Research Trends in Fault Detection and Analysis of Three Phase Induction Machine

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***Abstract* – Nowadays, in most of the industrial applications, induction motors are used compared to other types of motors and so fault detection in induction machine is became a major task to avoid the uncertain break downs and delay in production. Here the main concentration is applied on induction motor's vibration monitoring and signal conditioning using various signal processing techniques. This paper deals with the Literature survey of signal processing techniques (DFT, FFT, STFT, and DWT) used for various types of fault detection and for vibration signal's analysis (on time and/or frequency domain). The evaluation of the signal processing technique and platform mostly used to achieve above target has been proposed. The performance analysis of DWT technique in terms of wavelet function, level of decomposition, sampling frequency and hardware requirements (FPGA, LABVIEW and MATLAB).**

Keywords – DFT-Discrete Fourier Transform, FFT-Fast Fourier Transform, STFT-Short Time Fourier Transform, DWT-Discrete Wavelet Transform, and FPGA- Field Programmable Gate Array.

I. INTRODUCTION

Any industrial application without rotating equipment is just like an impossible. For example: bearing or motors or turbines or engines etc. Among all, the motors are mostly used in industrial application to convert an electrical energy to mechanical energy. These motors consume 60% of total energy produced in industries. Nowadays low-cost induction motors are used in industries to achieve maximum profits and annual targets. But these low-cost induction motors works on their non-security margins. Means probability of faults increases. Here, mainly faults of an induction motor can be classified into two main divisions: electrical faults and mechanical faults. Electrical faults: Air gap eccentricity, shorted turns and phase lose. Mechanical faults: Loose mounting, load unbalance and bearing faults.

Nowadays, Maintenance programs are scheduled periodically to avoid uncertain breakdowns and achieve maximum production on demand without uncertain delay. But it is still not an optimum solution to predict precisely the occurrence of maintenance. Also, sometimes we are not able to know that which equipment is running on its worst condition or healthy condition.

Generally, the Motor Current Signature Analysis (MCSA) and vibration analysis techniques are used for signal conditioning and fault detection. Motor Current Signature Analysis (MCSA): in this technique motor's current harmonics is analyzed which is directly related to rotating flux component, generated by fault in motor [2]. Vibration analysis: in this technique vibration sensor is mounted on motor and vibration signals are monitored by software and converted into data file and then fault detection is performed by analyzing that data. And before this analysis we needs to identify the type of the signal with which we are going to deal. Signal can be classified mainly into two main parts: Deterministic types of signals or Non-deterministic types of signals.

Deterministic signals: signals whose future and past values can be predicted from few experimental data or signal which can be expressed or presented by some mathematical equation. These types of signals can be further classified as: 1. Periodic signals: signals in which some specific amplitude value repeats over some fixed periods, these signals are called periodic signals. 2. Non periodic signals: signals in which specific amplitude values doesn't repeat over some fixed periods, these signals are called non-periodic signals.

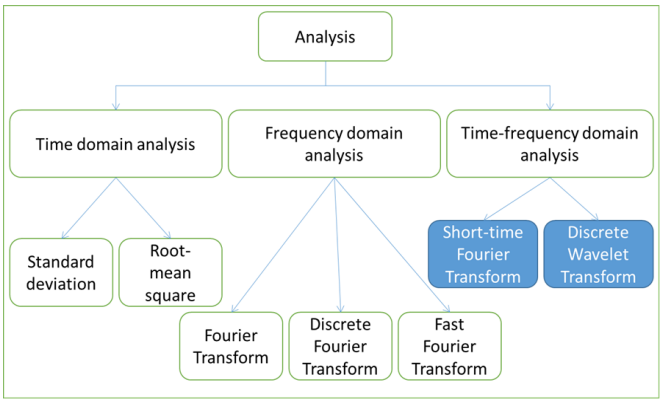
Non deterministic signals: signals whose future and past values can't be predicted from few experimental data or signal cannot be expressed or presented by any mathematical equation. These signals can be further classified as: 1. Stationary signals: signals whose statistical characteristics (standard deviation or mean or probability density function or cumulative density function or square root of its variance) don't change with time are called stationary signals. 2. Non stationary signals: signals whose statistical characteristics (standard deviation or mean or probability density function or cumulative density function or square root of its variance) change with time are called non stationary signals.

This paper is organized as follows. Section II presents Various Signal Processing Techniques, Section III presents

Various Fault's Detection and Analysis, Section IV presents Various Platforms and Section V presents Conclusion.

II. Signal Processing Techniques

Signal processing techniques are classified according the domain in which analysis is required. For example: time domain analysis, frequency domain analysis and time as well as frequency domain analysis [1].



Time domain analysis: in time domain, analysis of any mathematical function or physical signal is done with respect to time. For example: standard deviation and root mean square function etc.

Frequency domain analysis: in frequency domain, analysis of any mathematical function or physical signal is done with respect to frequency rather than time. 1. Fourier Transform: Fourier Transform represents the signal completely in frequency domain means it represents the whole signal in terms of frequency, amplitude and phase difference. 2. Discrete Fourier Transform: Discrete Fourier Transform converts the whole signal into equally spaced samples or discrete form of Fourier Transform. 3. Fast Fourier Transform: Fast Fourier Transform computes rapidly Discrete Fourier Transform in factor by factorizing DFT into product of spare factors means it reduce the complexity of computation.

Time-frequency domain analysis: in time-frequency domain, analysis of any mathematical function or physical signal is done with respect to time as well as frequency domain.

STFT determines the frequency and phase content of local sections of signal changing with time. Then computes the Fourier Transform of each section details [1].

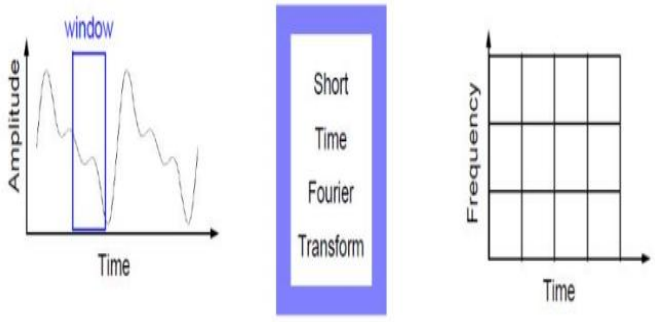


Fig.1: STFT function window and scale structure.

The mathematical definition of the STFT is:

$$STFT(t,f) = \int_{-\infty}^{\infty} x(t) \cdot g(t-\tau) e^{-j2\pi f t}$$

Where STFT(x,t) is the Fourier transform of the signal x(t) which has already been windowed by the window function g(t) with respect to the time shift variable τ.

CWT represents the continuous time signal into wavelets and constructs the time frequency representation. Means it provides time domain as well as frequency domain analysis. DWT discretely samples the wavelets. Means it reduces the computation complexity and raise the resolution [3].

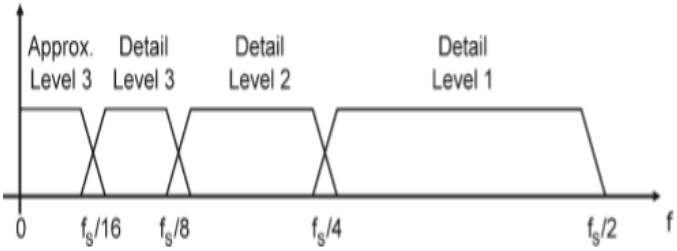


Fig.2: Frequency range devision.

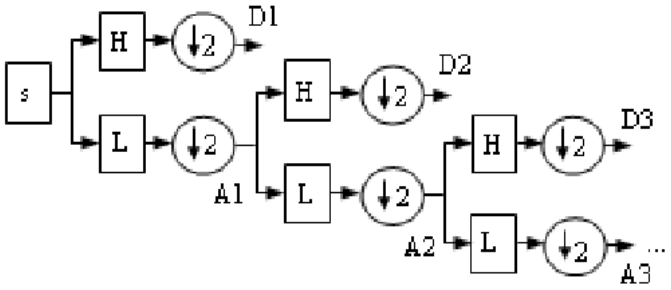


Fig.3: Principle of de-composition.

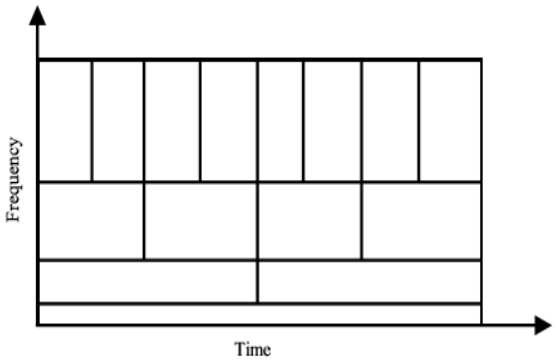


Fig.4: Time-scale representation of a signal.

This can be expressed mathematically as follows

$$Y_{high}[k] = \sum_n x[n] * g[2k - n]$$

$$Y_{low}[k] = \sum_n x[n] * h[2k - n]$$

Where, $Y_{low}[k]$ and $Y_{high}[k]$ are the outputs of the low-pass and high-pass filters respectively, after down-sampling by 2.

III. Fault Detection and Analysis

Load unbalance: it is associated with large increase in motor's running speed frequency as well as raised noise floor [4].

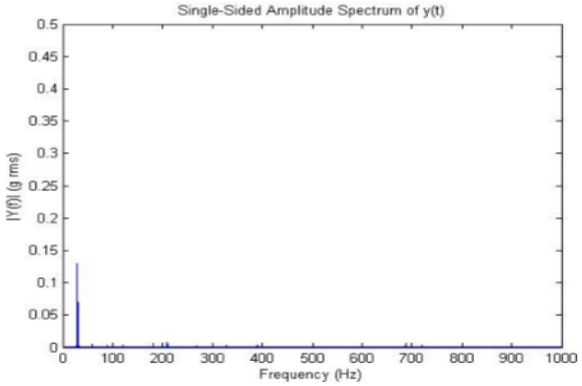


Fig.5: Load un-balance condition.

Mechanical looseness: it will be exactly equals to several multiples of motor's running frequency [4].

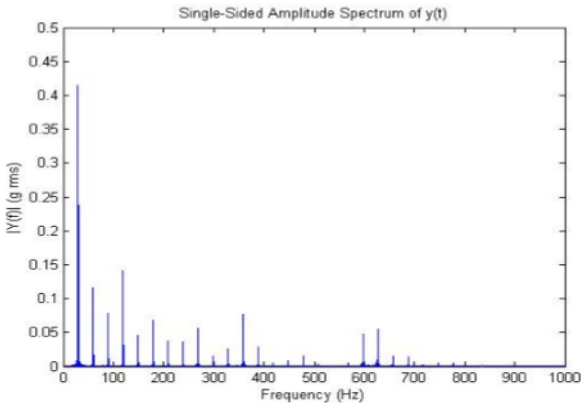


Fig.6: Mechanical looseness condition.

Damaged bearings: different types of damage generates different type of vibration frequency like: Shaft Speed Frequency, Inner race defect frequency (BPFI), Outer race defect frequency (BPFO), Cage defect frequency (FTF), Ball spin frequency (BSF), and Rolling element defect frequency [4].

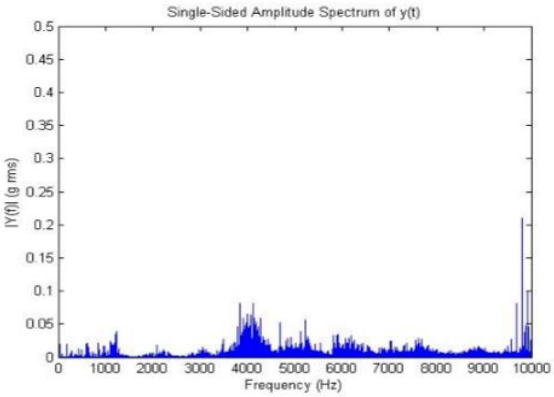


Fig.7: Damaged bearing condition.

Signal analysis: here by de-composing any non-stationary signal with wavelet function db1 and db4 is shown in fig.8. Also this signal is de-composed up to level 2 and up to level 3 respectively. From below fig we can see that very good fault detection depends on the type of fault means we cannot say that higher level of decomposition will give us precise fault detection always or any one type of wavelet function will give us best fault detection [3].

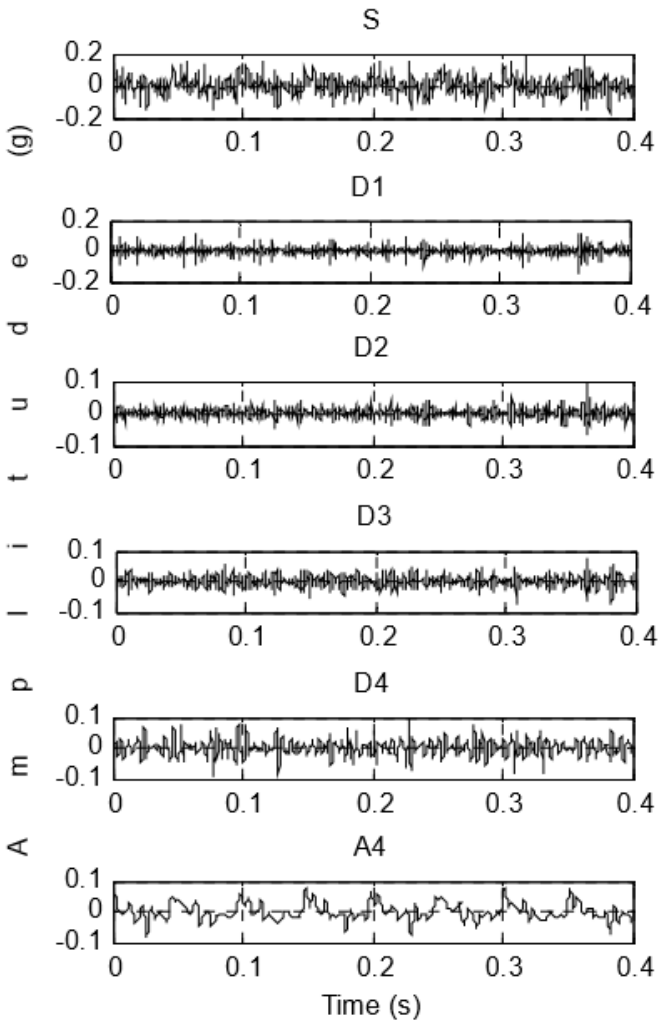


Fig.8: Signal de-composition using db4 upto level 4.

IV. PLATFORMS

There are so many platforms available in market to achieve this target. Some of them are: embedded platform using Arduino board or Arm processor based kit, FPGA based system and LABVIEW can be used for signal's data acquisition and monitoring.

Embedded platform: it is an open source electronic platform and easy to use software and hardware. In which analog or digital I/O interfaced with micro-controller and set of instructions are send to micro-controller to perform the desired calculations.

FPGA: it is an integrated circuit which can be developed according to requirement. In which programmable logic blocks can be configured for any complex combinational function. This logic blocks contains memory and flip flops and so many complex blocks.

LABVIEW: it uses data flow programming language. This software supports totally graphical programming in which all function blocks are already made and needs to connect with wires only to perform a desire task. And also DAQ card also available with different I/O and cable that provides flexible interfacing.

MATLAB: it is a multi-paradigm numerical computing environment. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

V. CONCLUSION

Using DWT, it is remained to decide perfect wavelet function for different specific types of fault detection and to decide precisely that up to which level of decomposition, we can differentiate between healthy and faulty motor with specific fault. Using FPGA based solution, though it is providing flexibility of changing parameters online, it becomes costlier solution than others. By combining LABVIEW graphical programming with MATLAB textural programming, will provide an expert signal monitoring and feature extraction system for fault detection and fault's classification.

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