Advanced Signal processor to find harmonics present before and after the fault occur. This data is used to detect the mechanical faults way before they cause harm to the motor and power system. Ball bearing fault is created practically to find the harmonics components in the current drawn. Most of the practical results match with the theoretical values obtained from the literature.**

Keywords*—*three phase induction motor; ball bearing fault; FFT; harmonics; power spectrum.

I. Introduction

Induction motors are complex electro-mechanical devices utilized in most industrial applications for the conversion of power from electrical to mechanical form. Induction motors are used worldwide as the workhorse in industrial applications. Such motors are robust machines used not only for general purposes, but also in hazardous locations and severe environments. General purpose applications of induction motors include pumps, conveyors, machine tools, centrifugal machines, presses, elevators, and packaging equipment. On the other hand, applications in hazardous locations include petrochemical and natural gas plants, while severe environment applications for induction motors include grain elevators, shredders, and equipment for coal plants. Additionally, induction motors are highly reliable, require low maintenance, and have relatively high efficiency. Moreover, the wide range of power of induction motors, which is from hundreds of watts to megawatts, satisfies the production needs of most industrial processes.

Induction motors are exposed to dirty environment which can cause wear and tear of motor components. . A motor failure that is not identified in an initial stage may become catastrophic and the induction motor may suffer severe damage. Thus, undetected motor faults may cascade into motor failure, which in turn may cause production shutdowns. Such shutdowns are costly in terms of lost production time, maintenance costs, and wasted raw materials.

Ball bearing and stator winding faults are discussed in the following section.

II. Literature Review

A. Faults in Induction Motor.

A large survey on faults in the motor is carried out by Electric Power Research Institute (EPRI), 1985.[1]The survey contains 5000 motors, 97% of those three phase squirrel cage induction motors. The most common fault is related to worn motor bearings. The detection of motor faults at their incipient stage is of prime importance to any industrial plant. In 41% of cases it is ball-bearing fault, 27% of the cases it is stator insulation fault. These two faults constitute almost 70 % of induction motor mechanical fault.

B. Techniques used in faults detection.

Several fault detection and identification techniques are based on stator current spectral signature analysis, which uses the power spectrum of the stator current to detect broken rotor bar faults. These fault detection techniques are based on the magnitude of certain frequency components of the stator currents. Specifically, a Fast Fourier Transform (FFT) of the current is taken.

The analysis of the negative sequence components of the stator current is another well-known. technique used to detect inter-turn short circuits. This technique is based on the detections of the asymmetries produced by a faulty motor with shorted turns in the stator winding.

Other techniques include vibration analysis, torque profile analysis, temperature analysis, and magnetic field analysis. additional electrical and mechanical installations, and frequent maintenance

III. METHODOLOGY

A. Experimental setup.

A three phase squirrel cage 0.5 HP induction motor is used for the project. National Instruments Data Acquisition System is used to process the current signal. Current sensor produces the output as voltage, which is calibrated in the LabVIEW platform. LabVIEW platform is used to create an interface to show the different current signal and FFT of the signal. The experimental setup is shown in the schematic below.

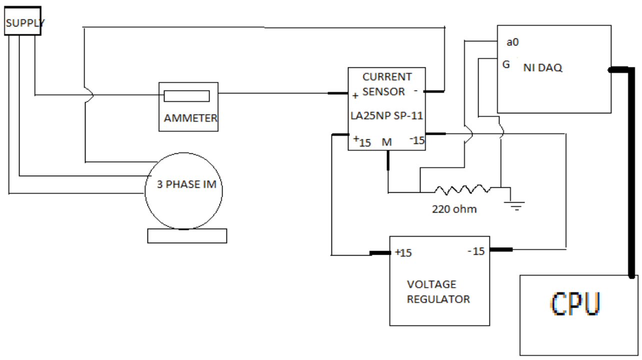

Fig.1 Schematic of the Experimental Setup.

B. Fault Creation

The challenging task of the whole project lies in creation of the bearing fault. Ball bearings are made up of hardened steel, which are very difficult to be damaged. Most of the methods in literature included drilling a hole, which doesn't replicate the natural fault.

In order to create a fault which is close to the natural fault, ball bearing with crown cage is used. Ball bearings which have crown type cage can be dissembled and assembled back. This helped in creating fault to outer surface of the inner race. The fault is created by grinding the outer surface to recreate the natural fault in a ball bearing inner race. A considered amount of surface is grinded for creating a significant eccentricity in the air gap. This inner race is assembled back in to the ball bearing and the bearing is installed in the motor.

Fig 2. Fault created on inner race of bearing.

C. *Theoretical formula*

Different formulae are used from the literature to calculate the harmonic components corresponding to a particular fault. Shown below is the formula that is used to find the theoretical frequency components of bearing fault.

$$F_v = n/2\ F_r\ [\ 1 + B_d\ /\ P_d \cos\beta] \qquad (1)$$

where n= number of bearings, F_r= mechanical speed of motor, B_d= ball diameter, P_d= pitch diameter of bearing, cosβ= contact angle of ball on race.

Here F_v is the vibration frequency component. To find the frequency component in current, below formula is used.

$$F_{bg} = |\ F_s \pm F_v| \qquad (2)$$

IV. RESULT ANALYSIS

Ball bearing fault is created and the result is analyzed in LabVIEW. Below is the graph of the current signal generated. The current signal is not pure sine wave as the top of the wave is not smooth. This is due to the result of non-eccentricity in the created in the air gap due to the ball bearing fault. The harmonic components in this wave is found out by doing FFT of this wave. This task is done in LabVIEW signal processor block.

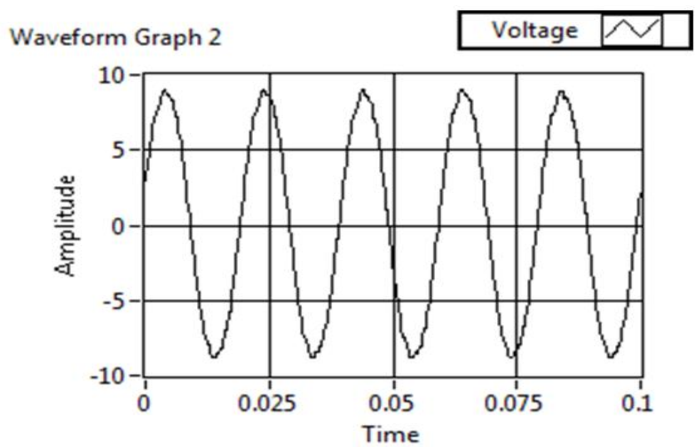

Fig. 3 current signal of motor with ball bearing fault.

The FFT of the current signal is shown below. The FFT graph shows different harmonics other than fundamental harmonic component. Power spectrum is also seen to find the harmonic components present. Fig 4 and Fig 5 show the FFT and Power spectrum of the current signal

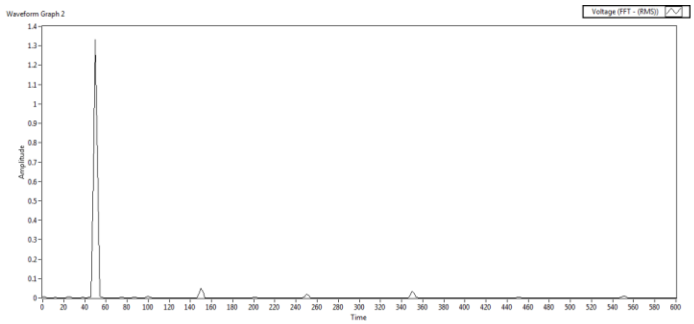

Fig 4. FFT of the current signal drawn by faulty motor

The FFT graph shows different harmonics other than fundamental harmonic component. Power spectrum is also seen to find the harmonic components present.

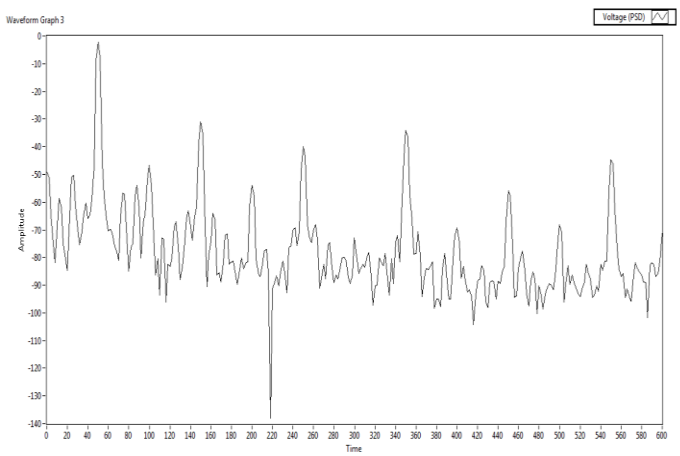

Fig 5. Power spectrum of current signal drawn by faulty motor

Spikes in the above figure show the harmonic component present. The obtained theoritical values using equation (1) and

Table 1. theoritical calculations.

m	F_l	F_u
1	75	175
2	199	299
3	323	423
4	448	548
5	572	672
6	697	797
7	821	921
8	946	1046
9	1070	1170
10	1195	1295

In the above table, Harmonic frequency components at different value of m is calculated. These values are compared with the practical values observed. All of these frequency components may not be observed due to limited sampling frequency. To find very slight variation in frequency components in power spectrum, high sampling rate is used.
Below is the table which shows the frequency component observed and compared it with theoretical value found.

Frequency observed	Conclusion after comparison with theoretical values
170 Hz	It is approximately equal to the theoretical value of 175 Hz. 199 Hz component is not observed due to sampling rate constraint.
330 Hz	It is approximately equal to the theoretical value of 323 Hz. 299 Hz is not observed due to sampling rate constraint.
570 Hz	It is approximately equal to the theoretical value of 573 Hz. 548 Hz is not observed due to sampling rate constraint.
660 Hz	It is approximately equal to the theoretical value of 672 Hz. 697 Hz is not observed due to sampling rate constraint
840 Hz	It is approximately equal to the theoretical value of 821 Hz. 797 Hz is not observed due to sampling rate constraint
1050 Hz	It is approximately equal to the theoretical value of 1046 Hz. 1070 Hz is not observed due to sampling rate constraint
1170Hz	It is equal to the theoretical value of 1170Hz. 1195 Hz is not observed due to sampling rate constraint
1270Hz	It is approximately equal to the theoretical value of 1295 Hz.

From the above table, we can observe that most of the theoretical result match.

V. CONCLUSION

Induction motor fault detection is an important task, as it may affect the production or output of Industries. The cost of induction motor is not comparable with the lost incurred due to halted production line.
Ball bearing fault is created and the harmonic frequency components are matched with the theoretical values. Most of the results can be used to detect the fault. These results can be stored in the database and a platform to detect the fault can be employed in real-time.

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