PERFORMANCE PREDICTION & PRODUCTIVITY ENHANCEMENT OF HORIZONTAL AXIS WIND TURBINE USING FAILURE MODE & ANALYSIS

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Abstract: failure mode effective analysis has been used as qualitative measures for identifying failure modes and cause. In order to mitigate the effects of failure in different parts of the wind turbine. With the help of failure mode effective analysis improvement in the reliability and reduces the breakdown in the wind turbine and resulting the optimum efficiency at optimum cost. A failure modes and effects analysis is a procedure in product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. Failure modes are any errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. Effects analysis refers to studying the consequences of those failures

I. INTRODUCTION

Wind Turbine- A wind turbine is a device that converts kinetic energy from the wind into mechanical energy. If the mechanical energy is used to produce electricity, the device may be called a wind generator or wind charger. If the mechanical energy is used to drive machinery, such as for grinding grain or pumping water, the device is called a windmill or wind pump. Developed for over a millennium, today's wind turbines are manufactured in a range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on sailing boats; while large grid-connected arrays of turbines are becoming an increasingly large source of commercial electric power.

FMEA- FMEA has been shown to be an effective way of improving machinery design reliability. The FMEA is a powerful design tool that provides a means, from a risk point of view, of comparing alternative machine configurations. The FMEA is also useful for considering designs improvements for a technology which is changing or increasing in rating, as WT configurations are. The FMEA is a formalized but subjective analysis for the systematic identification of possible Root Causes and Failure Modes and the estimation of their relative risks. The main goal is to identify and then limit or avoid risk within a design. Hence the FMEA drives towards higher reliability, higher quality, and enhanced safety. It can also be used to assess and optimize maintenance plans. The causes of failure are said to be Root Causes, and may be defined as mechanisms that lead to the occurrence of a failure. While the term failure has been defined, it does not describe the mechanism by which the component has failed. Failure Modes are the different ways in which a component may fail. It is vitally important to realize that a Failure Mode is not the cause of a failure, but the way in which a failure has occurred. The effects of one failure can frequently be linked to the Root Causes of another failure. The FMEA procedure assigns a numerical value to each risk associated with causing a failure, using Severity, Occurrence and Detection as metrics. As the risk increases, the values of the ranking rise. These are then combined into a Risk Priority Number (RPN), which can be used to analyze the system. By targeting high RPN values the most risky design elements can be addressed. RPN is calculated by multiplying the Severity, Occurrence and Detection of the risk. Severity refers to the magnitude of the End Effect of a system failure. The more severe the consequence, the higher the value of severity will be assigned to the effect. Occurrence refers to the frequency that a Root Cause is likely to occur, described in a qualitative way. That is not in the form of a period of time but rather in terms such as remote or occasional. Detection refers to the likelihood of detecting a Root Cause before a failure can occur. Since FMEA is used by various industries, including Automotive; Aeronautical; Military; Nuclear and Electro-technical, specific standards have been developed for its application. A typical standard will outline Severity, Occurrence and Detection rating scales as well as examples of an FMEA spreadsheet layout. Also a glossary will be included that defines all the terms used in the FMEA. The rating scales and the layout of the data can differ between standards, but the processes and definitions remain similar.

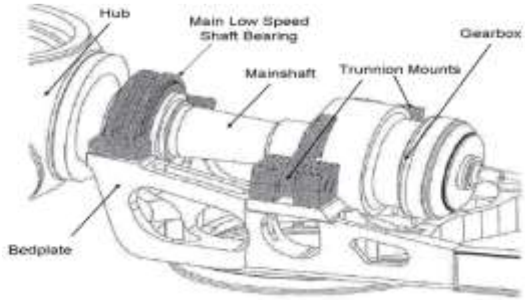

Figure 1

Failure Modes and Effects Analysis (FMEA) is methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome these issues, thereby enhancing reliability through design. FMEA is used to identify potential failure modes, determine their effect on the operation of the product, and identify actions to mitigate the failures. A crucial step is anticipating what might go wrong with a product. While anticipating every failure mode is not possible, the development team should formulate as extensive a list of potential failure modes as possible. The early and consistent use of FMEAs in the design process allows the engineer to design out failures and produce reliable, safe, and customer pleasing products.FMEA also capture historical information for use in future product improvement

There are several types of FMEA some are used much more often than others. FMEA should always be done whenever failures would mean potential harm or injury to the user of the end item being designed. The types of FMEA are:

1. System - focuses on global system functions
2. Design - focuses on components and subsystems
3. Process - focuses on manufacturing and assembly processes
4. Service - focuses on service functions
5. Software - focuses on software functions

2. DESIGN AND CONSTRUCTION OF WIND TURBINE- Wind turbines are designed to exploit the wind energy that exists at a location. Aerodynamic modeling is used to determine the optimum tower height, control systems, number of blades and blade shape. Wind turbines convert wind energy to electricity for distribution. Conventional horizontal axis turbines can be divided into three components.

1. The rotor component, which is approximately 20% of the wind turbine cost, includes the blades for converting wind energy to low speed rotational energy.
2. The generator component, which is approximately 34% of the wind turbine cost, includes the electrical generator, the control electronics, and most likely a gearbox (planetary gearbox, adjustable-speed drive or continuously variable transmission) component for converting the low speed incoming rotation to high speed rotation suitable for generating electricity.
3. The structural support component, which is approximately 15% of the wind turbine cost, includes the tower and rotor yaw mechanism.

3. METHODOLOGY- The goal of the failure modes and effects analysis is to anticipate, identify and avoid failure in the operation of a new system while the system is still on the drawing board. The recent occurrence of failure in some new system in operation has had disastrous effects on many lives. These events promoted the authors to evaluate the documented problems and to seek improvements in FMEA procedures and their applications.

FMEA Procedure

The process for conducting an FMEA is straight forward. The basic steps are outlined below.

1. Describe the product/process and its function. An understanding of the product or process under consideration is important to have clearly articulated. This understanding simplifies the process of analysis by helping the engineer identify those product/process uses that fall within the intended function and which ones fall outside. It is important to consider both intentional and unintentional uses since product failure often ends in litigation, which can be costly and time consuming.

2. Create a Block Diagram of the product or process. A block diagram of the Product/process should be developed. This diagram shows major components or process steps as blocks connected together by lines that indicate how the components or steps are related. The diagram shows the logical relationships of components and establishes a structure around which the FMEA can be developed. Establish a Coding System to identify system elements. The block diagram should always be included with the FMEA form.
3. Complete the header on the FMEA Form worksheet: Product/System, Sub Component, Design Lead, Prepared By, Date, Revision (letter or number), and Revision Date. Modify these headings as needed.
4. Use the diagram prepared above to begin listing items or functions. If items are components, list them in a logical manner under their subsystem/assembly based on the block diagram.
5. Identify Failure Modes. A failure mode is defined as the manner in which a component, subsystem, system, process, etc. could potentially fail to meet the design intent. Examples of potential failure modes include Corrosion,Hydrogen embrittlement Electrical Short or Open, Torque Fatigue Deformation, Cracking
6. A failure mode in one component can serve as the cause of a failure mode in another component. Each failure should be listed in technical terms. Failure modes should be listed for functions of each component or process step. At this point the failure mode should be identified whether or not the failure is likely to occur. Looking at similar products or processes and the failures that have been documented for them is an excellent starting point.
7. Describe the effects of those failure modes. For each failure mode identified the engineer should determine what the ultimate effect will be. A failure effect is defined as the result of a failure mode on the function of the product/process as perceived by the customer. They should be described in terms of what the customer might see or experience should the identified failure mode occur. Keep in mind the internal as well as the external customer. Examples of failure effects include:

- Injury to the user
- Inoperability of the product or process
- Improper appearance of the product or process
- Odors
- Degraded performance
- Noise

Establish a numerical ranking for the severity of the effect. A common industry standard scale uses 1 to represent no effect and 10 to indicate very severe with failure affecting system operation and safety without warning.
8. Enter the Probability factor. A numerical weight should be assigned to each cause that indicates how likely that cause is (probability of the cause occurring). A common industry standard scale uses 1 to represent not likely and 10 to indicate inevitable.
9. Identify Current Controls (design or process). Current Controls (design or process) are the mechanisms that prevent the cause of the failure mode from occurring or which detect the failure before it reaches the Customer. The engineer should now identify testing, analysis, monitoring, and other techniques that can or have been used on the same or similar products/processes to detect failures. Each of these controls should be assessed to determine how well it is expected to identify or detect failure modes. After a new product or process has been in use previously undetected or unidentified failure modes may appear. The FMEA should then be updated and plans made to address those failures to eliminate them from the product/process.
10. Determine the likelihood of Detection. Detection is an assessment of the likelihood that the Current Controls (design and process) will detect the Cause of the Failure Mode or the Failure Mode itself, thus preventing it from reaching the Customer. Based on the Current Controls, consider the likelihood of Detection using the following table for guidance.
11. Review Risk Priority Numbers (RPN). The Risk Priority Number is a mathematical product of the numerical Severity, Probability, and Detection ratings: RPN = (Severity) x (Probability) x (Detection) the RPN is used to prioritize items than require additional quality planning or action.
12. Determine Recommended Action(s) to address potential failures that have a high RPN. These actions could include specific inspection, testing or quality procedures; selection of different components or materials; de-rating; limiting environmental stresses or operating range; redesign of the item to avoid the failure mode; monitoring mechanisms; performing preventative maintenance; and inclusion of back-up systems or redundancy.
13. Assign Responsibility and a Target Completion Date for these actions. This makes responsibility clear-cut and facilitates tracking.
14. Indicate Actions Taken. After these actions have been taken, re-assess the severity, probability and detection and review the revised RPN's. Are any further actions required?
15. Update the FMEA as the design or process changes, the assessment changes or new information becomes known

Wind Turbine Failure Modes

Failure Mode Description

- Structural Failure
- Electrical Failure
- Mechanical Failure
- Blockage.
- Material Failure
- Electrical Insulation.
- Thermal Failure.
- Output Inaccuracy.
- Intermittent

Sub-assemblies major part

Table 1

Structure	Nacelle, Tower, Foundation
Rotor	Blades, Hub, Air brake
Mechanical Brake	Brake disk, Spring, Motor
Main shaft	Shaft, Bearings, Couplings
Gearbox	Toothed gear wheels, Pump, Oil heater/cooler, Hoses
Generator Shaft,	Bearings, Rotor, Stator, Coil
Yaw system	Yaw drive, Yaw motor
Converter	Power electronic switch, cable, DC bus
Hydraulics	Pistons, Cylinders, Hoses

Failure Root Cause

Table 2

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Failure	**Root cause**	**Effect**
Calibration Error	High Cycle Fatigue	Maintenance Fault
Connection failure	Installation Defect	Manufacturing Defect
Corrosion	Insufficient Lubrication	Mechanical Overload
Design Fault	Insulation degradation	Overheating
Electrical Overload	Lightning Strike	Presence of Conducting rubble
Excessive Brush Wear	Loss of Power Input	Presence of Debris

Action Plan of FMEA- Action plan of Failure mode & analysis

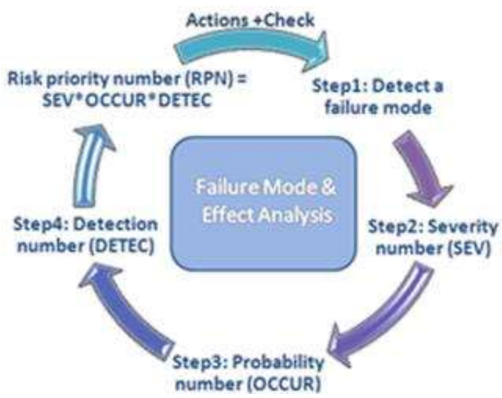

Figure 2

RESULTS-

1. Potential FMEA Manual is the authoritative reference.
2. Severity scores of 9 or 10 must be used for safety related risks.
3. Occurrence ranks how often each cause is likely to result in failure.
4. It is appropriate to focus on high severity items first.
5. Credit for preventive actions shows up in the frequency of occurrence.
6. Risk Priority Numbers provides a rank order to risks and action items.
7. An effective approach is to continual focus.
8. Process FMEA should result in tangible improvement to process.

CONCLUSION –

The FMEA has the potential to improve the reliability of WT systems especially for the offshore environment, where reliability will play a much stronger part in prospective cost-effectiveness. Furthermore, it is believed that in time, it will play a major role in the development of WTs, which require little or no maintenance, making wind a more cost-effective and sustainable energy resource. The different types of failure and the causes of failure were determined. In order to increase the availability of wind turbine generators, spare parts analysis was also done to determine the optimum number of spare parts required at the wind farms.

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