Generator bearing defect development evaluation based on discrete fault stages

1. **Introduction**

The fast growth of wind energy technology has yielded high demands regarding the reliability of the wind turbines. The estimates of the operation and maintenance expenses for a wind turbine of 20-years lifetime are 10-15% and 20-25% of the total revenue for onshore and offshore wind turbines respectively. Hence, many wind turbines manufacturers and operators have adopted condition-based maintenance strategies in order to optimize the time of troubleshooting and component replacement, increase the energy and time based availability of their systems and reduce the cost of energy (CoE). Techniques such as vibration, temperature and oil analysis have been extensively applied in modern wind turbines focusing mainly on the drive train components.

2. **Approach**

Fault detection in generator bearings can be successfully performed by installing accelerometers radially close to the bearing load zone. Numerous condition indicators are extracted in order to characterize the health of the bearing under fault condition monitoring systems (CMS) are commonly semi-automated, where the system intelligence is combined with operator interaction in order to alert, diagnose and evaluate the severity of the potential defect. Brüel & Kjær Vibro monitoring setup facilitates four discrete fault stages of varying severity and lead time ranging from action at the next scheduled service to stopping the wind turbine. The information is communicated to the end user via alarm reports consisting of detailed diagnostics and assessment of maintenance needs. By employing the above mentioned strategy in the maintenance planning, service providers can optimize the logistics process, mobilize cranes, manage resources and prioritize tasks.

3. Main body of abstract

The time interval between each severity stage is plotted based on 340 alarm reports issued for 119 developing generator bearing faults, mainly inner raceways defects. The presented cumulative density functions depict from statistical perspective the actual period required for the fault to develop and be upgraded to higher severity. In Figure 1, it is shown that progressing from the lowest severity level, i.e. 4 where no lead time is provided, to severity 3, where the lead time to inspection is 2 to 4 months, 80% of the faults will be upgraded within 10 months and 60% within 4 months. Correspondingly in Figure 2, the time period for a severity 3 fault to develop to severity 2 is 4 months for 80% and 2 months for 60% of the cases. Finally, the last acceptable fault state, severity 1, before turbine stop is recommended, is reached within 2 months for more than 80% of the faults tagged as severity 2 before, as illustrated in Figure 3. Furthermore, the Weibull and exponential density functions are fitted aiming on further evaluation of the underlying distributions.

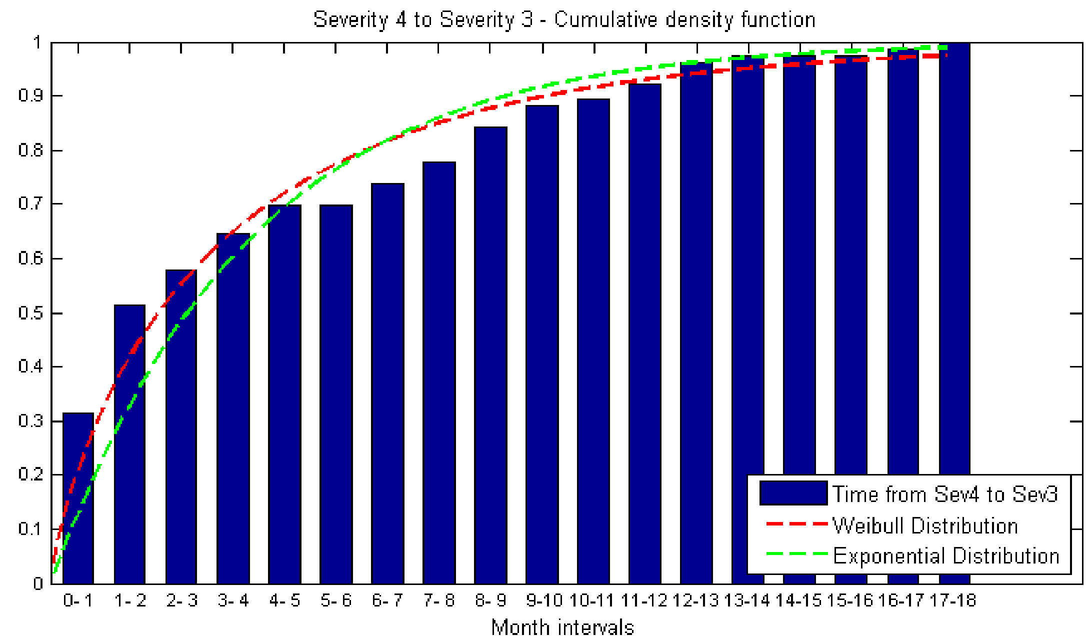

Figure 1: Cumulative density function of time interval for a fault to be upgraded from Severity 4 (lowest) to Severity 3

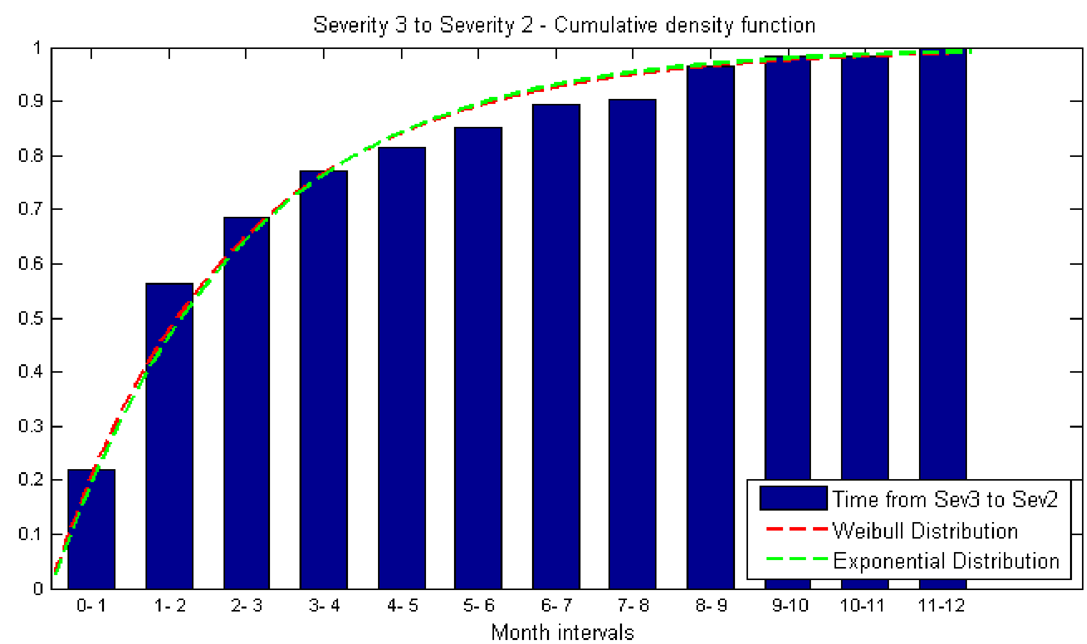

Figure 2: Cumulative density function of time interval for a fault to be upgraded from Severity 3 to Severity 2

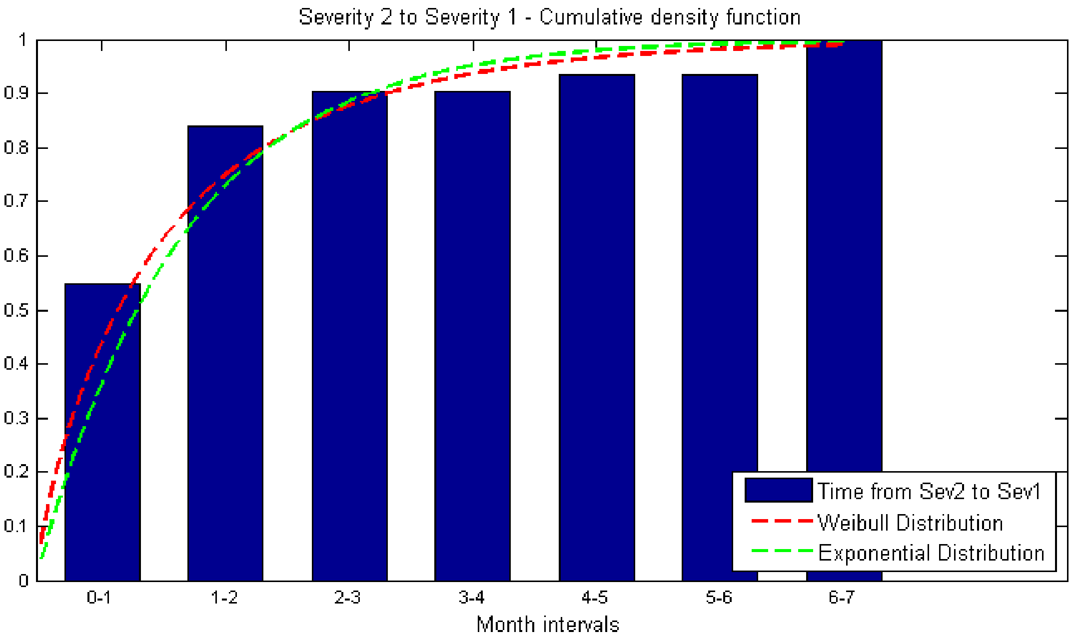

Figure 3: Cumulative density function of time interval for a fault to be upgraded from Severity 2 to Severity 1 (highest)

4. Conclusion

The employment of discrete fault stages is performed in order to characterize the health condition of wind turbine generator bearings. It is statistically shown that most of the faults under consideration develop faster as higher severity levels are reached, fact which is consistent with the provided lead time of the current prognostic setup. It is also shown that the exponential function show better fit in all three potential developments steps.

5. Learning objectives

This work highlights the fact that bearing deterioration accelerates as the defect develops from early to late stage. Furthermore, the probability that a fault progresses within a given period can be consistently evaluated by fitting statistical distributions.