Fault Diagnosis of Windmill by FFT Analyzer

Poonam Bhaskar Sonawane
Department of Mechanical Engineering
NDMVP'S KBTCOE, Nasik , Maharashtra , India

Prof. N.K.Kharate
Department of mechanical Engineering
NDMVP'S KBTCOE, Nasik , Maharashtra , India

Abstract- Wind energy conversion is the fastest growing source of new electricity generation in the world. Wind mills are located in harsh environment so their maintenance is very difficult. Wind mill consist of various parts such as blade, gearbox, tower, generators etc. Wind faults are mostly occurs in the gearbox, bearing, blades. The traditional fault diagnosis methods such as fast Fourier transform is used in this project. This present work deals with the occurrence of fault in wind turbine are investigated by using vibration analysis by using FFT analyzer and validate this results by MATLAB. There are various techniques are used for simple analysis of fault such as side band ratio [SBR], defect frequency for bearing and blade pass frequency for wind turbine blades. SER calculates the ratio of side band energy to gear mesh center frequency energy. It has demonstrated high sensitivity to gear damage in several cases. The failure of rotating machines is very critical and this leads to damages, losses of energy, personal injury, so it is very important duty of the maintenance department to prevent the fault of wind turbine. Vibration analysis technique is one of the best technique. In this technique vibration signals are collected by means of vibration analyzer equipped with sensor in time domain then this is converted into frequency domain by using FFT analyzer.

Keywords –fault detection, vibration signal ,sideband, gear mesh frequency

I. INTRODUCTION

Wind energy is a free, renewable resource so no matter how much is used today. There will still be the same supply in future. Wind turbines harness the power of the wind and use it to generate electricity. Instead of using electricity to make wind like a fan wind turbine use wind to make electricity. The proposed wind turbine is a 'horizontal axis' machine which consist of three rotor blade turning around a horizontal hub. The hub is connected to gearbox and a generator which are located inside a nacelle. The nacelle houses the mechanical and electrical components and is mounted on the top of a tabular tower as shown in figure 1.1

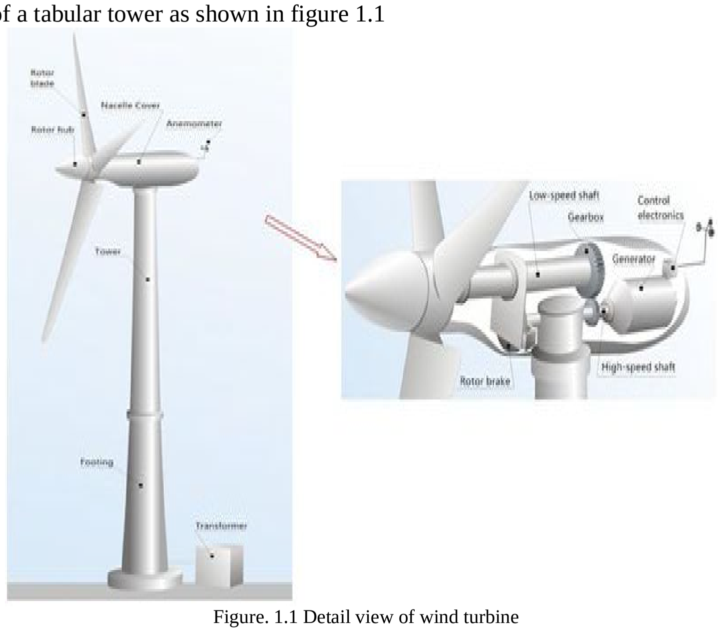

Figure. 1.1 Detail view of wind turbine

II. PROBLEM DISCRIPTION

From study of different research paper it is seen that these fault still unresolved problem in power generation.This will increases the vibration .Now this is the challenging task to reduce breakdown of windmill because of thisproject work considers the windmill fault.

Some of the latest windmill losses:

Sr No	Damage	Causes
1	Corrosion in Ball Bearing	Wear in wind turbine
2	Misalignment of Ball Bearing with shaft	Abnormal temp rise in bearing and housing and heavy wear
3	Normal fatigue failure of Ball Bearing outer race	Removal of small particle by spalling And causes heavy wear
4	Blade Damage	Frequently stop of the windmill
5	Random fracture of gear	Deficiencies in gear tooth and causes high stress concentration
6	Corrosive wear of gear	Affect the grain boundaries and causing fine pitting more or less over tooth
7	Breakage of pinion due to overload	An overload which exceed the tensile strength of gear material
8	Cold flow of pinion	Causes tenuous operation

III. VIBRATION MEASUREMENT

Vibration data were collected and processed using FFT analyzer. It is well known that a machinery analyzer generally consist of a sensor , a memory in which the signals are stored , electrical circuits that convert time domain signal to frequency domain signals (FFT process) and port by which vibration signals were transferred into a computer. The sensor used was an accelerometer with a sensitivity of 0.1 V/EU. Parameters for collecting of vibration signal were give in the table (1). Vibration was measured in axial, horizontal and vertical directions. Vibration data measured in the vertical direction was used to characterize the health of the machinery.

Number of lines	1601
Sampling frequency	2048 Hz
Frequency range	0-800 Hz
Spectral average mode	Normal
Window type	Hanning
Acceleration sensor sensitivity	0.1 V

Table1: Specification of FFT

IV. EXPERIMENTAL SETUP

An experimental test rig built up to predict defects in unit of wind turbine as shown in figure(). The test rig consist of a shaft with central rotor which is supported on two bearing. Motor is coupled to the shaft. A pair of spur gears with module of 1.25mm is tested. The driving gear has 58 teeth and driven gear has 20 teeth. The speed controller of gearbox operation is in range of 80-300 rpm. Blades are attach at the front end of shaft. Size of blade is 30 inch. This total assemble is mounted on tower whose height isc37.5inch .vibration characteristics are very important for study of diagnostic for fault. In the experiment setup consider all parts of wind turbine such as shaft, blade, gearbox, bearing with defect and without defect. All the part was attached to assembly one by one for carry the result. Dimensions of all parts are mention in design part. After taking the results it was seen that the value of amplitude and displacement was more for the all parts with defect compare to parts without defect. It was seen at the time of processing the data that for the defected parts the value of amplitude was increasing when frequency of the nearby natural frequency of the system. The various value of acceleration, velocity for the study of vibration characteristics were taken and these are shown in the figure respectively.

Fig 4.1 Experimental setup of windmill with FFT analyzer

V. EXPERIMENTAL ANALYSIS

1) Rolling element bearings:

A rolling element bearing consist of inner and outer races , a cage and rolling element(ball). Defect can occur in any part of the bearing and causes high frequency vibrations. We in this project we are consider the three types of defects that are corrosion , misalignment with shaft, normal fatigue failure of outer race. However the following formulas are used to determine bearing defect frequencies[1].

BPFI = $\frac{NB}{2}\left(1+\frac{BD}{PD}COS\theta\right)*RPM$

BPFO= $\frac{NB}{2}\left(1-\frac{BD}{PD}COS\theta\right)*RPM$

FTF= $\frac{1}{2}\left(1-\frac{BD}{PD}COS\theta\right)*RPM$

BSF= $\frac{PD}{2BD}\left[1-\left(\frac{BD}{PD}\right)2\,(COS\theta)\,2\right]*RPM$

NB=Number of balls
BD=Ball diameter
PD=Bearing pitch diameter

θ = contact angle in degrees

$BPFI$ = Ball pass frequency- inner

$BSFO$ =Ball pass frequency –outer

FTF = Fundamental train frequency (cage)

BSF = Ball spin frequency (rolling element)

Vibration of wind mill was monitor. The power and revolution of wind mill is 36.47 W and 85.9 respectively.Defect frequencies of rolling element bearing used in this study were given in table (2).

Bearing type	Shaft speed	Nb	BPFI	BPFO	FTF	BSF
SKF 6204	85.9	8	394.77	292.44	36.55	281.97

Table (2) : defect frequency of rolling element bearing

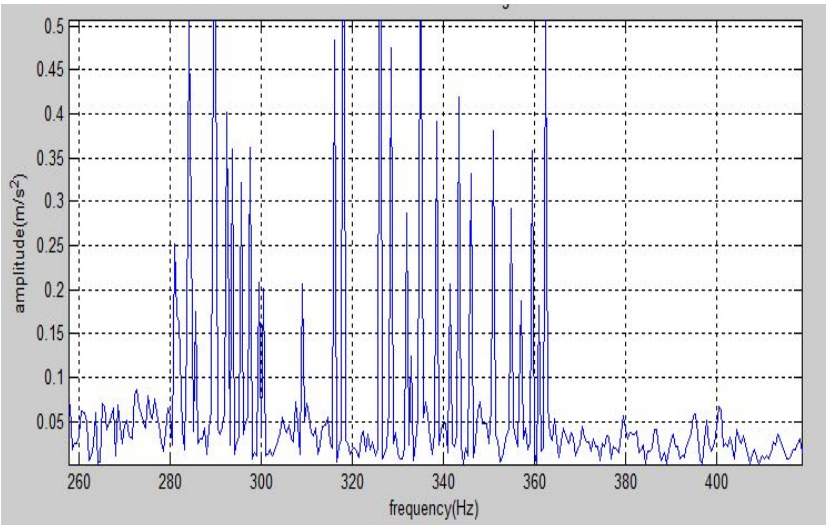

Figure 5.1.1Reference spectrum graph of the corrosion in ball bearing

Deep grove ball bearing is often used to support wind turbine. By analyzing the vibration signatures, it is shown that the bearing condition was so critical. Existing of multiplier of the ball outer race defect frequency (281.97Hz) on the spectrum graph and impact signal whose frequency is equal to ball spin defect frequency (BSF) as shown in above table (2) in time domain waveform graph indicates that ball bearing cage has a defect[1,2].

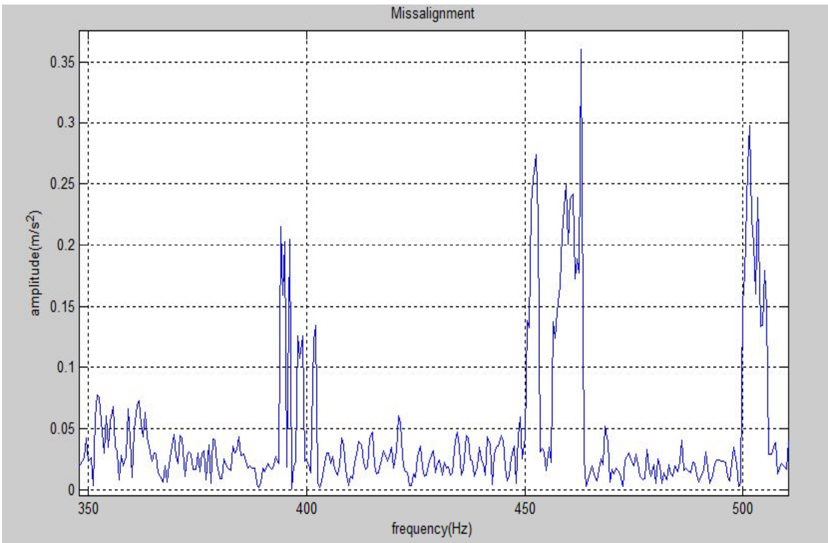

Figure 5.1.2 Reference spectrum graph of the misalignment of ball bearing with shaft

From above figure 5.1.2 this situation indicate that misalignment of bearing on shaft.it is analyze that the bearing condition was critical. Existing of multipliers of the ball bearing inner race defect frequency 394.77 Hz as shown in table(2). On the spectrum graph and whose impact signal is equal to ball pass frequency of inner race (BPFI) in the time domain waveform graph indicates that bearing has defect.

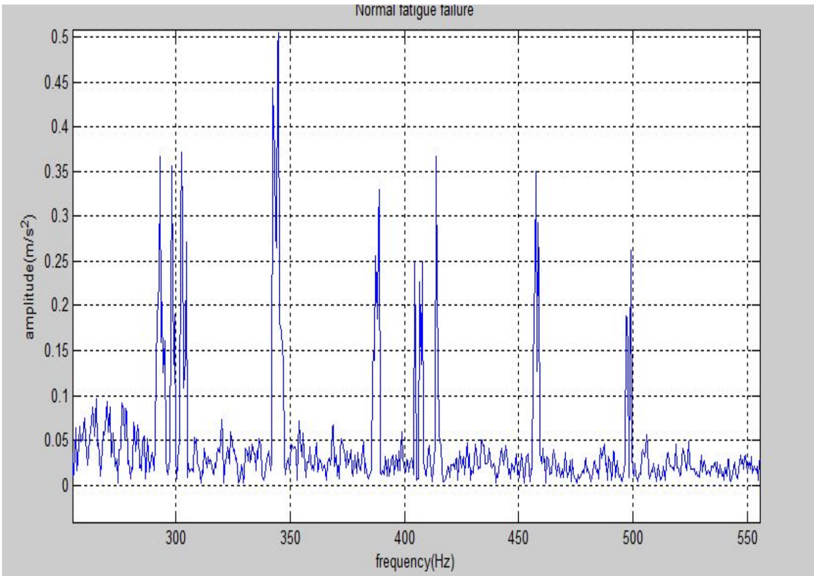

Figure 5.1.3 Reference spectrum graph of the normal fatigue failure of ball bearing outer race

From above figure 5.1.3 this situation indicate that fatigue failure at ball bearing were widely used in any type of rotating machinery. Thus determining the health of the ball bearing is very important. By analyzing the vibration signature. It is shown that the bearing condition was so critical. Existing of multipliers of the bearing outer race defect frequency 292.44 Hz as shown in table (2). On spectrum graph and impact signal whose frequency is equal to ball pass frequency outer race (BPFO) in time domain waveform graph indicates that ball bearing fatigue indicate that ball bearing has defect[1].

2) Gearbox failure-

A gearbox is a piece of rotating equipment that can causes the low frequency harmonics in the vibration spectrum. Spectrum of any gear box shows the 1x and 2x rpm along with the gear mesh frequency. Gear mesh frequency is calculated by the product of number of teeth of pinion or gear and running speed.

GMF= Number of teeth on gear/pinion*pinion /gear rpm

Side band ratio is calculated from high resolution spectrum data. Once spectrum is generated the SER algorithm sums the amplitudes of the first six sideband peaks on each side of the center mesh frequency and divide by amplitude of center mesh frequency[4].

SER=$\sum_{i=1}6$sideband amplitude i/ center mesh frequency amplitude

a) Gear defect :

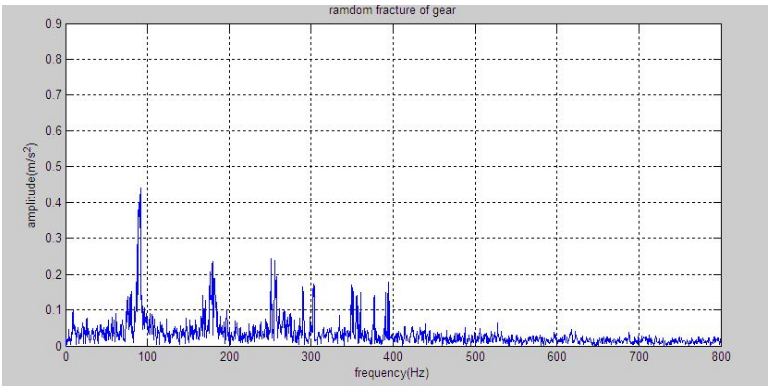

Figure 5.2.1 random fracture of gear

Figure shows a picture of random fracture of gear tooth during the inspection. All plots were generated by MATLAB software. In the spectrum plot shows first three harmonics of gear mesh frequency are denoted as 1X, 2X and 3X etc. Each gear mesh frequency has six side band frequencies which represents the expected location.The SER value for healthy gear is always less than one. From the above figure the 1X,2X and 3X frequencies are 7.3, 2.1 and 4.0 resp. SER value seen here indicates a defect on gear is presented[4].

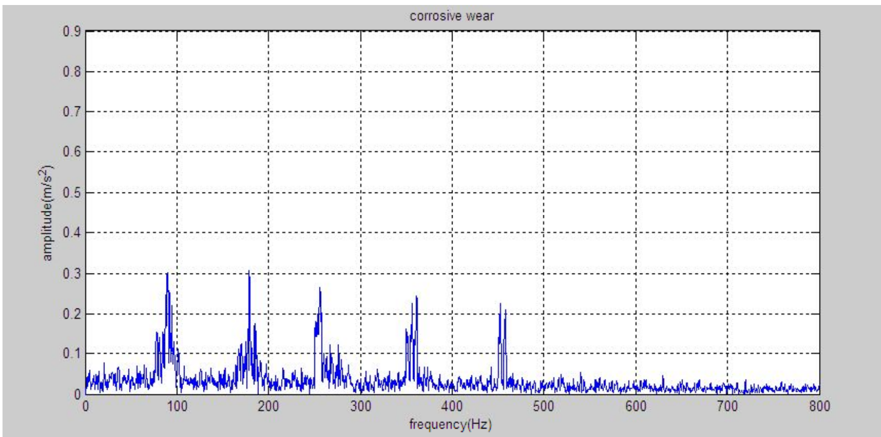

Figure 5.2.2 corrosive wear of four teeth of gear

Figure shows that spectrum graph of corrosive wear of four teeth of the gear. All the plots were generated by MATLAB software. Again spectrum plot acceleration data for this wind turbine gear box. First three harmonics of gear mesh frequency denoted as 1X,2X and 3X. SER values for 1X,2X,3X are 2.13,1.39,2.28 respectively.This value show that the gear is defected because for healthy gear contains SER value is 1.

b) Pinion defect:

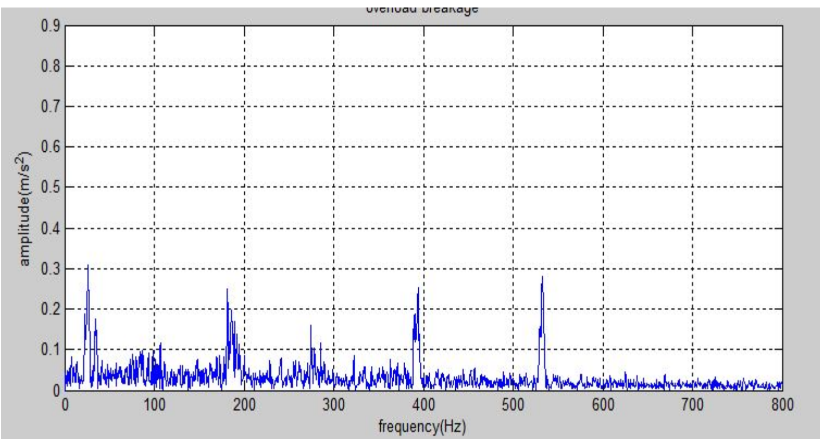

Figure 5.2.3 overload breakage of pinion

Figure shows that the picture overload breakage of pinion Which occur due to tensile strength of gear material. All the plot are generated by MATLAB software. In the spectrum plot of the figure the first three harmonic of the gear mesh frequency are denoted as 1X,2X and 3X. The SER value for 1X,2X and 3X are 4.57,4.1,1.43 respectively. Form SER value it is seen that pinion is defected.

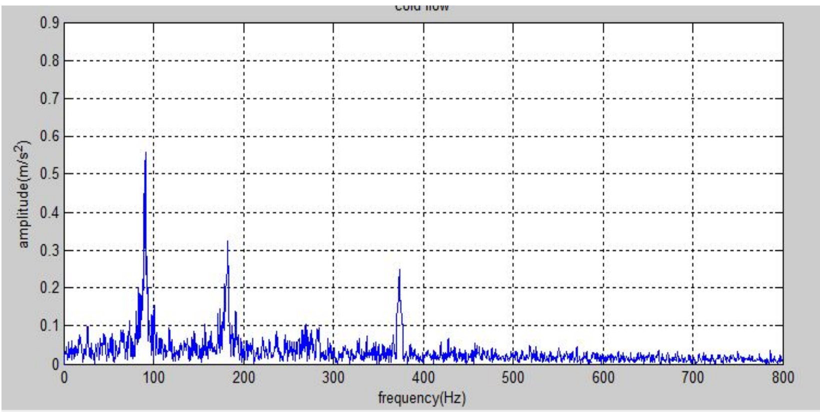

Figure 5.2.4 clod flow of pinion

Figure shows a picture of cold flow piniontooth during the inspection. All plots were generated by MATLAB software. In the spectrum plot shows first three harmonics of gear mesh frequency are denoted as 1X, 2X and 3X etc. Each gear mesh frequency has six side band frequencies which represents the expected location. The SER value for healthy pinion is always less than one. From the above figure the 1X,2X and 3X frequencies are 2.62,1.84 and 6.09 resp. SER value seen here indicates a defect on pinion is presented.

c) Blade defect:

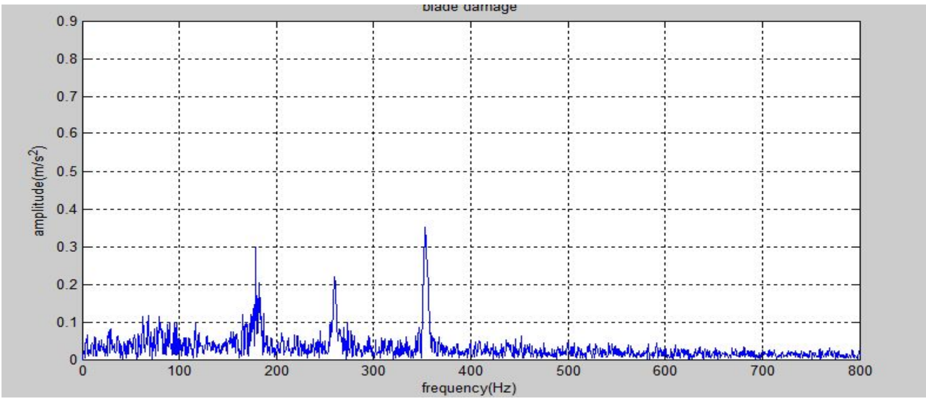

Figure 5.3.1 Blade damage

Figure shows a picture of spectrum plot of blade damage of wind mill. This damage occurs due to environment problem, lightening effect etc. The analysis of faults in the blades can be done by using blade pass frequency (BPF) technique. Blade pass frequency is calculated by the product of number of blades and its respective running speed.

Blade Pass Frequency (BPF) = Number of Blades * rpm

This frequency is generated mainly due to gap problems between rotor and stator. High BPF can be generated if wear in the ring seizes on the shaft. In addition high BPF can be caused by abrupt bends in line work. An FFT plot will immediately highlight the vain pass frequency of the impeller. Also BPF sometimes coincides with system natural frequency causing high vibrations.

BPF = 3*85.9 = 257.7 Hz

Blade pass frequency is generated at 257.7 Hz then for next blade pass frequency it increases twice.

VI. CONCLUSION

In this paper various technique of fault diagnosis methods are combine with the FFT is proposed to address non liner & non stationary fault signals of wind turbine parts. In this study diagnosis technique of ball bearing defects, gear defects, blade defects were investigated by vibration monitoring & spectral analysis as a predictive maintenance tool.Ball bearing misalignment, corrosion and normal fatigue failure defects were successfully diagnosed by using defect frequency method. The SER algorithm recent integrated wind monitoring system is designed to target the defection of gear related defect within a wind gearbox. In SER algorithm was successful in demonstrating not only fault in gearbox but also exactly which gear contain damage. For blade fault detection blade pass frequency technique is used. From the above discussion it concluded that by using vibration spectrum and from various techniques we can identified faults presented in windmills.

REFERENCES

[1] Sadettin Orhan, Nizami Akturk, Veli Celik, Vibration monitoring for defect diagnosis of rolling element bearing as a predictive maintenance tool: comprehensive case studies. NDT&E International 39(2006)293-298.

[2] Prof.U.A.Patel , Shukla rajkamal , Vibration analysis of Self Align Ball Bearing Having Local defect through FEA and its validation through Experiment, international journal of modern engineering research ,vol 2,issue.3 may –June 2014 pp-1073-1080.

[3] Amit R Bhende, G.K. Awari and S.P.Untawale , Assessment of bearing fault detection using vibration signal analysis,VSRD- TNTJ, vol.2 (5), 2011,249-261.

[4] J.Hanna, C.Hatch, M.Kalb, A.Weiss, H.Luo , detection of wind turbine gear tooth defects using sideband Energy Ratio, wind energy resource assessment and forecasting.

[5] Mariana IORGULESCU, ROBERT BELOIU, Vibration and current monitoring for fault’s diagnosis of Induction Motors,annals of the university of Craiova, Electrical Engineering series, No.32. 2008: ISSN 1842-4805.