Signature Analysis of Vibration in Induction Motor Failure Detection Using LabVIEW

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Abstract-- **Early detection of failures in equipment is one of the most important concerns to industry. Many techniques have been developed for early failure detection in induction motors. There is the necessity of low-cost instrumentation for online multichannel monitoring to provide a reliable continuous diagnosis without needing trained staff. To test the functionality of the proposed vibration analyzer, two experiments to test the functionality of the proposed vibration analyzer, three experiments on 746-W (1-hp) induction motors were carried out. Such experiments are intended to detect motor failures such as unbalance, and looseness. The obtained results show the efficacy of overall system performance. virtual instrumentation system has been widely adopted in test and measurement areas. It has gradually increased addressable applications through continuous innovations and hundreds of measurement hardware devices. The benefits that have accelerated test development are beginning to be used for better monitoring and control of industrial drives.**

Keywords-- *Failure detection, induction motors, vibration analysis, Laboratory virtual instrument engineering workbench (LabVIEW)*

I. INTRODUCTION

In present times, early detection of failures in equipment is one of the most important concerns to industry because it is necessary to guarantee the correct operation of production processes. Vibration analysis in the frequency domain is the most used technique since almost 100% of rotating machine failures are related to a change in its dynamics. In addition, frequency-domain analysis provides more detailed information about the machine state than time-domain analysis [2]. Staff in charge of preventive maintenance usually employs a general-purpose one- or two-channel spectrum analyzer for monitoring vibrations, however, general-purpose spectrum analyzers are expensive, and they are usually not designed for this application; even the few spectrum analyzers, which are designed for vibration monitoring, are not suitable for being permanently mounted to the machine for constant monitoring. For these reasons, low-cost instrumentation for online multichannel measurement and analysis of vibration in the frequency domain is necessary, and this could be fixed to the machine for continuous monitoring to provide a reliable continuous diagnosis without needing trained staff. To improve the performance of the spectrum analyzers proposed up to now, several works have been carried out to introduce new characteristics to the previous designs. In [3], a vibration analyzer where the main contribution is the multichannel measurement and analysis of vibration in the frequency domain, and this could be fixed to the machine for continuous monitoring. A possible improvement of this work is presented in [4], where a spectrum analyzer is proposed using a commercially available acquisition board, which provides a lot of operations under a friendly environment using LabVIEW, but still requiring a PC to work. In [5], an improvement of the technique introduced in [4] is described, in which the main contribution is the reduction of the processing time and the operational cost. High-speed hardware devices were introduced to improve the previous described techniques. In [6], a method that considerably reduces the processing time by using digital signal processing devices for computing the spectrum is reported. A fast Fourier transform (FFT) based analyzer able to adjust its parameter to improve the spectrum estimation using a PC for analyzing the result is introduced in [7]. In [8], a spectrum analyzer for vibration applications based on the work of [7] is proposed. The reported results show different failure detection methods, where the spectrum for each failure is simulated using a signal generator. FFT alone is not the most reliable spectrum estimator because of the undesired leakage effects and the noise susceptibility of the process [11]. A better spectrum estimator, as compared with the FFT, can be used to improve system reliability [12]. The novelty of this work is the development of a highly reliable low-cost multichannel vibration analyzer, based on the time signal analysis (TSA) periodogram. A fast response PC based vibration analyzer which has been developed for fault detection and preventive maintenance of process machinery. The analyzer acquires multiple vibration signals with high

ISSN: 2278 – 909X

resolution, and computes frequency spectra, root mean square amplitude, and other peak parameters of interest. Fast execution speed has been achieved by performing data acquisition and frequency spectrum computation using C language. Vibration signals up to 10 kHz can be analyzed by the spectrum analyzer. Special algorithms, such as window smoothing, digital filtering, data archiving and graphic display
A qualitative comparison of the results obtained using direct FFT and the time signal analysis (TSA) Method have been incorporated.

Fig. 1(a) shows the ideal spectrum of a sinusoidal signal plus white noise. Fig. 1(b) shows the obtained spectrum applying the FFT on the same signal. Fig. 1(c) shows the obtained spectrum of the same signal using the TSA method. In Fig. 1, it can be seen that the leakage and noise effects are reduced using the TSA method instead of just using the FFT From this, it can be concluded that the averaged periodogram is a better spectrum estimator than the FFT itself.

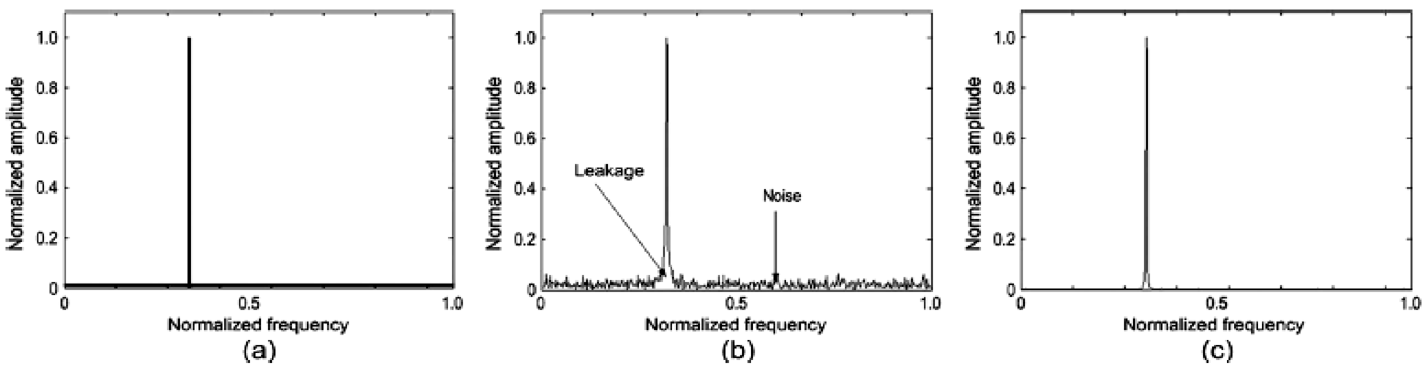


Fig. 1 Spectral estimation of a sinusoidal with white noise. (a) Ideal spectrum. (b) FFT spectrum estimation. (c)Time signal analysis spectrum estimation.

II. Methodology

Methodology contains a whole process for the vibration measurement. The proposed system used NI-9234 compact DAQ for data acquisition. Data acquisition involves gathering signals from measurement sources and digitizing the signal for storage, analysis and presentation on a personal computer (PC). For FFT The LabVIEW analysis virtual instruments (VIs) in the Signal Processing palette maximize analysis throughput in FFT-related applications. The Fourier transform is one of the most powerful signal analysis tools, applicable to a wide variety of fields such as spectral analysis, digital filtering, applied mechanics, acoustics, medical imaging, modal analysis, numerical analysis, seismography, instrumentation, and communications. As FFT alone is not the most reliable spectrum estimator because of the undesired leakage effects and the noise susceptibility of the process . A better Spectrum estimator, TSA Periodogram can be used to improve system reliability.

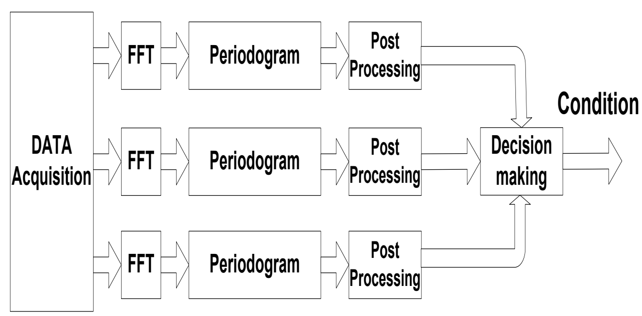


Fig. 2 Block diagram of the general algorithm.

A. Data Acquisition

Real time data acquisition system makes the system more reliable and avoids more complication. It is in great demand due to its fast operation in consumer applications and many industries. These DAQ systems have substituted the various multisite job operations with great ease. A single worker can interact with the machine and collect various data from ongoing work in a single work station. The NI USB-9234 has four BNC connectors that provide connections to four simultaneously sampled analog input channels. Each channel has a BNC connector to

ISSN: 2278 – 909X

which you can connect a signal source. The components of data acquisition system includes-

1. Sensor that converts physical parameters to electrical signals.
2. Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
3. Analog-to-digital converters, which convert conditioned sensor signals to digital values.

B. Fast Fourier Transform

In LabVIEW FFT-based spectral computations assume that the finite block of signal data represents one period of a periodic signal. Equations (1) and (2) show the mathematical definition of the discrete Fourier transform and FFT algorithms, respectively.

$$X(k) = \left| \sum_{n=0}^{N-1} x(n) e^{-2\pi jnk/N} \right| \quad (1)$$

Where

x(n) discrete time signal

X(k) frequency spectrum of the signal x(n)

N Number of Points

N discrete time index

K frequency index

In addition

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} A \\ W_N^k B \end{bmatrix} \quad (2)$$

With

$$W_N^k = e^{-2\pi jnk}$$
$$= Wr + Wk$$
$$= \cos(-2\pi jk/N) - j \sin(-2\pi jk/N) \quad (3)$$

extended signal shows energy spreading into frequencies that were not present in the original signal. To reduce this spectral leakage, use smoothing windows to taper the sharp transitions in the effective signal. You do not typically use windows if you can acquire an integer number of cycles of each frequency component measured or if you are analyzing noise spectra.

C. TSA Periodogram

Periodogram computes the PSD of a time series using the periodogram method according to the following equation:

$$S(f) = \frac{\sum_{k=0}^{w-1} Xt(k) \exp(-j2\pi kf/fs)}{df \times NBW \times N} \quad (4)$$

where *S*(*f*) is the PSD of the time series. *df* is the frequency interval, which is computed as f_s/N. *NBW* is the noise power bandwidth of the window. *N* is the number of frequency bins. f_s is the sampling rate. Before computing the PSD, this VI wraps the original time series X_t to an *N*-point series X_t.

D. Postprocessing Unit

This unit selects the limited spectrum range depending on the analyzed failure, and then, it obtains the weighting parameter to be compared with the calibrated threshold in the decision making unit to give the motor condition as a result.

E. Peripherals

To complement the system functionality, several peripheral units are integrated such as the PC with LabVIEW for motor condition display. The PC controller allows the user to visually display the spectra in a linear or a logarithmic scale.

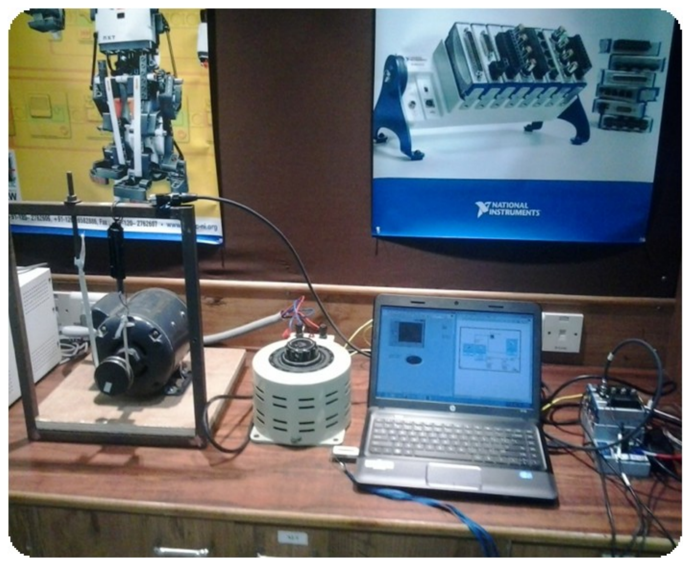


Fig.3 Experimental setup

III. EXPERIMENT SETUP

The experimental system includes a single phase induction motor with a spring balance for variation in loading effects. A vibration sensor (IMI 603C01) for vibration measurement is mounted on the top of the structure because amplitude of the vibration is maximum at the top. Auto transformer is used to test the load conditions at different voltage levels.

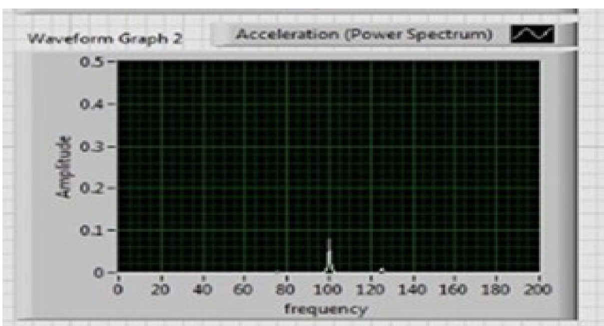
A compact DAQ-9234 is used for acquire the signal from the vibration sensor and send those signal to PC for analysis. The frequency range is selected depending on the kind of failure to be analyzed. To test the functionality of the proposed vibration analyzer, two experiments on 1-hp induction motors

ISSN: 2278 – 909X

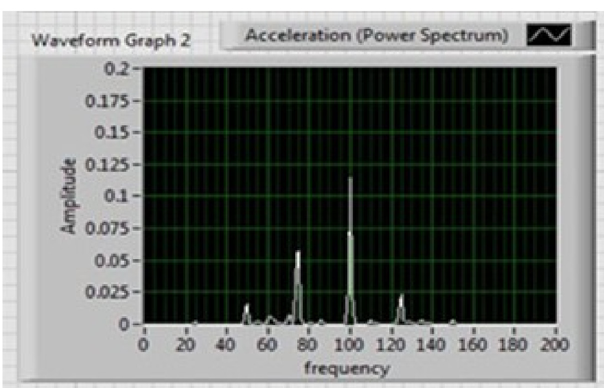
were carried out, as shown in Fig. 3. The experiments are intended to detect motor failures such as, unbalance, and looseness. Next, a brief description of each loading condition and corresponding experimental setup for different failure detection methods is given.

A. Unbalance Loading

For unbalance loading detection, two identical pulleys were used. One of the identical pulleys was modified by adding a small weight on its end, producing a small unbalance on the motor. Fig. 4 shows the analyzed frequency region. Frequency range is selected from 50Hz to 100 Hz. as it contains the fundamental frequency and almost all the visible sideband frequencies. Some important observations from experimental results are given below in Fig. 4. In Fig. 4 (a) vibration spectrum for a balanced motor is shown and in Fig. 4 (b) vibration spectrum for a unbalanced motor is shown vibration has been increased from the balanced loading condition.



(a)

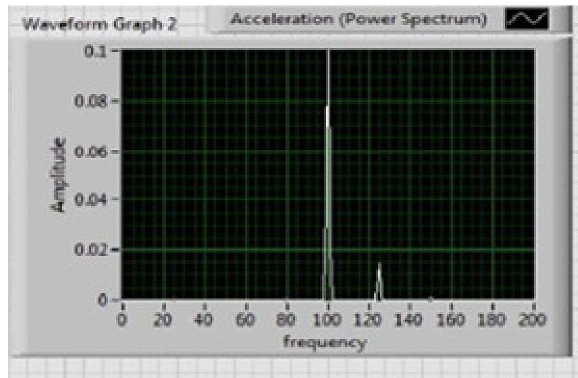


(b)

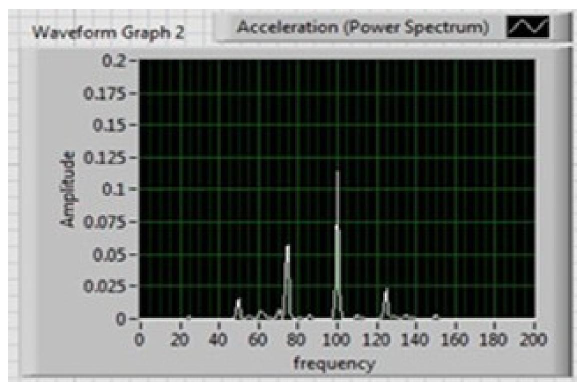
Fig. 4 Resulting vibration spectrum for the (a) balanced motor and (b) Unbalanced motor

B. Looseness of foundation

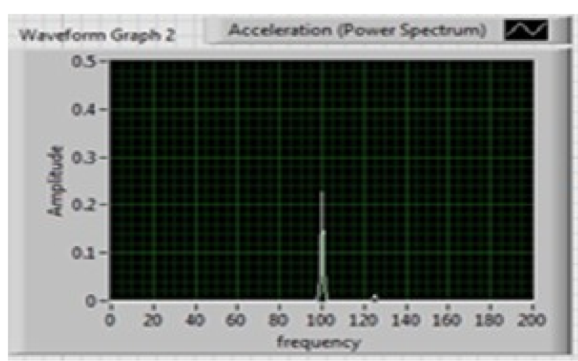
For looseness detection, three different test conditions were considered with 4 screws on foundation. The first test condition considers a healthy motor perfectly fixed (0% of looseness). The second test condition considers a motor with a loose screw at its base (25% of looseness), and the third test condition considers a motor with two loose screws at its base (50% of looseness). The number of periodgrams used for this failure is. Fig. 5 shows the analyzed frequency region. Fig. 5 (a), (b) and (c) shows the analyzed frequency region for perfectly fixed motor, motor with 25% looseness and motor with 50% of looseness respectively.



(a)



(b)



(c)

ISSN: 2278 – 909X

Fig. 5 Resulting vibration spectrum for the (a) perfectly fixed motor (b) (b) motor with 25% looseness, and (c) motor with 50% looseness

IV. CONCLUSION

Recent advances in condition monitoring systems include better diagnostic intelligence, advanced signal processing, and the support of open industry standard networks, making it possible for condition monitoring to be applied in a more cost-effective manner. Plus, scalable designs no longer force a small bakery to use the same condition monitoring package as a large refinery or power plant.

The experimental setup consists of developing a low-cost vibration analyzer able to carry out online monitoring and provide an automatic diagnosis on the motor state. The proposed methodology establishes well-defined detectability regions for healthy and faulty motors due to FFT and periodogram processing, which allows providing a reliable diagnosis on the state of the motor by separating a specific frequency range. In the proposed work two specific failures have been analyzed yet, the system has the capability of analyzing and detecting another kind of failure by selecting the corresponding frequency range on one specific acceleration axis from the vibration spectrum. The frequency range of the failure to be analyzed is determined.

The novelty of this work is due to the applications of LabVIEW, Virtual instrumentation software which is an innovative solution to meet the challenges in the field of test, measurement and control. It combines rapid development software and modular, flexible hardware to create user-defined test systems. Virtual instrumentation delivers, Intuitive software tools for rapid test development. Fast, precise modular I/O based on innovative commercial technologies. A PC-based platform with integrated synchronization for high accuracy and throughput. The investigations can be expanded by introducing Field-programmable gate arrays (FPGAs) which are distinguished by being very fast and highly reconfigurable devices, allowing the development of scalable parallel architectures for multichannel analysis without changing the internal hardware and also improves the system speed.

V. ACKNOWLEDGEMENT

The Author is grateful to HOD ECE, Ajay Kumar Garg Engineering College, Ghaziabad and TIFAC CORE for providing facilities For Conducting the Work.

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ISSN: 2278 – 909X

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ISSN: 2278 – 909X