

# Wind Turbine Reliability Analysis in case of Wind Generator

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**ABSTRACT:** Generator Protective systems are sometimes very intricate incorporating several dissimilar equipment groups. The inherent dependability parameters such as reliability, availability, maintainability and probability of such complex systems are an apprehension of the protection engineer and present a considerable analytical problem. This paper evaluate the use of the failure modes analysis and their effects (FMEA) for analyzing the steadiness of the protection systems and the fault tree method for analyzing the dependability parameters of generator stator phase fault protection system and screening the advantages of backup protection system. The team FMEA enables to design those failures out of the system with the bare minimum of effort and resource outflow, in that way reducing development time and costs. It is extensively used in manufacturing industries in a range of phases of the product life cycle and is now gradually added decision utilize in the service industry.

**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. 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.

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- 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 identified 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.

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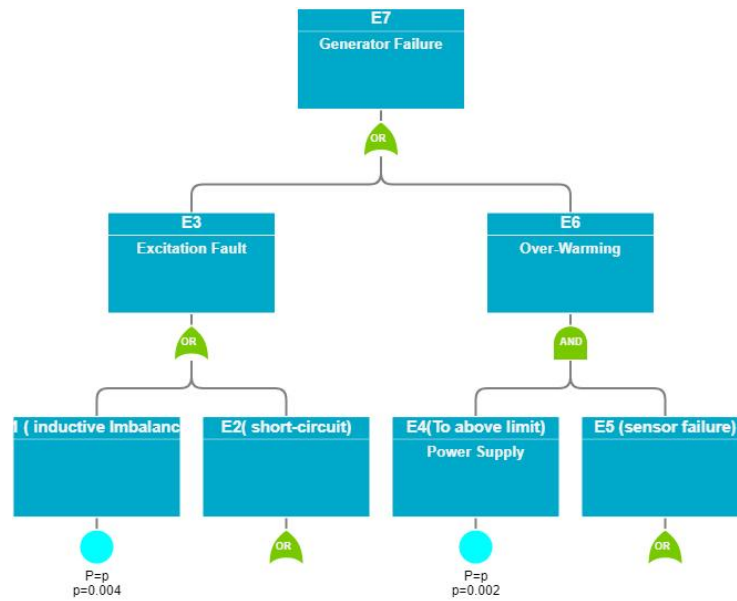


Fig. 1. Fault Tree Diagram of Generator

The fault tree diagram of Generator determines the various defects and the reasons due to which it causes the failure of the over-all system. The diagram of Generator is constructed using Free Web fault tree Analysis (FTA) software tool. It calculates the probability and constructs the diagram with the help of logic gates. From the above diagram it been clearly depicted that the Generator failure is the top most event followed by the sub-components which is responsible for the cause of the failure which is the over-warming and the excitation fault. The excitation fault is connected by the OR gate which means if any of the two inputs cause the failure the top-event automatically shut-downs. The other failure cause ‘over-warming’ is connected by the AND gate which means both the input should fail for the over-all shutdown of the system.

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	Inductive Imbalance	0.27	100	32074.07	$3.11 \times 10^{-5}$	0.996	0.004
2	Short-Circuit	0.99	300	8545.45	$1.17 \times 10^{-5}$	0.965	0.035
3	To above limit(power supply)	0.45	400	18577.77	$5.38 \times 10^{-5}$	0.978	0.022
4	Sensor failure	0.73	250	11657.53	$8.57 \times 10^{-5}$	0.978	0.022

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.

From the above table, it has been depicted that the data has been derived from the region.

- From the given data, the MTBR is calculated.
- From MTBR, the failure rate is further calculated as it the reciprocal of the MTBR i.e.  $1/\lambda$ .
- Further, Reliability is calculated using the formula  $e^{-\lambda t}$ .

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### III. FTA METHOD AND CALCULATION FOR GENERATOR

From the assigned codes and values, calculations can be drawn out for the reliability and probability of the unknown components.

E1=Inductive Imbalance, E2=Short-circuit, E3=Excitation Fault, E4= To above limit (power supply) , E5=Sensor failure, E6= Over-warming of winding , E7= Generator failure

$$\begin{aligned}
 E3 \text{ (Excitation Fault)} &= \Pr (E1) + \Pr (E2) - \Pr (E1 \cap E2) && \text{-----1} \\
 &= (4 \times 10^{-3}) + (0.035) - \{(4 \times 10^{-3}) \times (0.035)\} \\
 &= (0.039) - (1.4 \times 10^{-4}) \\
 &= 0.038 && \text{-----2}
 \end{aligned}$$

- $E6 = E4 \cap E5$  -----3
- $= \Pr (E4) \cdot \Pr (E5)$  -----4
- $= (0.022) (0.022)$  -----5
- $= 4.84 \times 10^{-4}$  -----5

Now, the overall probability of the generator failure can be calculate as:

- $\Pr (\text{Generator}) = \Pr (E3 \cup E6)$  -----6
- $= \Pr (E3) + \Pr (E6) - \Pr (E3 \cap E6)$  -----7
- $= (0.038) + (4.84 \times 10^{-4}) - \{(0.038) \times (4.8 \times 10^{-4})\}$
- $= 0.038 - 1.82 \times 10^{-5}$

$= 0.0379$  -----8

Hence, the reliability of Generator R(s) = 0.962. -----9

### IV. FMEA FOR GENERATOR

Failure and effect analysis of the Generator 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-G Generator 20/11/2017 2 of 2					
FUNCTION: Convert Mechanical Energy into Electrical Energy							
Failure cause	Effect on WT	Failure Cause	Detection Method	O	S	D	RPN
Generator Failure	Non-Conversion of energy System Failure Effect on Gearbox Grid loss Shut-down	Excitation Failure Over-warming Inductive Imbalance Short-circuit Bearing Fault	Visual Inspection Condition Monitoring SCADA	4	6	7	168

Table 2 :- FMEA Spreadsheet of the Generator Failure

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## V. RESULTS AND DISCUSSIONS

In this paper the reliability of the turbine system is analysed. The various calculations has been done on the main components of the Generator turbine system. 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.

### VI. THE RELIABILITY ANALYSIS OF THE GENERATOR

The below bar graph depicts the percentage of the reliability the generator. From the graph, it can analysed the reasons behind the failure of the Gearbox is mainly due to the fatigue, oil filtration problem and then to some extent the wear and tear in the tooth surface. The least contributed is the combination of particles, the debris collected in the components of Gearbox.

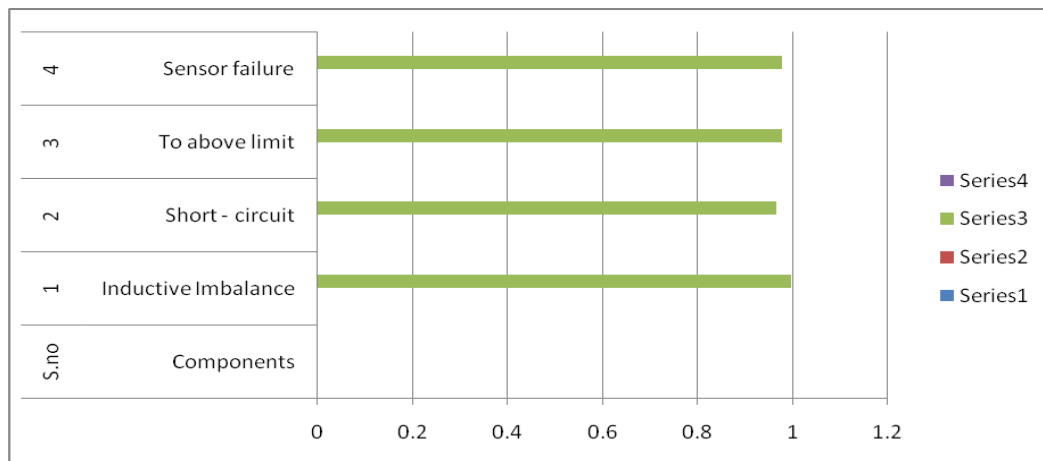


Fig. 2. The percentage of the Reliability of the generator and the reasons that contribute to the failure of the generator .

From the above graph it can be easily analysed that almost all the factor share the equal proportion in the failure of the Generator and how much reliable they can be in case of Generator. The factors that contribute to the failure are mainly because on the sensor failure, the inductive imbalance or due to the short circuits. The Reliability percentage lies mainly in the range of 0 to 1.

Failure Mode	Effect on WT	Failure Case	Preventive Measures	O	S	D	New RPN
Generator Failure	Non-Conversion of energy System Failure Effect on Gearbox Grid loss Shut-down	Excitation Failure Over-warming Inductive Imbalance Short-circuit Bearing Fault	Condition monitoring system can be used to decrease the operation and maintenance costs. The optimal threshold failure probability values can be determined by applying the CBM optimisation. SCADA system provides remote monitoring by collecting data from the	2	6	7	84

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			<p>system and sending them to a central computer for monitoring and control usages.</p> <p>Over-warming of the rotor surface, wedges and rings gets melted from the high currents of self-starting.</p> <p>The salient pole construction can be integral with shaft mounted out board exciter.</p> <p>Short-circuits usually occurs due to the unbalanced stator voltage, which is caused by an unbalanced load in the power line. In order to prevent first identify the situation of the shorted-coil. Same methodology can be used to detect the faults that occur due to the generator rotor imbalance.</p> <p>Bearing fault detection technique in the wind generator need mechanical sensors, such as vibration sensors (accelerometers) which are mounted on the surface of the wind generator.</p>				
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Table 3:- FMEA Spreadsheet of Generator with Remedial Measures

## VII. CONCLUSION

The benefits of the FTA and FMEA is been proved in the Reliability analysis of the Wind turbine. Probabilistic analyses to assess the safety and reliability of wind turbines constitute a necessary supplement to the deterministic studies and design rules to achieve a more balanced design. The calculations had been done with the help of FTA method so to calculate their reliability and the fault tree is constructed. In this thesis work, we analysed the failure mode of wind turbine system by the traditional FMEA method. The important features of this methodology can be summarised as follows: The reliability and probability analysis has been carried out for generator which assesses the safety and reliability of wind turbine and the calculations has been done with the help of FTA and FMEA analyzed the failure mode. This methodology helps to enhance the RPN index which is the multiplication of occurrence, Severity and the detection method of a failure. The paper is unusual in calculating the each factor which leads to the failure of generator. FTA tree is unhurried of each constituent and each FMEA table is established.

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