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Condition Monitoring of Wind Turbine Gearbox by Vibration Analysis

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Abstract: ***The main aim of this paper is to implementation of condition monitoring on wind turbine gearbox. In condition monitoring we use vibration analysis which is proactive maintenance technique. Condition monitoring is advance and useful tool of proactive technique. Condition monitoring helps to identify the various type of deterioration in wind turbine gearbox. To improve the reliability and performance of wind turbine we apply condition monitoring systems which monitored key component of wind turbine like gearbox. In all renewable energy sources one of them is wind energy. Wind energy is fastest growing energy source in the world. The wind turbine industries still experience gearbox failure, which lead to increase the maintenance and operating cost and also increase cost of energy. To produce wind power more economically it is very important to reduce the downtime of turbine gearbox and improve the reliability. Condition monitoring technique helps to provide necessary information to avoid costly failure, enabling cost effective operation and maintenance practices.***

Keyword: Condition monitoring, Vibration analysis, wind turbine gearbox, Time domain and frequency domain analysis, stress wave histogram.

1. Introduction

Wind energy is one of the best renewable energy sources. It is also free of cost and requires very less operation cost. Installation cost of wind power plant is high. But reducing the maintenance cost of these plants we provide economic wind energy. Wind energy is fastest growing energy source. The installation cost is fixing for every plant but maintenance and operating cost play an important role in cost of energy. In this competitive world, we reduces the maintenance and operating cost of wind turbine and only by help of this we reduces the per unit cost of wind energy. Wind power plants still struggle with the premature failure of wind turbine gearbox which leads the maintenance and operating cost and increase the cost of energy, therefore we reduces the turbine gearbox downtime and reliability. Condition monitoring is a process in which we maintain all parameters of machines and health of machine components. Condition monitoring gives the information about machine health such as:

A) Early detecting costly failure.
B) Evaluating machine health and condition.
C) Find out root causes.

Condition monitoring gives information to improved turbine gearbox operation. It is recently uses in wind industry due to growth of wind industries; application of condition monitoring technique is dramatically changes. In maintenance of wind turbine, we consider all major substances like wind tower, foundation, blades, nacelle, drive-train. In this paper only focus in drive-train (gearbox). The gear box is costly and critical substance of whole drive train of wind turbine. Condition monitoring of the gear box done by vibration monitoring which gives the vibration spectrum pattern by analysing this vibration pattern we easily operates and maintain the wind turbine without any cetaesotropic failure.

2. Condition Monitoring

Condition monitoring a tool of condition based maintenance. Condition monitoring is an element of long term maintenance services. Condition monitoring provides information of machines condition and health's. Condition monitoring also gives rate of change of machine health with respect to time.

Condition monitoring defines by some authors:

[1]Broch: There has been considerable interest in the maintenance techniques based on condition monitoring, with the analysis of vibration characteristics generated by machines, which make it possible to determine whether the machinery is in good and bad condition.

[2]Simmons: Opened that vibration from their sources origin may be small but excite the resonant frequencies of the rotating parts such as the rotor shaft and set-up considerable extra dynamic load on bearings. The cause and effect reinforce each other and the machine progresses toward ultimate break down.

[3]Gyarmathy: There are generally two situations in which vibration measurement are taken. One is surveillance mode to check the health of machinery on routine basis. The second situation is during an analysis process where the ultimate goal to tag the problem is. In the later case, vibration measurements are taken to understand the cause, so that an appropriate fix can be under taken.

[4]Lingarajun: Vibration monitoring which is most frequently used method in condition monitoring provides information about machinery health as it can reveal the cause of potential problems and provides an early indication of mechanical failure. This gives the possibility for diagnosing and converting malfunctions leading to an optimum management of engine operation.

[5]RKBiswas: states that Condition Monitoring is defined as the collection, comparison and storage of measurements and defining machine condition. Almost everyone will recognize the existence of a machine problem sooner or later. One of the objectives of Condition Monitoring is to recognize damage that has occurred so that sample time is available to schedule repairs with minimum disruption to operation and production.

[6]G Suresh: Condition monitoring essentially involves regular inspection of equipment using human sensory facilities and a mixture of simple aids and sophisticated instruments. The central emphasis is however on the fact that most inspections should be preferably done while the machine is running.

Condition monitoring ascertained by choosing the required parameters for calculating deterioration and recording. Condition monitoring also applies in the running stage of machine and collect the recording data. After analysed this recording data we get whole information about machine health. In condition monitoring we installed sensors and transducers on operational machinery such as gear box, and get the signal vibration patterns with analysis of this patterns we take the maintenance operation. Condition monitoring also a test and quality assurance, equipment for continuous processes. Some condition monitoring techniques are as follow:

a) Contaminant or debris monitoring
b) Corrosion monitoring
c) Performance monitoring
d) Shock pulse monitoring
e) Sound monitoring
f) Vibration monitoring
g) Visual monitoring

3. Wind Turbine Gearbox

Wind turbines are designed by resist the strong winds speed. The height of wind turbines are always more than 60 meters. In whole wind turbine drive train the following subsystem are consist: Hub, Gearbox and Generator. They are connected to each other with helps of bearings, shaft and gears. The main aim of gearbox to convert low speed rotating high torque power to high speed low torque. In between the hub and generator the gearbox is placed such as fig (1).

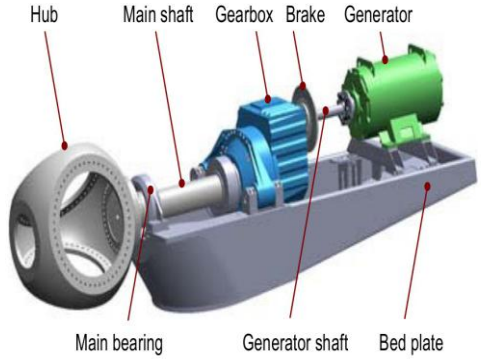

Figure1: Wind turbine drive-train

The wind turbine gearbox model varies with respect to their mechanism and their manufactures. But one of the internal configuration wind turbine gear box is generally adopted by wind power industries. In figure 2 and figure 3 shows the internal configuration and mechanism of gearbox.

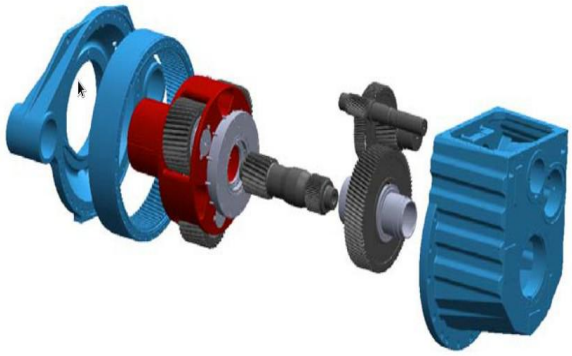

Figure 2: Internal configuration of gearbox.

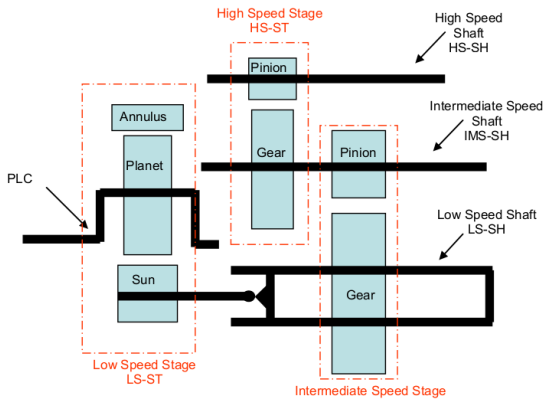

Figure 3: Mechanisms of gearbox.

In both figure 2 &3, one low speed planetary stage and two parallel stages gears are mounted. The low speed stage gear has consisted of three planet gears, one annulus gear and one planet carrier gear. The annulus and sun gear are coupled with planet gears. Which is connected to gear on the low speed shaft. The planet carrier gear supported by two fall complement cylinder roller bearings and planet gear supported by two identical cylinder roller bearing. In gearbox the parallel shaft supported by a cylinder roller bearing on the up end side and in downwind side tapper roller bearing are mounted.

4. Vibration Analysis

In vibration monitoring we measure the frequency and amplitude of vibration. All the mechanical rotating and reciprocating machine components generate their own vibration pattern in running condition. However such raw vibration pattern consist lot of background noise, which interpreted to identify the actual vibration pattern. So it is very important the location of transducers or sensors. To capture the useful data, vibration should be measure very carefully. Vibration monitoring is important method for calculating physical movement of machine component due to imbalance, misalignment and wear of component. For measurement of vibration we generally used such types of

transducers: Electromagnetic, Electrodynamics, Capacitive and piezoelectric accelerometer.

Vibration monitoring also so important because of these following factors:

a) In vibration signature each and every kind of defect produces an unique vibration pattern.
b) All machine rotating and reciprocating component vibrates either smaller or greater.

Generally different vibration monitoring techniques may have different approaches. In terms of vibration monitoring analysis algorithms, it also varies to as per their different techniques. vibration monitoring analysis algorithms are generally categories by two methods.

A) Time Domain Analysis (TDA).
B) Frequency Domain Analysis (FDA).

A) Time Domain Analysis- In TDA methods we analysis the amplitude and phase information of vibration time signal and to identifying the fault and damage of rotor, shaft, bearings and gear etc. TDA also divided into following types:
A1) Time waveform analysis- Mainly all vibration analysis are measured in the time domain. In time waveform analysis to detect the changes in the vibration signature caused by faults. Time waveform methods the RMS value, Crest factor and peak values are used to quantify the time signals.
A2) Indices- Indices are used to measure the vibration analysis, The Root Mean Square(RMS), peak value and their ratio crest factor are used to quantify the vibration signals. Peak value is the half difference between maximum and minimum signal values. RMS values are generally using when the signals are stead y-state and continuous amplitude. Crest factor is the ratio of peak value to RMS value.
A3) Statistical method- This method also depends on time domain analysis. Kurtosis is very similar to crest factor and measure the impulsive nature of signal. Skewness is measure the symmetry of signals more precisely. It is more precisely measure the collecting data. In form of symmetry it check the signal from center to left and right side signal.

B) Frequency Domain Analysis- In FDA included Fast Fourier Transformation (FFT), Frequency Band Analysis (FBA) and Spectra analysis. FDA method we uses difference in spectrum density of the signal due to faults of component. In frequency domain the position represent the frequency and height represent the amplitude of vibration signal.
B1) Fast Fourier Transformation (FFT)- It is a special algorithm which applied in Discrete Fourier Transformation(DFT) and saving the calculation time. In FFT we just reduce the number of calculation as compare to DFT. In DFT 2N^2 no. of calculation require for N points but in FFT only 2NlogN (base 2) no. of calculation require for same N points.
B2) Frequency Band Analysis(FBA)- In FBA method the overall vibration signal divided into the wave shaped matrices. This is done by analogue band pass filters which are mounted between measurement devices and vibration sensors. The main function using band pass frequency is that, the fault may not change significant in vibration signals but change in frequency band. So it is very useful method to measure the fault and damage.
B3) Spectral Analysis- It is representing the signal in frequency domain analysis. It is very commonly using vibration analysis method of condition monitoring technique. In all machine component produces vibration over a broad band of frequency. In spectral analysis we convert this broad band frequency into in narrow band frequency. This narrow band frequency helps to identify the fault and damage of machine component. Condition monitoring of wind turbine gearbox, vibration analysis has been used to monitored the gearbox of wind turbine drive-train. The complex dynamic structure of gearbox is generally monitored by on-line condition monitoring.

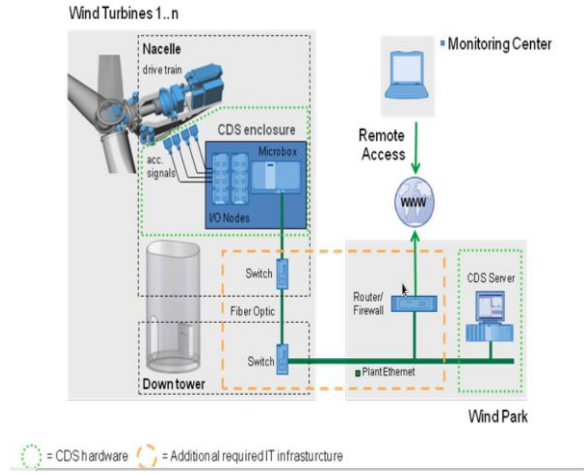

Figure 4: Setup of Vibration monitoring on wind turbine.

In figure 4 various sensors, transducers and Data Acquisition System(DAS)are mounted in gearbox. It is directly connected to data server and Condition Diagnostic System(CDS). The condition diagnostic system refers the data to remote monitoring centre by help of fibre optic and Ethernet. The vibration monitoring software reviewing and analysing the collected data and presenting the vibration analysis results.

The main aim of vibration monitoring is to measure the physical movement of moving component with helps of sensors, transducers and accelerometer. To install these devices we need correct measurement location and proper analysis algorithms are required to evaluate the collected data.

Figure 5(a): AM1

Figure 5(b): AM2

Figure 5(c): AM3

Figure 5(d): AM4

Figure 5: Installation of accelerometer for gearbox condition monitoring.

In the above figure 5 shows the location of the accelerometer in the gearbox which almost covers all gearbox system. The mounted accelerometer notation given in figure 5. These 4 accelerometer transducers are mounted on gearbox one for planetary in radial direction AM1 or AM2 and one for each stage of gearbox AM3 and AM4.

The time domain parameter used to monitor the trend of overall vibration level over time a specific measurement location. For measurement of vibration we used one triggering mechanisms like a time interval based or vibration level based can be install in time domain parameter overall trending process. Whenever we use this trigger mechanisms, got a discrete frequency analysis snapshot. To evaluating these snapshots we identify the gearbox health &condition and also measure the amplitude & meshing frequency or gears.

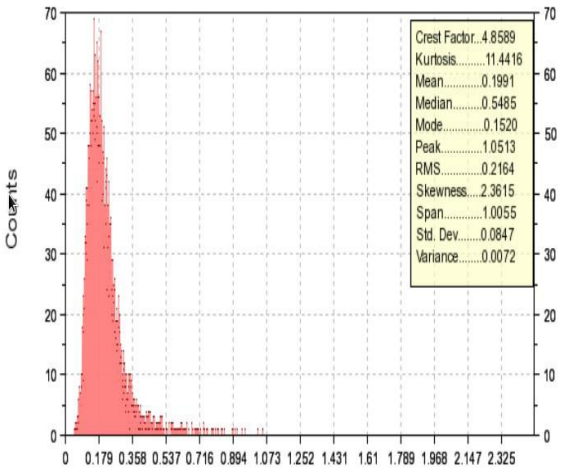

Figure 6(a): Healthy amplitude histogram.

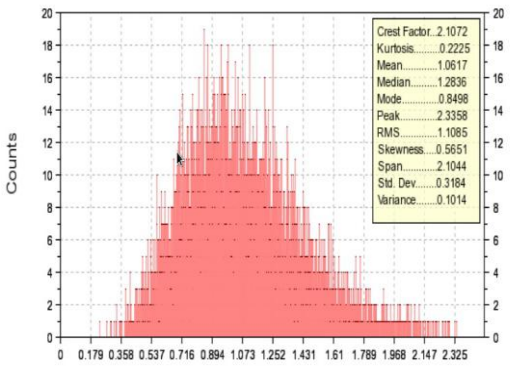

Figure 6(b): Abnormal amplitude histogram.

Line vibration analysis is another popular condition monitoring technique used by wind turbines. This line vibration analysis also known as stress wave analysis. The stress wave signals are come through friction and strike event in monitored structure. The results gives the stress wave technique is knows as amplitude histogram. In figure 6(a) and 6(b) stress wave amplitude shows. Figure 6(a) shows the healthy condition of helical gear and figure 6(b) shows the abnormal condition of helical gear.

5. Conclusion

Condition monitoring is effective method to evaluating the condition of machine or any other component. This paper condition monitoring technique applies in gearbox of wind turbine and analysis the health of gearbox. Vibration monitoring is one of the important methods of condition monitoring, here vibration monitoring method used to measure the fault and damage in gearbox. In gearbox we mounted some accelerometer and stress wave transducers which gives the vibration signal and vibration patterns. Time domain and Frequency domain two type of signal produce by sensors as per our requirement we choose any of them. This vibration signals gives the information about machine health and condition. It also helps to avoid the unnecessary maintenance of gearbox with considerable saving of resources.

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