

# Wind Turbine Reliability Analysis In Case of Wind Turbine Blades

Kiran Pal Kour <sup>1</sup>, Loveneesh Talwar <sup>2</sup>, Navneet Singh Bhangu <sup>3</sup>

Assistant Professor, Department of Electrical Engineering, YCET, Jammu, India<sup>1</sup>

Head of Department, Department of Electrical Engineering, YCET, Jammu, India<sup>2</sup>

Associate Professor, Department of Electrical Engineering, GNDEC, Ludhiana, India<sup>3</sup>

**ABSTRACT:** Wind turbines are leaning in the equivalent direction so that, instead of subsequent the sun, they may pursue the wind and harness its potential energy. Failure mode and effects analysis (FMEA) has been broadly worn by wind turbine assembly manufacturers for analyzing, evaluating and prioritizing potential/known failure modes. However, quite a lot of restrictions are connected with its practical implementation in wind farms. First, the Risk-Priority-Number (RPN) of a wind turbine system is not enlightening an passable amount of for wind farm managers from the perspective of criticality; second, there are variety of wind turbines with different structures and hence, it is not correct to compare the RPN values of assorted wind turbines with each other for prioritization purposes; and lastly, some significant economical aspects such as power production losses, and the costs of logistics and transportation are not taken into account in the RPN value. In order to surmount these drawbacks, we expand a mathematical tool for risk and failure mode analysis of wind turbine systems by integrating the aspects of traditional FMEA and some economic considerations. In this paper, the work is being carried out to check the Reliability analysis, this data is collected from the region of Dhule, Maharashtra which is the 1000 MW capacity project set up under the Suzlon Wind Energy. The data is collected from the site and various calculations have been carried out in this thesis using FTA for the reliability. For determining the Reliability it is very important to find out the Mean time between failures, (MTBF) of the different failures that causes the total shut-down of the system. After finding the reliability, the probability of the system is found out so that FTA should be verified. FMEA process is way to indentify the failures, effects, and risks within a process or product and then eliminate or reduce them. The relative risk of a failure and its effects is determined by three factors: severity, occurrence and detection. Then RPN is calculated for each potential failure and effect. After taking the remedial measures it has been found that the reliability of the system increases and the occurrence of the system decreases which directly reduce the RPN index. The work conceded in this thesis had never been proposed by plant personnel and promoter.

**KEYWORDS:** Mean time between failures (MTBF), Fault Tree Analysis (FTA), Risk Priority Number (RPN), Failure Mode and Effect Analysis (FMEA).

## I. INTRODUCTION

The wind power industry has diverse during the past few years and the growth has mainly concentrated on a growing market and the development of larger wind turbines. Different designs have emerged and the technical knowledge makes it possible to put wind turbines off shore [1]. The fast expansion of the wind power market has also come with some obstacles. There is a notable need for improved reliability in the design, manufacturing quality, operation, and maintenance of wind turbines. Industry and others have acknowledged the importance of reliability in the continued growth and enlargement of markets for wind turbine technology. Reliable operations are critical for the hostile environments where turbines are sited and the impacts of reliability (or unreliability) are broad, ranging from economics to betterment of designs [2]. Reliability can be interpreted as the probability that a product will execute its intended function under stated condition for a specified period of time. Reliability analysis had a great influence on safety if the number of hazardous actions can be reduced through decreased failures rates and improved reliability.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

Early wind turbine designs were troubled with fundamental gearbox design errors confined with under-estimation of the operational loads. As we know gearbox is the most costly component of the wind power system, higher than the predictable failures rates are enumerating to the cost of wind energy. Gearbox failures do not begin as gear failures or gear-tooth design deficits. The majority of wind turbine gearbox failures act to initiate in bearing area. Gearbox has the prominent work for increasing the slow rotor speed to meet electromechanical requirements. Gearbox composed of planetary stage and several parallel shaft stages [5].

- There are various methods for calculating the reliability analysis of wind turbine system one of them is the fault tree analysis and FMEA. Fault tree analysis and FMEA both are symbolic and analytical logic techniques that can be implemented to analyse system reliability and its associated characteristics.
- Review the process or product.
- Then, brainstorm potential failure modes.
- Make the list of potential effects of each failure mode.
- A severity Ranking is assigned for each failure mode.
- After that detection ranking for each failure mode or effect is assigned.
- Calculate the RPN for each effect.
- Prioritize the failure Modes for Action.
- Take action to eliminate or reduce high risk failure modes.
- Calculate the RPN again as the failure modes are reduced or eliminated.

## II. PRESENT WORK

The work in present includes the case study of the Wind Farm (Dhule) Maharashtra to check the reliability of some of the components used in the wind turbine system by doing various calculations using the FTA and FMEA method.

The fault tree analysis used to describe the complete set of system failures. The most popular and diagrammatic technique that is FTA, is used to analyse the undesired states of a system using AND gate and OR gate. The main indentified failures modes in the wind turbine sub-assemblies are listed as: fatigue, cracked, deterioration, misalignment, loose, deformed, collapse.

If the technique is being applied one should take the necessary steps:

- Using the list of information required for assessment, one should define the system that will be focused of the FTA.
- Identify what should be for the system either by indentifying the system purpose or goals or by defining the criteria.
- Then identify the factors that are in the top undesired event and that could be causing it.
- Working with an expert team on the system, build the fault tree and determine the top undesired event to identify the underlying causes. Write the top undesired event at the top of the tree.
- Look at each of the key factors identified in the previous step. Indentify the sub-factors and place them underneath the appropriate factor on the tree.
- Continue with the procedure building the tree like graphic until there is a general consensus that the tree is finished.
- Once the fault tree had been completed work with experts to carefully and systematically analyse it for accuracy. Compare the fault tree factors and structure against the actual system being analysed.
- Analyse the fault tree. The analysis done systematically through informal methods. To analyse quantitatively to determine the probability of all the contributing factors.
- By drawing the analysis one should be able to identify the potential factors for the performance problem that can be identified at the top undesired event.
- Focus particularly on the factor that appears lowest in the tree and apply remedial measures to rectify it.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

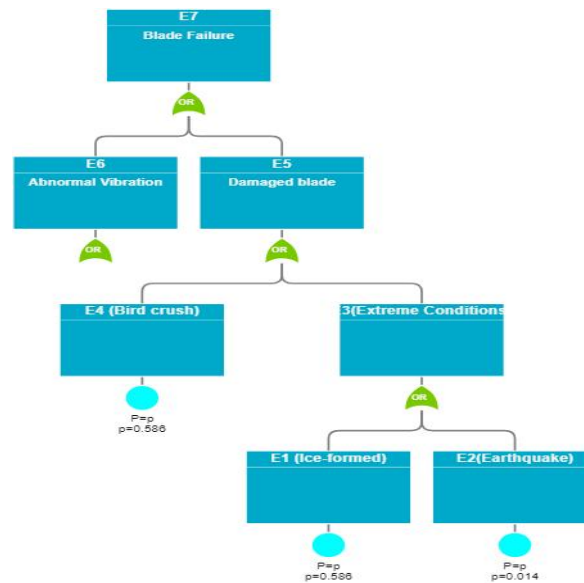


Fig. 1. Fault Tree Diagram of Wind Turbine Blades

From the diagram, the cause of the over-all WTB is depicted in the diagram using FTA. The main cause of the failure of the WTB is due to the Bird-crush and the other extreme environmental conditions like Earthquake and the Ice-forming.

S.NO	Failure Cause	No. Of Failure	Failure time (t)	MTBF	Failure Rate( $\lambda$ )	Reliability $e^{-\lambda t}$	Probability of Failure $P(t)=1-R(t)$
1	Ice formed	0.33	200	25939.39	$3.855 \times 10^{-5}$	0.992	$8 \times 10^{-3}$
2	Earthquake	0.80	150	10762.5	$9.29 \times 10^{-5}$	0.986	0.014
3	Bird crush	30	250	283.66	$3.52 \times 10^{-3}$	0.414	0.586
4	Abnormal Vibration	0.27	600	30222.22	$3.30 \times 10^{-5}$	0.980	0.02

Table 1:- Depicts the values of the failure rate and outage time which helps in calculating the MTBF of the system. The MTBF is defined as the mean time between failures and is used to calculate the reliability which is the ultimate criteria.

### III. FTA METHOD AND CALCULATION FOR WIND TURBINE BLADES FAILURE

Using the codes, the following calculations can be done as under:

$$E3 \text{ or Blade failure} = E1 \cup E2 \quad \text{-----1}$$

$$= \Pr(E1) + \Pr(E2) - \Pr(E1 \cap E2) \quad \text{-----2}$$

$$= (8 \times 10^{-3}) + (0.014) - \{(8 \times 10^{-3})(0.014)\}$$

$$= 0.022 - 1.25 \times 10^{-4}$$

$$= 0.021 \quad \text{-----3}$$

$$E5 = E3 \cup E4$$

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

$$\begin{aligned}
 &= \Pr (E3) + \Pr (E4) - \Pr (E3 \cap E4) && \text{-----4} \\
 &= (0.021) + (0.586) - \{(0.021) (0.586)\} \\
 &= 0.607 - 0.012 \\
 &= 0.595 && \text{-----5}
 \end{aligned}$$

The overall probability of the blade failure:

$$E7 \text{ or } \Pr (\text{Blade Failure}) = E5 \cup E6 \text{-----6}$$

$$\begin{aligned}
 &= \Pr (E5) + \Pr (E6) - \Pr (E5 \cap E6) && \text{-----7} \\
 &= (0.595) + (0.02) - \{(0.595) (0.02)\} \\
 &= 0.615 - 0.575 \\
 &= 0.04 && \text{-----8}
 \end{aligned}$$

Hence, the reliability of blade failure = 0.96.

### IV. FMEA FOR WIND TURBINE BLADES

Failure and effect analysis of the wind blades carried out with effect on wind turbine and failure cause. The FMEA with the detection values, occurrence and severity shows the higher values of RPN.

System Date Sheet				N-BF Blade Failure 12/12/2017 3 of 3			
Function: It helps in making wind energy to be used as electricity							
Failure Mode	Effect on WT	Failure Cause	Detection Method	O	S	D	RPN
Blade Failure	High Dynamic stress Low-rotation speed	Bird Crush Ice-formed Earthquake Abnormal Vibration Damaged Blade due to Gust winds and lightning shock	Visual Inspection	4	4	7	112

Table 2 :- FMEA Spreadsheet of the Wind Turbine Blades

### V. RESULTS AND DISCUSSIONS

In this paper the reliability of the turbine system is analysed. The various calculations has been done on the wind turbine blades. The calculations to analyse their reliability and equally finding the probability using first the FTA method and then with the help of the FMEA their RPN is calculated. The FMEA is a systematic procedure in indentifying the modes of failure and evaluating their consequences. The essential work of an FMEA is to consider the major part of a system how it fail, detection method and the prevention method.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

### VI. THE RELIABILITY ANALYSIS OF THE GEARBOX

The below bar graph depicts the percentage of the reliability the Wind Turbine Blades. From the graph, it can analysed the reasons behind the failure of the Blades is mainly due to the Bird Crush, Ice-formed, Earthquake, Abnormal Vibration ,Damaged Blade due to Gust winds and lightning shock fatigue.

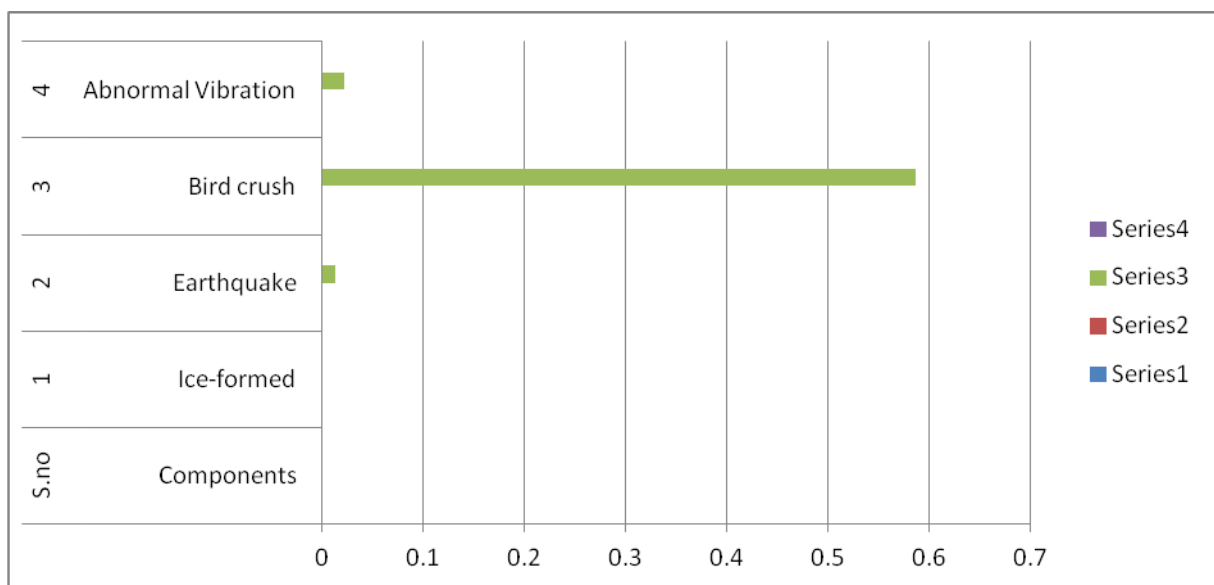


Fig. 2. Bar- graph of Reliability of the Blade (WTB) .The percentage of the reliability mainly lies in the range of 0 to 0.7. The other reason could be the transportation which causes damage to the blades

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

Failure Mode	Effect on WT	Failure Cause	Preventive Method	O	S	D	New RPN
Blade Failure	High Dynamic stress Low-rotation speed	Bird Crush Ice-formed Earthquake Abnormal Vibration Damaged Blade due to Gust winds and lightning shock	Visual inspection even with suitable light, mirrors and careful cleaning of all surfaces cannot be depend on so magnetic testing for cracks is widely done. Blades should be re-inspected and repaired periodically. Inspectors from the ground save time and money. Better choosing of sites and use of radar technology keep the birds away from the site. A higher protection level requires a smaller rolling – sphere radius for the lightning strikes. To minimize the downtime period and benefit from the more favourable winter winds. To keep the rotor turning and therefore limit the ice growth to leading part of the blade that is fitted with some ice protection equipment. Seismic analysis and modelling of soil should be done so to avoid earthquakes. Use powerful electronic sirens to warn against earthquakes.	2	4	7	56

Table 3:- FMEA Spreadsheet of Wind Turbine Blades with Remedial Measures

### VII. CONCLUSION

In this section, a quantitative relative study is conceded out using the traditional and the proposed FMEA methodologies on wind blades. Both the wind turbines have the same power rating, structure, and same condition monitoring system to detect failures. The only difference between the turbines is in their geographical features (such as location, weather conditions, wind speed and temperature). The building blocks of RPN method are discrete, and

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 10, October 2019

therefore cannot represent effectively the strength of criticality. The proposed FMEA methodology would be suitable for use in “risk analysis and evaluation” phase, or during the “operation” stage. At this stage, a more detailed

### REFERENCES

- [1] Kumar Prem M. and Ganesan K., “Fault Tree Analysis of Wind Turbine Gearbox,” International Journal of Science and Engineering Research, Volume 3, Issue 4, 2015, pp.1-3
- [2] Ribrant John., “Reliability Performance and Maintenance-A survey of failures in Wind Power system”, Springer, Volume 2, Issue 4, 2009, pp.5-6
- [3] Baig Ali Ahmed, Ruzli Risza and Baung .B. Azizul, “Reliability Analysis Using Fault tree Analysis,” A review International Journal of Chemical Engineering and Application, Volume 4, Issue 3, 2014, pp.1-5
- [4] Hill R. Roger , Stinebaugh , A. Jennifer and Briand Daniel , “Wind Turbine Reliability- A Database and Analysis Approach,” Sandia National Laboratories, Volume 3, Issue 2, 2008, pp.2-6
- [5] Shafiee Mahmood and Dinmohammadi Fateme, “An FMEA- Based Risk Assessment Approach for Wind Turbine Systems: A comparative study,” Energies, Volume 7, Issue 3, 2014, pp.1-13
- [6] Refsanjani Mirzaei Hesam and Sorensen Dalsgaan John, “Reliability Analysis of fatigue failure of cast components for Wind Turbines,” Volume 8, Issue 5 2015, pp.5-6
- [7] Chennz Varun, “Fatigue- Induced Failure in Horizontal Axis Wind Turbine (HAWT) Blades and HAWT Drive Train Gears,” Volume 8, Issue 4, 2014, pp.1-4
- [8] Katsavounis Stefans, Patsianis Nikoloas, Konstantinidis, E. I and Botsanis Pantelis, “Reliability Analysis on crucial sub-systems of a Wind Turbine through FTA approach,” Volume 7, Issue 2, 2017, pp.1-6
- [9] Panwar, V.S and Mogal,S .P (2015), “A case study on various defects found in a Gear System,” International Research Journal of Engineering and Technology ,Volume 2, Issue 3, 2017, pp.1-5
- [10] Ayoub ,F.M , Mokhtar ,M.O.A, Maalahi ,K.Y and Mohamed ,A ,A .M , An approach to Assess the Reliability of Wind Turbines, Volume 2 Issue 6 , 2016 , pp.15-14
- [11] Rademarkers, M.M.W.L, Seebregts , A and Horn Den Van, B, “Reliability Analysis in wind Engineering ,” ECWEC 93 conference 1993, Volume 5, Issue 3, 2016, pp.1-5
- [12] Wilson, G and McMillan, D, “Modelling the relationship between Wind Turbine failure modes and the environment”, Volume 7, Issue 3, 2014, pp.1-5
- [13] Smolders, K, Hong .H, Feng, Y and Tanver, P, “Reliability Analysis and Prediction of Wind Turbine Gearbox” Volume 5, Issue 4, 2010, pp.1-4
- [14] Skode Rahul and Patil N Anmol “Failure Investigation for Input shaft of Auxiliary Hoist Gearbox,” International Journal of Engineering Research and Technology, Volume 6, Issue 4, 2017 pp.1-4
- [15] Ahadi Amir, Aval Mohsen Sayed, “Reliability Evaluation of Wind Turbine System Components,” Volume 5, 2016 pp.160-168.
- [16] Bin Wang, Zhi-Ling Yang, Xing-Hui Dong and Hao Liu “Expert system of fault Diagonosis for Gearbox in Wind Turbines” 2nd International Conference on Complexity Science and Information Engineering, Volume 4, 2012, pp.189-195
- [17] Qiu Yingning , Chen Lang , Feng Yanhui and Xu Yili, “An approach of quantifying Gear fatigue life for Wind Turbine Gearboxes Using Supervisory Control and Data Acquisition Data,” Energies, Volume 3, Issue 4, 2017, pp.1-5
- [18] Jiang Zhiyu, Hu Weifei, Dong Wenbin, Gao Zhen and Ren Zhengru, “Structural Reliability Analysis of Wind Turbines: A Review,” Energies , Volume 7, Issue 2, 2014 pp.1-8
- [19] Dabrowski Dariuz and Natarajan Anand “Assessment of Gearbox operational loads and Reliability under High Mean Wind Speed,” 12th Deep Sea offshore Wind R&D Conference, EERA Deep Wind, Volume 4, Issue 3, 2015 pp.38-46
- [20] Nacef Tazi, Eric Chatlet and Yousef Bouzid “Using a Hybrid Cost-FMEA Analysis for Wind Turbine Reliability Analysis,” Springer open, Volume 2, Issue 3, 2017, pp.1-20

### BIOGRAPHY



Er. Loveneesh Talwar (Head of Department, Electrical Engineering, YCET, Jammu) received his B.E Degree in Electrical Engineering from MBS College of Engineering and Technology, University of Jammu, India and also received M. Tech. Degree in Energy Management from Shri Mata Vaishno Devi University, Kakrayal, Katra, Jammu, J&k, India. He worked as academic arrangement lecturer in the Department of Electrical Engineering at GCET Jammu for next one and half year and also worked as Head of Department in the department of Electrical Engineering at I.E.C.S Polytechnic, Jammu for next Five years. Presently working as Assistant Head of Department, Electrical Engineering, Yogananda College of Engineering & Technology, Jammu. He had published 10 Research papers in different International Journal and had attended almost 30 National and International Conferences organised by various Institutes and universities. He worked as Co-convenor for 1<sup>st</sup> International conference Riset organised by YCET Jammu in the year 2015. He has attended various short termed courses conducted by different organizations like NITTTR Chandigarh, Dale Carnegie & Associates, Inc. Trainer and Wipro, Usha Automation Panchkula.

## International Journal of Innovative Research in Science, Engineering and Technology

*(A High Impact Factor, Monthly, Peer Reviewed Journal)*

Visit: [www.ijirset.com](http://www.ijirset.com)

**Vol. 8, Issue 10, October 2019**



Er. Kiran Pal Kour received her B.E Degree in Electrical Engineering from MBS College of Engineering and Technology, University of Jammu, India and also received M. Tech. Degree in Power System Engineering from Guru Nanak Dev Engineering College, Ludhaiana, India. Presently working as Assistant Professor in the department of Electrical Engineering YCET, Jammu, India. she got Certificate of participation in national seminar on Smart Grids and Alternate sources of energy also got Certificate of participation “AICTE SPONSORED FACULTY DEVELOPMENT PROGRAMME” in waste management by additive manufacturing. she Worked as an Assistant Editor in TRB Group- The Digital world for their upcoming newspaper.