A Study on Vibration Signals of Wind Turbine through the Condition Monitoring System

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Abstract

A study on wind turbine vibration signals caught by Condition Monitoring System, CMS, was carried out on Gasi wind farm of Jeju Island, South Korea. The vibration signal with about 10khz was measured by strain gages which were installed on the gearbox of wind turbine for two months from February to April, 2016. The time domain analysis was performed with the data above 50 % of the sampling rate. The vibration data were processed with band pass filter to clearly detect the wind turbine faults. The frequency domain analysis was also performed applying enveloping technique to find turbine faults with low frequency. Also, Fast Fourier Transform, FFT, was applied to the processed vibration data. As a result, defect frequencies of bearings of a gearbox were measured in the range from 9hz to 464hz and these acceleration values were lower than the vibration acceptance level of 0.5 m/s^2. It could be confirmed that the bearings of the gearbox worked in good condition at present.

Keyword

Wind Turbine, Condition Monitoring System, Vibration Signals, Defect Frequency

1. Introduction

As large onshore and offshore wind turbines have been developed, advanced maintenance technology has become more and more important to achieve higher availability of the turbines. In order to detect possible wind turbine failures earlier, Condition Monitoring System, CMS, technique has been applied to wind turbines, using which downtime of a wind turbine can be minimized, which results in maximized electric production. CMS is particularly useful to monitor the complex system which consists of a variety of bearings, shafts and gears. By analyzing vibration data measured using CMS, Ribrant[1]found that the gearbox was one of the main causes of wind turbine failures. Antoniadou [2] was reported that Empirical Mode Decomposition(EMD) method was useful to decompose the vibration signals in gearbox under varying load conditions. Brian P. Graney [3] pointed out that rolling element bearings required multiple parameters to investigate the bearing condition and it is confirmed that some parameters were useful to check failures.

This investigation aims to analyze vibration behavior on the gearbox of a wind turbine. To do that, we performed the fault diagnosis by comparing acceleration value of defect frequency with the vibration acceptance level.

2. The wind turbine tested and methods

Figure 1 shows Gasi wind farm, Jeju Island of South Korea where CMS was installed at the 7th wind turbine. The vibration signal data were gained from eight acceleration sensors which were installed on the drive train of the wind turbine. The different types of accelerometers were used for analyzing the signals from low to high frequency ranges. Since it is required to take into account not only the measuring ranges but also the sensitivity of the sensors [4], they were chosen with care.

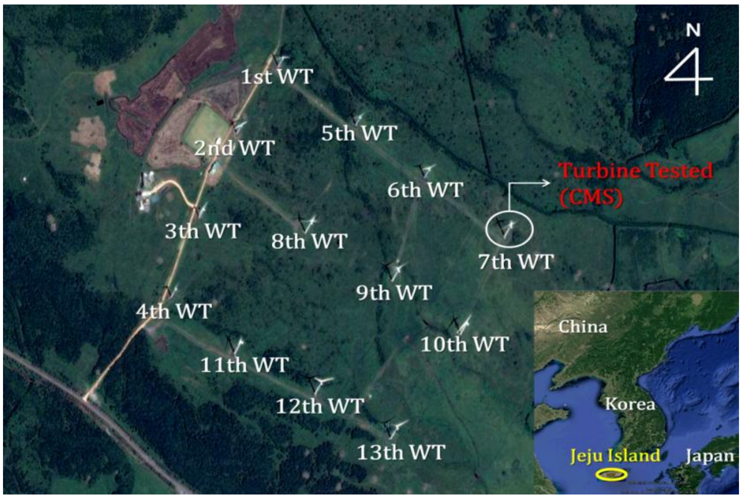


Figure 1.Gasi wind farm, Jeju Island of South Korea where CMS was installed

Figure 2 shows sensor locations of CMS on the gearbox of the 7th wind turbine. Five sensors were used on the gearbox. The 2nd and 3rdsensors were installed at input bearing and the ring gear, respectively. The 4th sensor was installed in axial direction at low speed shaft. Also 5th sensor was installed in radial direction at low speed shaft and 6th sensor was installed at high speed shaft. These sensors were made of piezoelectric effect element, which converts the pressure into an electrical signal. These sensors were attached close to the loading components using ceramic glue [5].

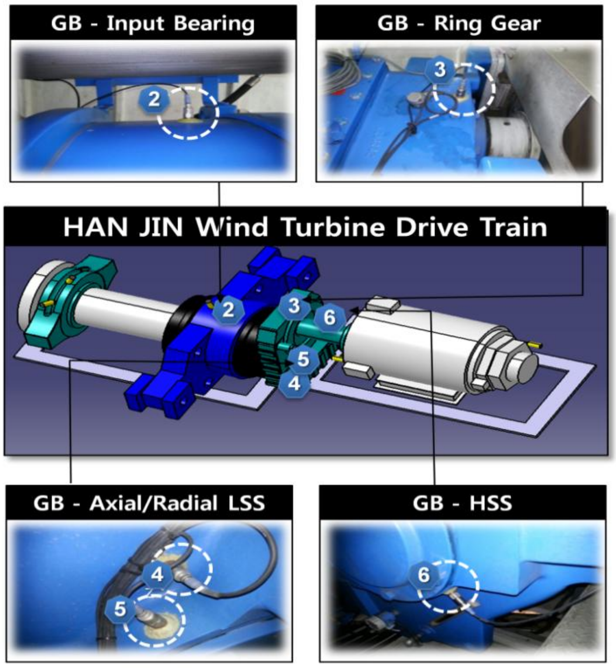


Figure 2. Sensor locations of CMS on the gearbox of the 7th wind turbine

Figure 3 shows flow chart for the data analysis. Two domain analyses, time domain and frequency domain analyses, were performed for the turbine fault diagnosis. After acquisition of the vibration data, time domain analysis is performed. At this step, various statistics such as the mean, variance, root mean square, etc. are calculated. Next, the acceleration value measured on each component should be compared with the acceptance acceleration level which was suggested by VDI 3834 standard. In this work, the acceptance acceleration level was regarded as the threshold value identifying the likelihood of component failures. If measured acceleration values are lower than the acceptance levels, it is considered that there are no component faults at present. On the other hand, if measured acceleration values are higher than the acceptance levels, it is considered that there may be some component faults. Next, frequency domain analysis is performed. FFT technique was applied to convert time domain to frequency domain. Frequency domain analysis is conducted to find the faulty location of components because each component is operating with each specific frequency value. Next, defect frequency in each component is calculated, and then the acceleration value measured should be compared with the acceptance acceleration level given by VDI 3834 standard to identify the likelihood of component failure.

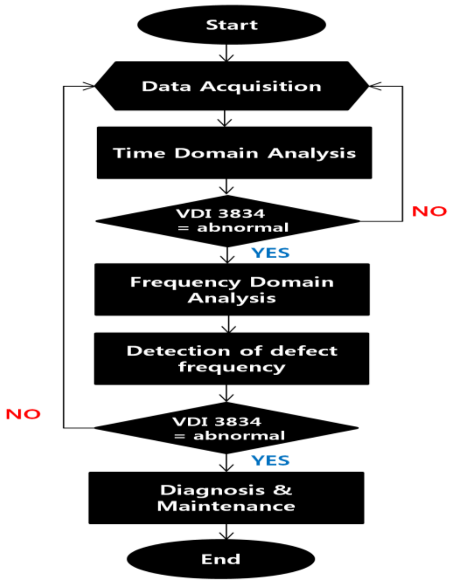


Figure 3. Flow chart for the analysis

3. Vibration signal analysis

Figure 4 presents the trend signal of High Speed Shaft, HSS, of the gearbox. The vibration signal data were stored for two months from February to April in 2016. This analysis makes it possible to visualize the temporal fluctuation of the characteristic values with elapsed time. The signals are usually mixed with vibration signals of shafts, gears, and other mechanical components[6].Thus the signal should be classified according to each component. The value of 0.5m/s^2(0.1-10Hz), 12m/s^2(10-2000Hz) were considered as vibration acceptance levels for the gearbox.

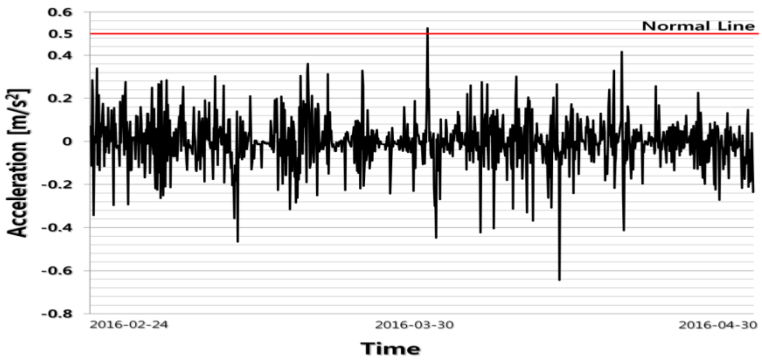


Figure 4. Trend signal of HSS of gearbox (Normal level : 0.5[m/s^2], Source: VDI3834)

Defect frequencies of the relevant components were calculated using the following equations (1)to(4):

$$F_{inner} = \frac{1}{2}Nw\left(1 + \frac{d}{D}\cos\alpha\right) \quad (1)$$

$$F_{outer} = \frac{1}{2}Nw\left(1 - \frac{d}{D}\cos\alpha\right) \quad (2)$$

$$F_{roller} = \frac{1}{2} w \left(\frac{D}{d}\right)\left[1 - \left(\frac{d}{D}\cos\alpha\right)^2\right] \quad (3)$$

$$F_{cage} = \frac{1}{2} w \left(1 - \frac{d}{D}\cos\alpha\right) \quad (4)$$

here, N = Number of rollers
w = Inner race speed
d = Roller diameter
D = Roller pitch diameter
α = Contact angle

For applying these equations, the information of the machine's RPM, the number of rollers, roller diameter, pitch diameter and contact angle is required[7]. The information of them and the defect frequencies calculated for the gearbox bearing are listed in Table1.

Table 1. Specification and defect frequencies of the gearbox bearing

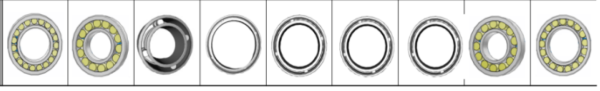
Number of bearing		1th	2th	4th	5th	6th	7th	8th	9th	10th
Type of bearing		Cylindrical Roller Bearing								
Number of rollers		19	14	4	4	4	4	4	13	17
Reference speed (rpm/60)		40	40	11	5	4	8	8	30	37
Roller diameter		54	68	58	53	63	51	51	82	65
Pitch diameter		243	224	280	590	745	400	400	272	268
Defect Frequency (Hz)	Inner race	464	365	25	12	9	17	17	254	387
	Outer race	296	195	17	10	7	13	13	136	236
	Roller	86	59	20	27	22	26	26	35	57
	Cage	16	14	4	2	2	3	3	10	14
Bearing Model										

Figure 5 shows frequency spectrum of HSS of gearbox and defect frequency of bearing inner race. Fundamental bearing frequencies and their harmonics are generally observed in the frequency spectrum. Defect frequencies of the bearings of the gearbox were measured in the range from 9hz to 464hz. These acceleration values were lower than the vibration acceptance level of 0.5 m/s^2. Therefore it could be confirmed that the bearings of the gearbox worked in good condition at present.

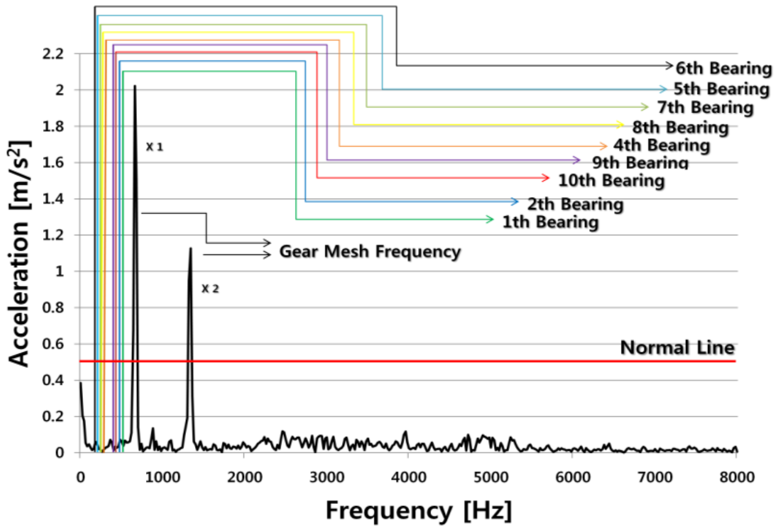


Figure 5.Frequency spectrum of HSS of gearbox and defect frequency of bearing inner race (Normal level : 0.5[m/s^2], Source: VDI3834)

4. Conclusions

1) Defect frequencies of the bearings of the gearbox were estimated in the range from 9hz to 464hzand these frequencies were found to be nearly the gear mesh frequency.
2) Based on the vibration acceptance level which was suggested by VDI3834 standard, the acceleration values of defect frequency were lower than the normal level, 0.5 m/s^2.
3) It was estimated that vibration behavior of the bearings was within the range of normal operation, which led to the conclusion that there were not any defects for the bearings.

Acknowledgments

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