MAJOR FAILURES IN THE WIND TURBINE COMPONENTS AND THE IMPORTANCE OF PERIODIC INSPECTIONS

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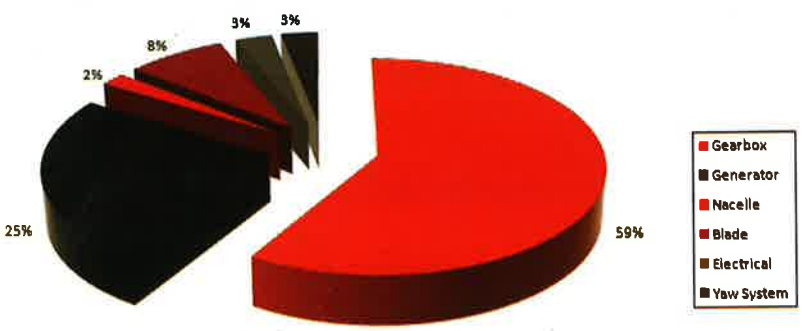
Reliability of wind turbines is a pre-requisite to ensure the healthy growth of wind energy. Even if new designs and prototypes performed by manufacturers and validated by certification bodies offer safer and more reliable wind turbines, their development and related improvement are based on the experience with turbines smaller than those currently being erected. Therefore the technology is still coming up against its limitations. To this end it has been recognized that there is a need for the continuous monitoring of major wind turbine components such as gear box, generator and Rotor blades. These components are seen to require substantial maintenance and repair efforts or even retrofits. Hence, periodic inspection of these components by any independent third party to ensure the safe and efficient operation is also necessary.

I. Major Failures in the Wind turbine components and its impacts

A wind turbine is a complex machine functioning in a complex environment. Wind turbines are built by the integration of various technologies and elements coming from aeronautics, mechanical engineering, hydraulics, electrical and electronic engineering, automation, informatics as well as civil works for the foundations. Fig. 1 shows a quick review on the cause of failures occurred on a wind turbine.

As for any integrated system, some of the components are more important than others, so, for a wind turbine, neuralgic components hence identified as critical are the gearbox, generator and rotor blades.

WIND TURBINE FAILURES



The Fig 2 shows the various failures that occur in the wind turbines, frequency of the failure and the impact of those failures in the wind turbine operation. From the figure it is clear that, the failures which occurs in the neuralgic components such as gearbox, generator are having more down time and also it causes more economic losses for the wind farm operator.

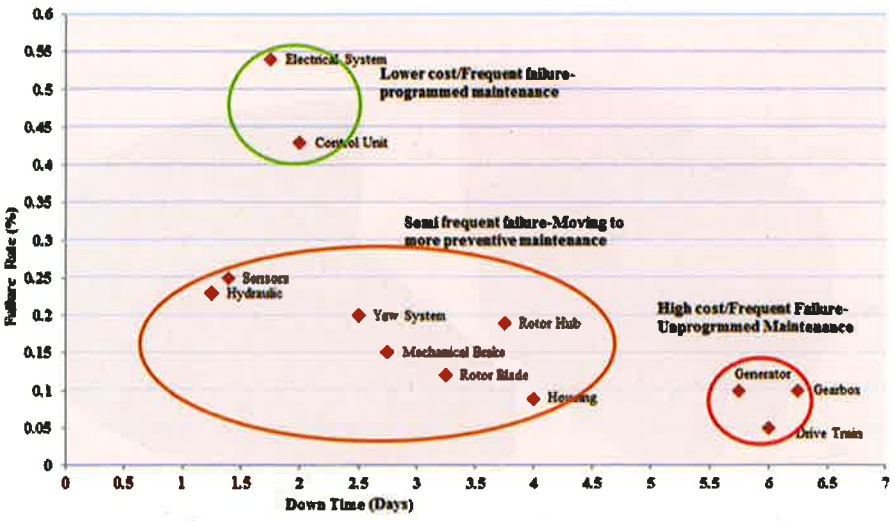
These critical components have to be carefully controlled by means of a maintenance program and regular inspections. If a fault is occurring on one of these main components, it may lead to an unsafe situation for the wind turbine itself and for others but inescapably lead to a financial risk with a loss of production. Therefore, a wind turbine has to be efficiently controlled by frequent inspections in order to protect the goods and preserve the continuity of production or, at least, to minimize as far as possible the shutdown period when performing maintenance work, repair or exchanging a component.

i. Gearbox

The conversion of the greatly differing rotational speeds of the rotor and the electric generator has given the designers of the first wind turbines many headaches. This situation has changed with the progress which has been made in gearbox technology.

Today, high-performance gearboxes with gear ratios of up to 1:100 and more are available. Regardless of this favorable situation, the gearbox has been and still is a source of failures and defects in many wind turbines because of their complexity and multiple moving parts which are possible weaknesses (e.g. bearings).

FIGURE: 2 RELIABILITY AND COST OF FAILURES (SOURCE: ISET, UPWIND, EMERGING ENERGY RESEARCH)



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GEARBOX FAILURES

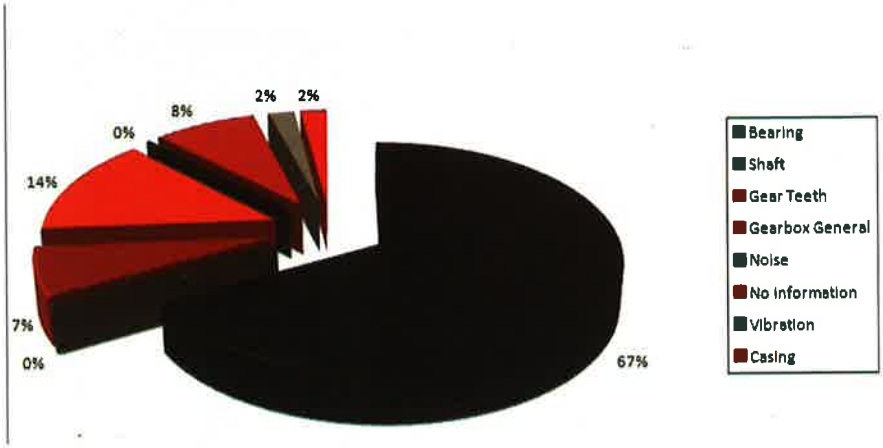


FIGURE 3 PERCENTAGE OF VARIOUS FAILURES OCCURS IN THE DIFFERENT PARTS OF THE GEARBOX

The reasons for these failures are varied and can be attributed to manufacturing quality lapses when controlling the material supply and production activities, inappropriate design decisions or extreme weather situations on a given site.

The Fig 3 shows the percentage of various failures occurs in the different parts of the gearbox. Statistically, in a wind turbine the gearbox is replaced every 5 to 7 years. Even in a year when a turbine gearbox has not failed, gearboxes represent single-handedly a financial risk because of their environmental impact through their acoustic emission which may lead to possible recourse action or financial resources to be implemented for maintenance work. Hence they require more maintenance as well as careful inspections.

The most common failure in the Gearbox is Bearing failures and the various reasons are heavily loading/ lightly loading, Misalignment, Incorrect package of thermal effects and Poor lubrication. The other failures which occur in the gearbox are cracks/ breakage in the gear teeth and the surface fractures. The reasons for these types of failures are excessive loading and due to vibration.

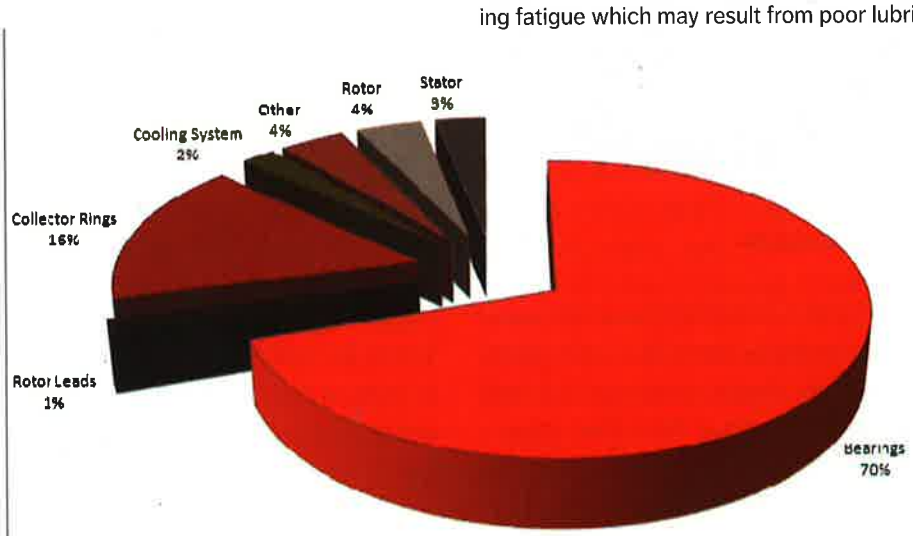
ii. Generator

The Generator is the component of the wind turbine that transforms mechanical energy in to electrical energy and it is a very critical component of the wind turbine with high failure rates. The main reason is that the generator works with a power source supplying highly fluctuating mechanical power

Two main categories of failures are known regarding the generators:

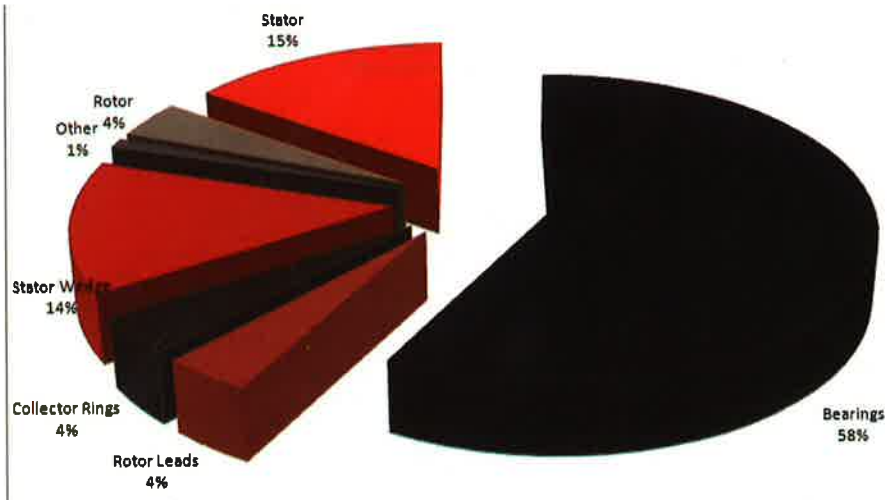
1. Winding failure which may result from defective insulation systems or poor winding design
2. Mechanical failure because of early bearing fatigue which may result from poor lubri-

MEDIUM GENERATORS



THE FIG 4 SHOWS THE DIFFERENT FAILURES WHICH OCCUR IN THE DIFFERENT PARTS OF THE WIND TURBINE GENERATORS.

LARGE GENERATORS



cation

The quality of the insulation is affected over the years because of functional stress. This stress reduces the electrical resistivity of insulations which creates an increase of the leakage currents and then can lead to incidents which may affect the safety of goods and persons as well as causing production losses due to shut down periods.

The Fig 4 shows the different failures which occur in the different parts of the wind turbine generators. Figure: 4 Different failures which occur in the different parts of the wind turbine generators

the localization of the deviations:

•Inside the blade: cracks at the bonding resin, missing adhesive, discontinuities on the sandwich, delamination's within the glass fiber reinforced plastics (GFRP) or the sandwich, crack on web, excess of bonding resin, problems in the bonding, waves, air inclusions, etc.

•Outside, on the surface: erosion impact on the blade surface, deviations to observing laminate (spalling, flaking and cavities), deficient bond at the bonding surfaces, cracks

TABLE.1 POSSIBLE DAMAGES ON BLADE AND TIME FOR CORRECTION

POSSIBLE DAMAGES FOUND ON BLADE	***RECOMMENDED TIME FOR CORRECTION***
MINOR SUPERFICIAL DEFECTS FOUND INSIDE AND OUTSIDE	24 MONTHS
FIRST SIGNS OF DAMAGE IN THE STRUCTURE, SEVERAL SURFACE DEFECTS AND THIN CRACKS AT THE BONDING	12 - 24 MONTHS
DAMAGE IN THE STRUCTURE, CRACKS IN THE SHELL AND IN THE BONDING, SEVERAL SURFACE DEFECTS	3 - 12 MONTHS
MAJOR DEFECTS IN THE MAIN STRUCTURE AND IMPORTANT CRACKS THAT DECREASE THE AERODYNAMIC STRUCTURE	0 -3 MONTHS WITH POSSIBLE REDUCTION OF POWER
DAMAGE THAT CANNOT COMPLY WITH A SAFE OPERATION	STOP OF THE PRODUCTION FOR SAFETY REASON

iii. Rotor Blades

The rotor blades of a wind turbine catch the energy of the wind. This energy is transformed into mechanical energy through the rotor that turns the main shaft of the wind turbine and then the generator to produce electrical energy. The blades are permanently stressed by environmental conditions like rain, moisture, temperature change, ice, UV radiation and of course lightning. There are several types of damages according to and of course lightning strikes. It is obvious that rotor blades are a highly stressed part of a wind turbine because of the constant wind contact. They need regular inspection to evaluate their structural safety by experienced experts. Failures, damages and debris on the rotor blades can reduce the overall productivity of a turbine which can result in expensive repairs and important losses of production. Critical areas of a blade are beam and webs, bonding (web, leading edge and trailing edge) and the sandwich at the maximum profile depth (see Tab. 1).

Regarding the economic facts and costs to exchange a blade, it makes sense to be sure that the blades are in a good condition and that they will last a long time. To face this operational reality, it is strongly recommended to take care of the blades by performing yearly blade inspections as well as making sure that repairs and cleaning are part of the preventative maintenance program implemented by the manufacturer or other maintenance service company mandated by the owner or its operator.

II. What is meant by WTI (Wind Turbine Inspection)?

The periodic inspections of the wind turbine and the main components are carried out by an independent technical expert who shall have access to the relevant technical documentation.On the basis of these documents, a specific checklist with the evaluation criteria is prepared in order to perform the inspection. The assessment and results have to be based on the Guideline for the Certification of Wind Turbines of Germanischer Lloyd and the IEC standards in their latest editions The inspection plan includes all critical components related to the power production, the protection system and the protective measures for safety of the staff. The inspection report is written and signed by the technical expert. At least, this report has to contain the following information:

•Manufacturer, type and serial number of the wind turbine and the tower

•Location of the owner and the operator of the wind turbine

•Operating hours and total energy produced

•Date and weather condition on the day of inspection

•Persons present at the inspection

•Detailed description of the scope of inspection

•Remarks, defects and deviations found. A

timeframe shall be prescribed for repairs and recommended corrective actions.

•Result of the inspection

The owner has to file the inspection reports for the operating life of the wind turbine.

III.Various types of Wind Turbine Inspections

Various types of WTI (Wind Turbine Inspection) services are:

At appropriate times

For periodic technical inspections during life time of the wind farm/Wind turbine

With specific inspections on main components

i. Fitted inspections at appropriate times

-At the workshop as soon as nacelles and blades have successfully passed the manufacturing quality control process.

-At the site during the delivery of the components from unloading until the definitive storage condition.

-At certain stages during assembly/construction of the wind turbine or wind farm.

ii. Periodic inspections

The complete turbine shall be examined closely by visual inspection on individual components as well as rotor blades. The structural integrity of the wind turbine, including machinery, functioning of the safety and braking systems, shall be checked at the period stated below:

- Just after the commissioning performed by the manufacturer to inspect the work done and to establish a snag list before signing the official take-over certificate of each wind turbine.

- 6 months prior to the contract completion (turbine sale contract or operation and maintenance contract) in order to address to the manufacturer the remaining issues before the end of the warranty period.

-Before a Merge & Acquisition of the Wind Farm.

- Whenever during the life time of wind farms/ turbines, recommended every 2 or 4 years.

iii. Specific Inspections on Main Components

a. Gearbox inspection

In order to perform a general assessment of the gearbox's condition, investigations are aided by a visual and by a video-endoscopic inspection inside the gearbox to detect wear and deviations on bearings and gears. The possibility of inspecting the main drive by vibration sensors analysis is also available. A gearbox inspection scope includes these following issues:

•Oil Condition sample and analysis

•Gearbox condition

•Gearbox's cooling system and oil lines of the cooling systems.

•Inspection of the gearbox via a flexible video-endoscope on all visible bearings, cogs, pinions and sprockets.

•Inspection of the drive train components via off-line vibration sensor analysis allows detecting the evidence of early fault defects especially at the Gearbox and Generator.

b. Generator inspection

A generator inspection work consists of these following investigations:

-Verification high speed shaft coupling, shaft alignment and calculation of the compensations to re-align the coupling train,

-Check if abnormal noise is heard from the bearings

-Generator's cooling system,

-Insulation test of the generator (stator and rotor).

c. Blades Inspection

Both interior and exterior sides of each blade and its root region are checked for air inclusions, cracks, lightning damages, erosion wears, delamination, defective bonds and other quality problems. The condition of the joint seals, lightning protection systems and additional aerodynamic parts are checked as well as existing rain deflectors or possible repaired areas. The lightning protection system can be verified with a measurement of the ohmic resistance.

Conclusion

To briefly sum up the situation, on the one hand, there is the demand for wind energy which is rapidly expanding and on the other hand, the heart of the industrial process that converts wind energy into electrical energy consists of a complex machine made of critical and neuralgic components that may lead to important production losses and repair costs. If we draw a parallel between these observations, wind turbine inspection is an essential service that facilitates our wind industry to produce reliable wind power and for enhanced safety related aspects.

IV. UL-DEWI offers Wind Turbine Inspection services to Ensure a Safe and Efficient Operation

UL-DEWI offers all type of Wind Turbine Inspection services. Our goal is to bring you the keys in order to maintain your wind turbines in optimal condition by means of an assessment of the current technical state, clarification of technical issues and initial damages summed up with accurate recommendations in a well-documented report.

Technical Expertise -

Damage Analyses

In case of damage on or caused by wind turbines, UL-DEWI, as an independent expert, can clarify the nature of the damage and determine the root cause at any stage of the defect occurrence, from the component delivery to any time during the operating period.