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Vibration based condition monitoring by using Fast Fourier Transform "A case on a turbine shaft".

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ABSTRACT

This paper Examine the fault detection in rotating of Turbine shaft by analyzing its vibration signals using FFT technique. By using this Tool an approach is made to decompose the vibration signals in order to extract the transient information from the signals. Most commonly seen that signals having short time duration, long time duration, wide bandwidth, narrow bandwidth, time-varying bandwidth in results as rub & buzz noise, decayed resonance, an imbalanced shaft generates noise as increased in the machine speed. By exploiting the mean values from the waveform the faults are efficiently detected and diagnose.Effective and efficient feature extraction techniques are critical for reliably diagnosing rotating machinery faults. Various vibration feature extraction methods have been proposed for different types of rotating machinery during the past few decades. However, limited research has been conducted on synthesizing and analyzing technicians need to choose a technique suitable for application. This paper presents an updated review of a variety of vibration feature extraction techniques that have demonstrated success when applied to rotating machinery. The literature is categorized into the following groups: time domain, frequency domain, time frequency analysis. The paper will comment on future directions for research on vibration feature extraction for fault diagnosis of rotating machinery.

Keywords - Turbine shaft; spectrum analysis; time domain, frequency domain.

I. INTRODUCTION

The most important goal of any maintenance program is the elimination of machine Breakdowns. Very often a catastrophic breakdown will cause significant peripheral damage to the machine, greatly increasing the cost of the repair. Complete elimination of breakdowns is not at present possible in practice, but it can be approached by a systematic approach to maintenance. The second goal of maintenance is to be able to anticipate and accurately plan for maintenance needs. This means spare parts inventories can be minimized and overtime work largely eliminated. Repairs of mechanical systems are ideally planned for scheduled plant down times. Goal number three is to increase plant production readiness by significantly reducing the chance of a breakdown during operations, and to maintain system operational capacity through reduced down time of critical machines. Ideally, the operating condition of all the machines would be known and documented. The last goal of maintenance is to provide predictable and reasonable work hours for Maintenance personnel.

II. DATA ACQUISITION

The first stage of any detailed analysis is the data acquisition from the various critical locations on the machine. The measurement locations are carefully selected on the machine and measurements are done in horizontal, vertical and axial directions wherever possible. Detailed frequency analysis is also carried out at important locations.

DATA INTERPRETATION

The data interpretation is the process of comparing the vibration data with various details of the machine to arrive at conclusions. The most important aspect of diagnosis is the combination of frequency analysis and phase analysis. The common defects in any machinery system can produce vibration frequencies equal to one time the rpm, two times the rpm, three times the rpm and higher harmonics depending on the nature of problems. Antifriction bearings can excite broad band medium frequencies whereas oil whirl, etc. can produce subharmonic components. In order to distinguish defects that can produce similar frequency

components, the phase observations are very much helpful. In this case, a combination of manual and semi-automatic data collection and interpretation are employed.

III. FFT APPROACHES TO CONDITION MONITORING & FAULT DETECTION.

The most common technique in frequency analysis is done usually by FFT (Fast Fourier Transform). Fault diagnosis of such systems is of particular importance in several industries. The success in vibration analysis of these systems depends largely on the techniques used in processing the vibration signals. By using an appropriate signal processing method, it is possible to detect changes in vibration signals caused by faulty components and to judge the conditions of the machinery. Traditional analysis has generally relied upon spectrum analysis based on Fast Fourier Transform (FFT). Fourier analysis is suitable for stationary signal processing, but provides a poor representation of signal well localized in time and so it is unsuited for non-stationary, transient signal analysis, typically seen on defect induced machine vibrations, so their effectiveness in accurate machine condition monitoring and assessment is limited. This limitation of the Fourier transform therefore led to the introduction of time–frequency signal processing tools. In the last ten years Wavelet transform, a type of time-frequency approach, has obtained great success in machine fault diagnostics for its many distinct advantages. It is a new method for time-varying or non-stationary signal analysis, offer a new set of techniques of time-frequency analysis that have been shown to be powerful in transient detection[11].

Traditional vibration signal analysis has generally relied upon the spectrum analysis via the Fourier Transform (FT). Fourier analysis transforms a signal f(t) from a time-based domain to a frequency-based one, thus generating the spectrum that includes all of the signal’s constituent frequencies (fundamental and its harmonics) and which is defined as

$$F(\omega) = \int_{-\infty}^{\infty} f(t)\, e^{-i\omega t}\, dt$$

The assumption in this technique is that the frequency change within a single time interval is small, so that the necessity of a stationary signal for frequency transformation is not largely violated. If the frequency changes significantly within this time interval, then the FFT will yield an error in the actual value of the signal.An important deficiency of the FFT is its inability to provide any information about the time dependence of the spectrum of the signal analyzed, as results are average to the entire duration of the signal. This feature becomes a problem when analyzing non-stationary signals. In such cases, it is often beneficial to acquire a correlation between the time and frequency contents of the signal. Non-stationary signals could be classified into two groups: Evolutionary harmonic or frequency-modulated signals: these signals are generated by some underlying periodic time-varying phenomenon like a change in rotational speed during ‘‘start-up or coast-down’’. Transient signals: these signals have short durations and an unpredictable time behavior, and are therefore viewed as being random in nature. Examples of such signals are impact loading.

This important limitation of the FFT has led to the introduction of time–frequency signal processing tools, such as the Short-Time Fourier Transform (STFT) and others. The STFT maps a signal into a two- dimensional (2D) function of time and frequency [19]. The difficulty in using the STFT is that the accuracy of extracting frequency information is limited by the length of the window relative to the duration of the signal. Once the window function is defined, the area (time-bandwidth product) of the window function in the time–frequency plane remains fixed, which means that the time and frequency resolutions cannot be increased simultaneously. Consequently, for an STFT, there is a trade-off between time and frequency resolutions.

IV. EXPERIMENTAL SETUP AND DATA COLLECTION

The vibration analysis of turbo-generator set was carried out at load 169 mw, frequency 49.83 Hz, at speed 3000 rpm and above. It was reported that the Generator rear bearing housing vibration in axial direction has increased. The purpose of the visit is to assess the health condition of the entire

Unit and also to probe the cause of High axial vibration at Generator rear bearing. The present analysis was carried at 116 mw load. The shaft vibration was collected from E-pro Online Vibration Monitoring System and the bearing housing vibration was collected from the field with a portable FFT Analyzer.

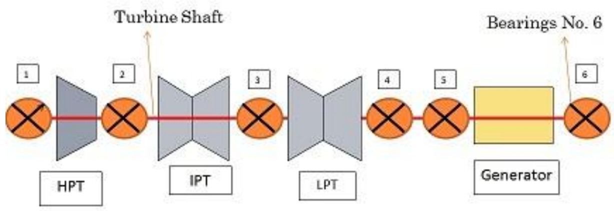
V. INSTRUMENT USED FOR ANALYSIS

The following equipment was used to carry out the Vibration analysis:

ON-LINE SHAFT VIBRATION
Hardware: French Make OROS Model OR-36 - MOBIPACK 16
Channel Analyzer for measurement of "Shaft Vibration" from online vibration Monitor.

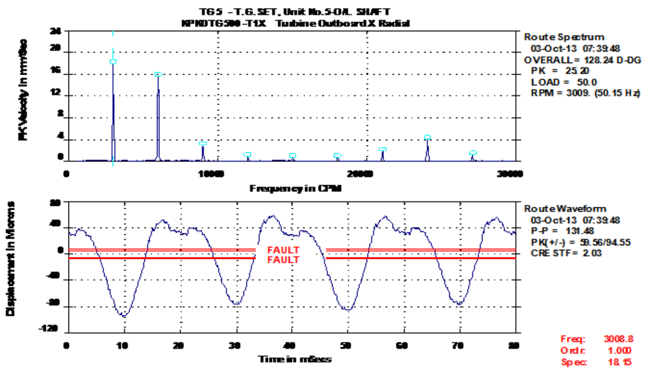
The remaining faults are not detected by the FFT-based technique. Hence, more powerful signal processing methods are therefore needed to unambiguously detect all faults. Our proposed approach is introduced to remedy this situation.

BEARING HOUSING (FIELD) VIBRATION
Hardware: Crystal instruments - Model CO CO-80 – 4 Channel FT Analyzer for "Bearing Housing" Measurement from the Field.

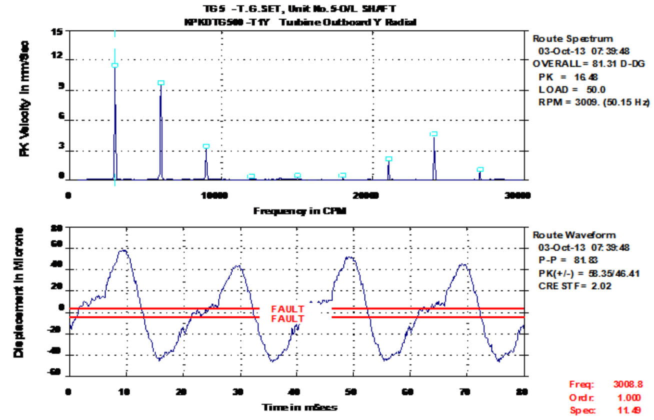


Turbo-generator set: - HPT, IPT, LPT, Turbine Shaft, Bearings (Six), Generator.

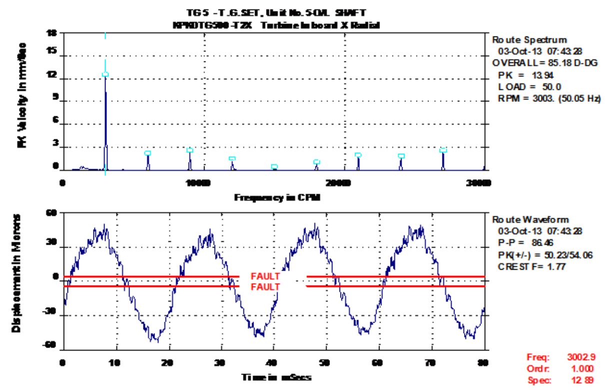
EXPERIMENTAL RESULTS USING AN FFT
Equipment:(TG5)T.G.SET,Unit.No.5-O/L SHAFT
Meas. Point:-T1X -->Turbine Outboard X Radial
RPM= 3009. Units=mm/Sec PK



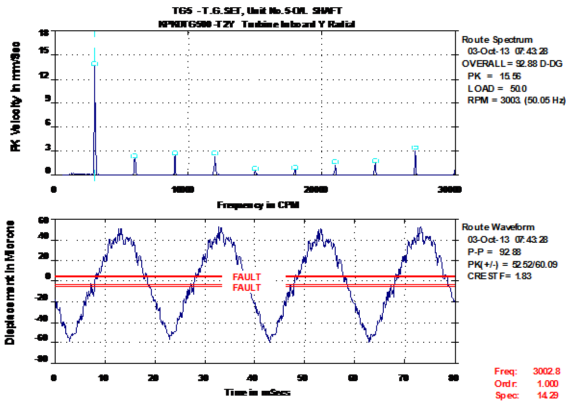
Equipment:(TG5)T.G.SET,Unit.No.5-O/L SHAFT
Meas. Point:-T1Y -->Turbine Outboard Y Radial
RPM=3009. Units=mm/Sec PK



Equipment:(TG5)T.G.SET,Unit.No.5-O/L SHAFT
Meas. Point:-T2X -->Turbine Outboard X Radial
RPM=3009. Units=mm/Sec PK.



Equipment:(TG5)T.G.SET,Unit.No.5-O/L SHAFT
Meas. Point:-T2Y -->Turbine Outboard Y Radial
RPM= 3009. Units=mm/Sec PK



The experiment is carried out to locate the natural frequencies of shaft and to simulate the occurrence of non-stationary and transient faults. The expected faults from these experiments are unbalance and misalignment.

The unbalance in rotating machinery is one of the main causes of vibration. A perfectly balanced shaft is hard to achieve so even under normal operating conditions, the frequency spectrum using the traditional FFT technique may show as pike at the operating speed. The shaft misalignment is the deviation of the relative shaft position from a collinear axis of rotation measured at point.when the equipment is running at normal condition the shaft misalignment is considered to be another major vibration problem that occurs in rotating machines. Traditionally, a vibration engineer diagnoses the shaft misalignment in the frequency spectrum from the harmonics of multiples of rotational speed, so-called at 2X, 3X, etc.The remaining faults are not detected by the FFT-based technique. Hence, more powerful signal processing methods are therefore needed to unambiguously detect all faults. Our proposed approach is introduced to remedy this situation.

ROTOR IMBALANCE

Rotor imbalance exists to some degree in all machines and is characterised by sinusoidal vibration of once per revolution.In the absence of high resolution analysis equipment,imbalance is usually blamed for any excessive once per revolution vibration - vibration that can be caused by several different faults. More detailed analysis can differentiate between these faults and eliminate unnecessary and expensive balancing operations.

A state of imbalance occurs when the centre of mass of a rotating system does not coincide with the centre of rotation.The imbalance can be in a single plane (static imbalance) or multiple planes (couple imbalance). In either case, the result is a vector that rotates with the shaft, producing the classic once per revolution vibration characteristic.

The key characteristics of the vibration caused by imbalance are (I) it is sinusoidal at a frequency of once per revolution (2) it is a rotating vector and (3) amplitude increases with speed. These characteristics assist in differentiating imbalance from faults that produce similar vibration. The vibration caused by pure imbalance is a once per revolution sine wave sometimes accompanied by low-level harmonics. The faults commonly mistaken for imbalance usually produce high-level harmonics or occur at higher frequency.In general, if the signal has harmonics above once per revolution, the fault is not imbalance. However, high level harmonics can occur with large imbalance forces, or when horizontal and vertical support stiffness's differs by a large amount.

Other faults are often mistaken for imbalance because they result in increased levels of vibration at running speed. Such faults are Misalignment, Load variation, Mechanical looseness, and Resonance and Excessive clearance in fluid film bearings. Each of these does, however, have distinctive characteristics which can be used for identification.

MISALIGNMENT

Vibration due to misalignment is usually characterised by a 2 times running speed component and high axial levels.Misalignment takes two basic forms, (1) preload from a bent shaft or improperly seated bearings and (2) offset of the shaft centre-lines of machines or parts of machines in the same train. Flexible couplings increase the ability of the train to tolerate misalignment but are not a cure for serious alignment problems.

VI. CONCLUSION

The Present investigation was carried out to study the application of FFT transform, to fault detection in rotating machinery; an area of supreme importance to various industries. The effective use of the traditional FFT approach in fault detection was demonstrated and its major weakness in detecting faults from non-stationary signals was clearly exposed in the study, which produced a typical impulsive and non-stationary test signal. The relation between condition of the equipment and vibratory behavior prevailing at that moment has been studied. Vibration monitoring is carried out for the detection of earlier condition in turbine shaft and also relating frequencies obtained by Fourier transform with condition of the equipment. Diverse time and frequency domain techniques or parameters for vibration based condition monitoring and diagnosis are described. Both the time and frequency domain information should be used in conjunction for effective and correct diagnosis of faults in machines. The study ensures to observe the rise of amplitude at the pertinent frequencies for turbine set in Fourier transform and to interpret the fault in an adequate manner. Identification of the fault frequencies of the component and the level of amplitude at their fault frequencies has been studied and analyzed. Using The Fft Spectrum Of Shaft Vibration Signals, It Can Be Concluded That The Condition Of The Shaft Is Defective. The Conclusion Motivate Further Work To Incorporate Other Condition Monitoring Parameters And Technique With Vibration Monitoring To Develop More Robust Intelligent Systems For On Line Machine Health And Faults Signature Analysis.

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