Science & research abstracts

1. Introduction

In the last decade, the installed capacity of offshore wind turbine is higher than other renewable energy sources. Offshore wind power systems come with higher failure rate, lower reliability and availability and higher operation and maintenance (O&M) costs. Then a reliability evaluation and proper maintenance plan are indispensable to predict the expected energy not served and to minimize failures and unavailability, in order to improve reliability and making offshore wind energy profitable. Therefore for any energy equipment, reliability is a fundamental attribute that needs to be guaranteed. Reliability analysis on DTU-10MW offshore wind turbine (OWT) was performed with PTC Windchill Quality Solution in order to achieve RAMS (reliability, availability, maintainability, safety) parameters.

2. Approach

This report is carrying out on investigations undertaken into reliability of offshore wind farms considering different reliability strategies and understanding how failure modes are propagated through wind turbine. A reliability model of different wind turbine components (blade, drive train, nacelle, structural module, power module and wind farm system) has been developed. Shortly after a Reliability Predictions and Reliability Block Diagram (RBD) on DTU-10MW Offshore Wind Turbine have been carried out.

A comprehensive literature review has been undertaken in the areas of offshore wind turbines: reliability concepts, reliability data sources, offshore accessibility issues and maintenance strategies. The research on the reliability of offshore wind turbines showed which are the critical items with highest failure rate and potential failure mode. A functional reliability model is created in order to evaluate the real configuration on the DTU 10 MW OWT.

3. Abbreviations

OWT Offshore Wind Turbine

4. Main body of abstract

4.1 Reliability Analysis Procedure

The procedure for developing the reliability analysis is depicted in the Figure 4-1.

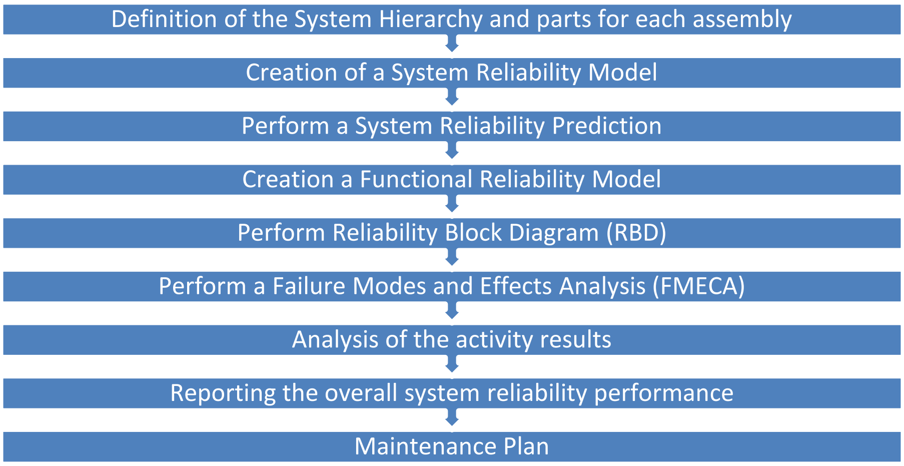

Figure 4-1 **Reliability analysis procedure**

4.2 Reliability Prediction

Reliability prediction is a quantitative analysis technique that has been used to predict the failure rate of the OWT under operating conditions and established calculation models.

The goal of **reliability prediction** is to predict the rate at which components and systems fail. The prediction has been done by part count method.

4.2.1 *Conversion factor*

Published reliability data of offshore wind farms doesn't exist; therefore it is necessary to use published data of onshore wind turbines in order to calculate the failure rate from onshore to offshore and to construct the reliability model. In order to carry out the reliability prediction, the right wind turbine data source has been found. Reliawind data source is the best data-base that could be used before a literature review of data sources has been done.

4.2.1.1 *Wind Turbine Failure Data Source*

Reliawind is a project which has investigated the current reliability of large wind turbines and recommended methods of measuring reliability and processing data from wind turbines and wind farms. The project ran from March 2008 to March 2011 with active involvement of 10 partners, included **Relex Italia s.r.l.**. Therefore Relex Italia s.r.l. has available a wide onshore data-base of two turbines with about one thousand components each.

4.2.1.2 *Failure rate transformation from onshore to offshore*

In order to convert the data-base from onshore to offshore ,a conversion factor based on parameters for simulating different condition in the system as environmental, power utilization, stress, etc. has been used. This factor depends of two parameters such as:

$K_{1\,offshore}$: is the environmental stress factor and it is defined as the effect of environmental condition (weather, environmental and humidity condition, etc.) on offshore wind turbine.

$K_{2\,offshore}$: is the power rating stress factor and the reliability is affected through the operating power ranges of the wind turbine. It can be known that in offshore the percentage utilization is higher than in onshore because winds are stable and strong.

The equation below can be used in order to calculate the failure rate on the offshore wind turbine:

$$\lambda_{offshore} = \lambda_{onshore} \cdot (K_{1\,offshore} \cdot K_{2\,offshore})$$

4.2.2 Reliability prediction results

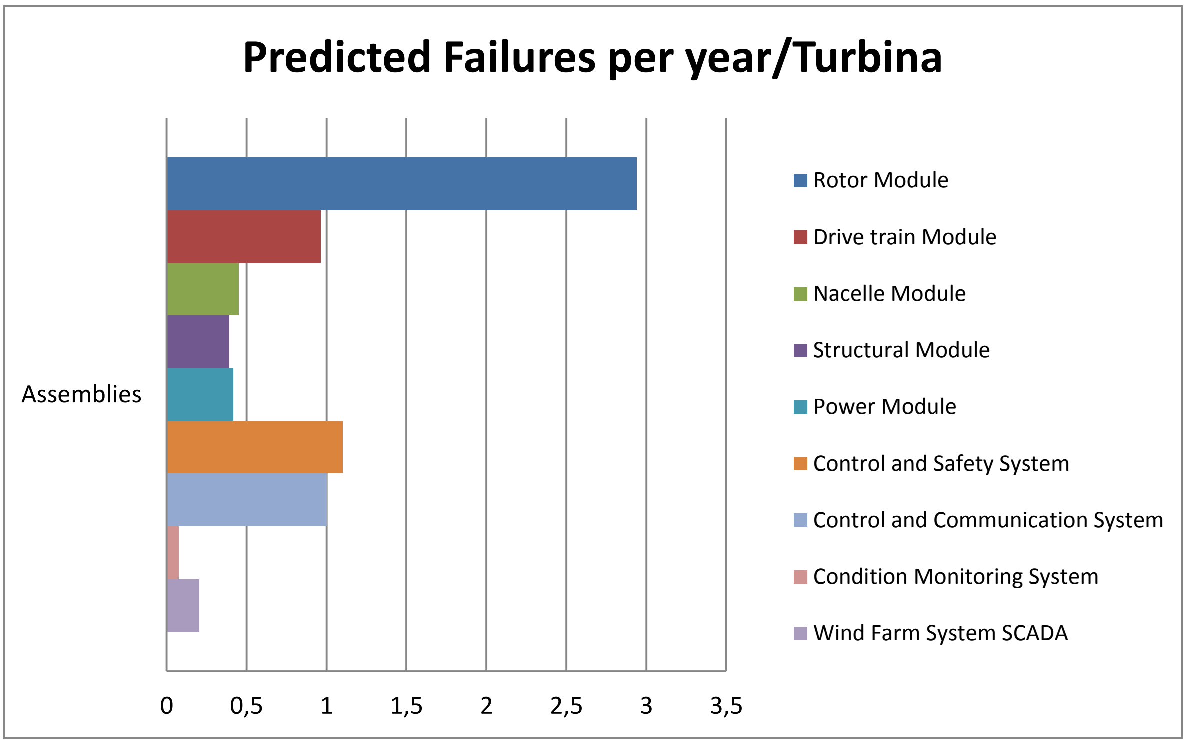

Figure 4-2 Results Reliability Prediction on Assemblies

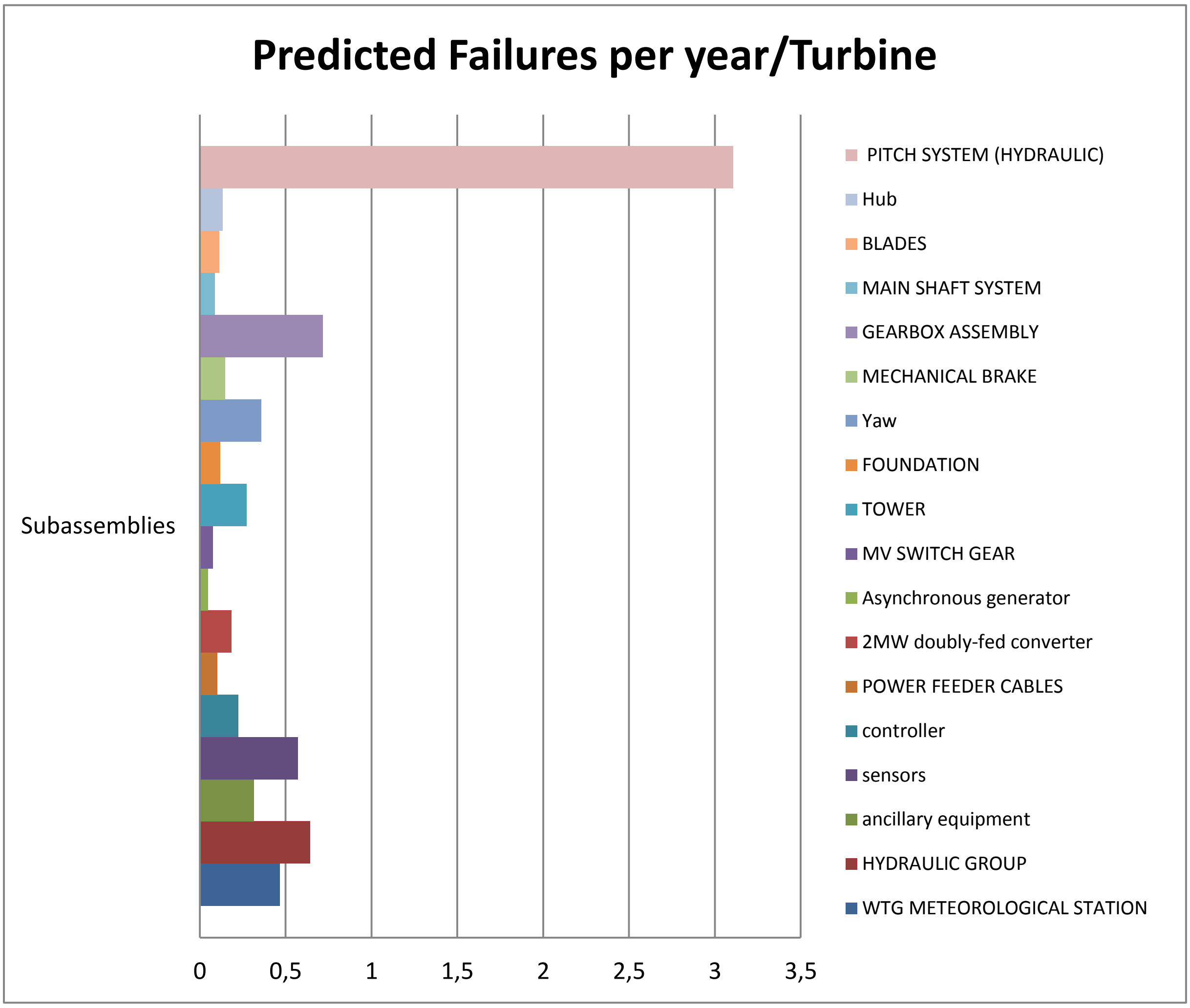

Figure 4-3 Results Reliability Prediction on Sub-Assemblies

Prediction has come out a failure rate value of **1866,36 failures per million of hours**. This value is a little bit high due to the offshore environment, data source came from the handbooks and the conversion factor. Some characteristics of the results have been that

- Rotor Module has highest failure rate, followed by Control and Safety System, Control and Communications System and Drive Train Module. Rotor Module has highest failure rate, then an excellent maintenance plan should be carried out in order to keep the system without failures and keeping high availability.
- The Figure 4-2 and Figure 4-3 show, wind turbines are subject to higher *environment, temperature, humidity, stress and sensitivity*. Then the failure rate of the system is increased, due to their location in marine environment and the high nominal power of the turbine (10MW), which will have more stresses and vibrations hence a higher failure rate. Moreover environment, humidity and temperature will be more pronounced and therefore these factors will make a wind turbine with higher failure rate as figures show.

4.3 Reliability Block Diagram (RBD)

Reliability Block Diagram (RBD) is a graphical representation of the system through blocks (representing components) and how they are connected logically to fulfil the system requirements.

It represents the real condition of the system with a wide range of system configurations and hence the right reliability assumptions of the system. Also the main goal of RBD analysis is the determination of almost all reliability and maintainability metrics of the whole wind turbine, like:

- Reliability
- MTTF
- Failure Rate
- Availability
- MTBF
- MTTR

Each block could be linked to another RBD. The modelling of the wind turbine is complicated due to a lot of assemblies, sub-assemblies and components (almost one thousand components has the reference turbine) depicted in Figure 4-4.

The elements which are necessary for the required function are then connected **in series**, while elements which can fail with no effect on the required function (redundancy) are connected with **redundancy**.

RBD should be made with redundant configurations, if it is required to perform the required function.

Monte Carlo has been calculated on the OWT where the performance of the logical model of the system under analysis is repeatedly evaluated using RAM parameter values selected from designated probability distributions. In a Monte Carlo simulation, a logical tree of the system being analysed is repeatedly evaluated, each run using different values of the distributed parameters. Parameters are selected randomly but with probabilities governed by the relevant distribution functions. The results are depicted in Figure 4-5, Figure 4-6, Table 4-1 and Figure 4-7.

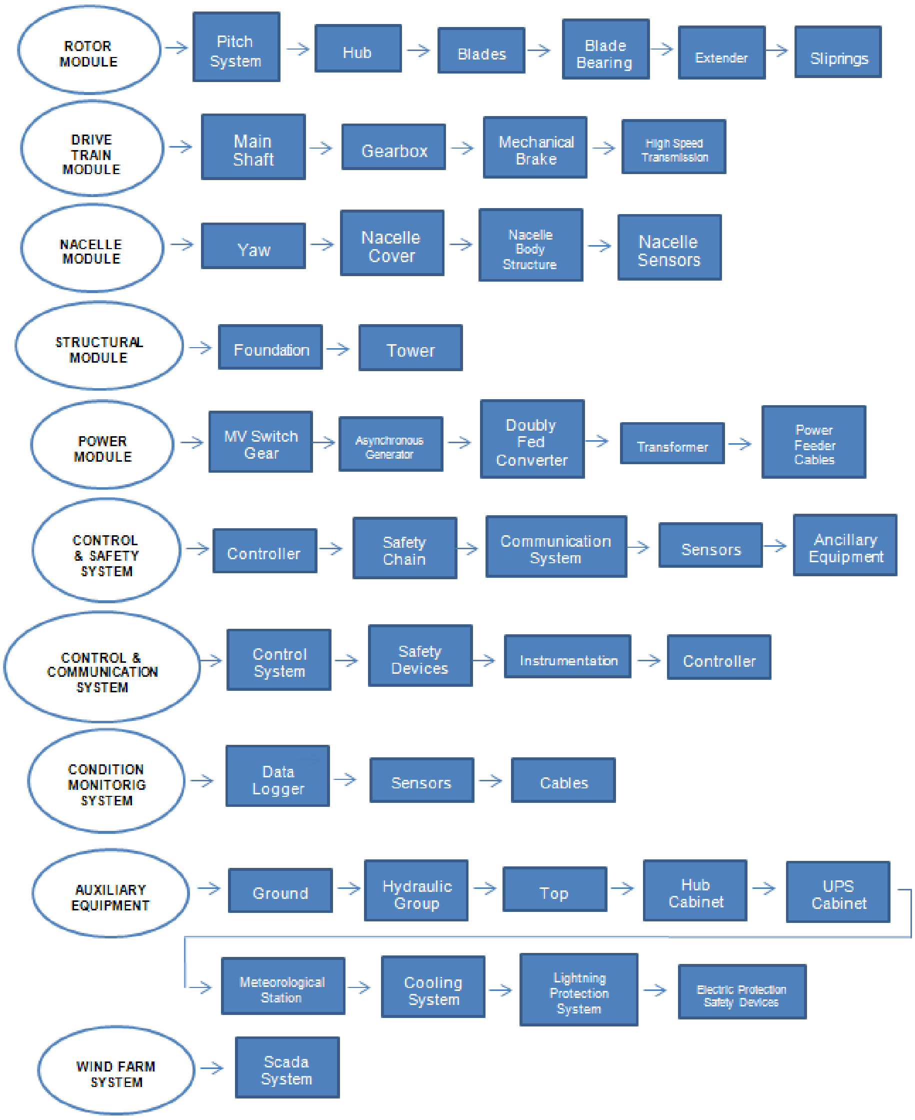

Figure 4-4 Whole Hierarchy Offshore DTU 10MW Wind Turbine

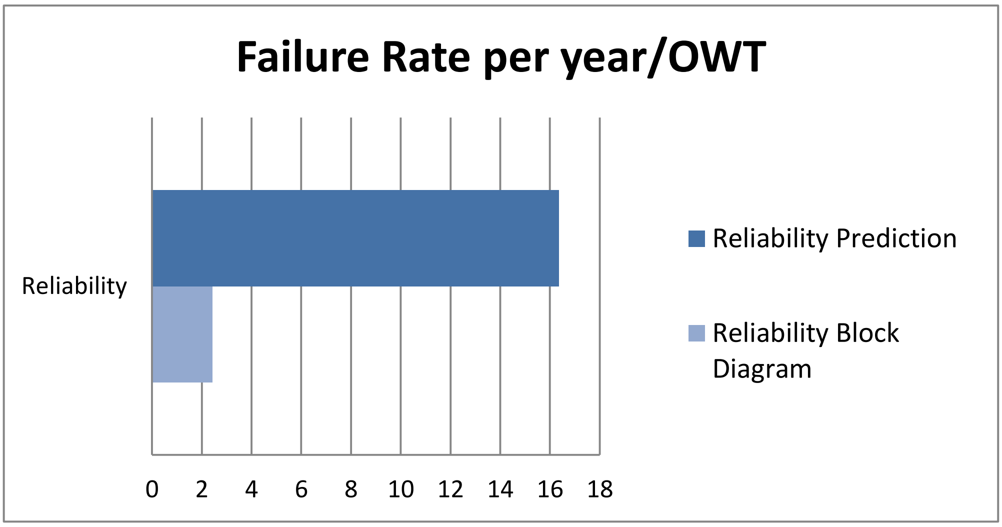

Figure 4-5 Comparative results between RBD and Reliability Predictio

Reliability Method on OWT	MTBF [hours]	Failure Rate(λ)[million of hours]
Reliability Prediction	536	**1866,36**
RBD	3644,44	**274,39**

Table 4-1 Comparative results between RBD and Reliability Prediction

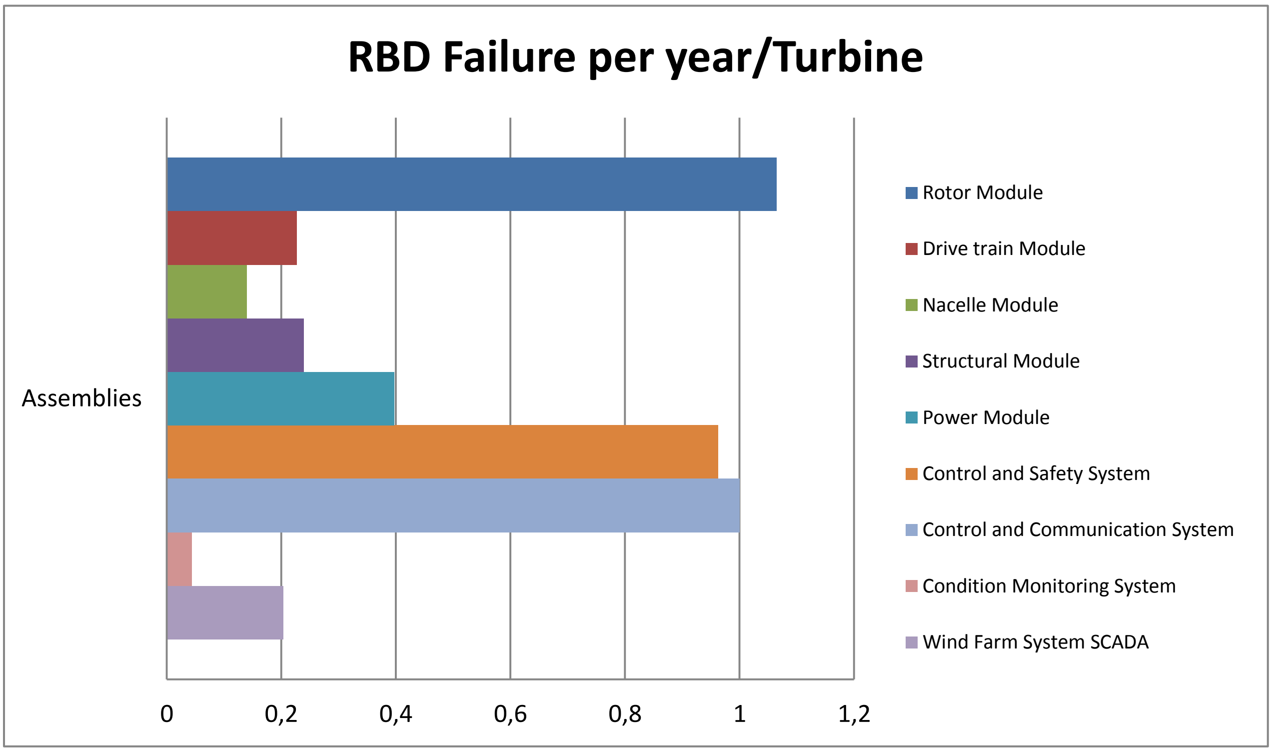

Figure 4-6 Results RBD on Assemblies

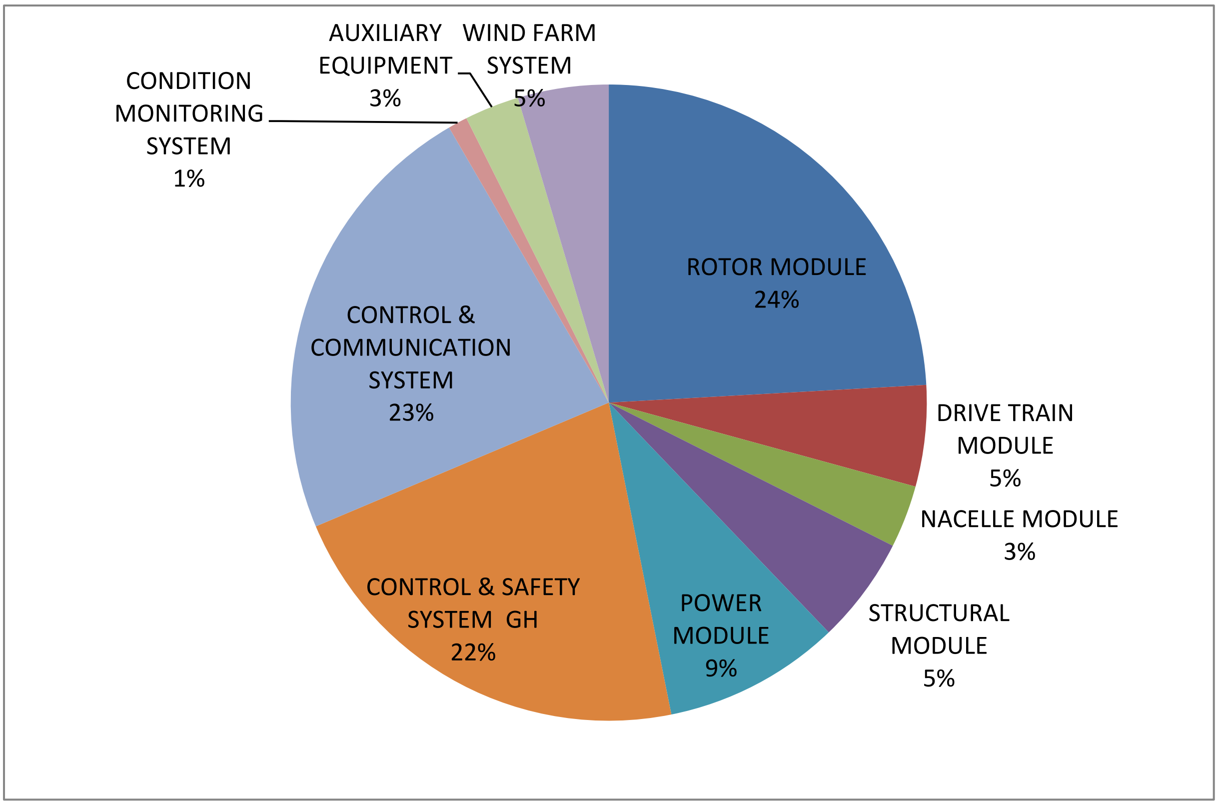

Figure 4-7 Distribution of failures per year/turbine

Reliability block diagram results have been published in appendix 2. How the results show, the offshore wind turbine is expected that **appears a failure at the fifth month. The availability has reached to 99% in a year** (great achievement) and it could be higher if the MTTR is more accurate. Under a great condition monitoring system and a good RCM plan (maintenance about the fifth month), the offshore wind turbine will achieve an excellent reliability.

As expected, the results show a great difference between the reliability prediction and the reliability block diagram because the reliability prediction is made in order to know a first estimation of failure rate and after that RBD simulates the real operating condition of the offshore wind turbine.

5. Conclusion

This report shows a reliability modeling of the DTU 10MW offshore wind turbine, in which the reliability of this wind turbine is estimated and the time that is hoped to appear the first failure. In order to keep available the wind turbine, maintenance and a right health condition monitoring must be carried out before the first failure

The conversion from onshore to offshore was done by the best way possible. Environmental condition and stresses regarding the difference of power between turbines have been taken under consideration, creating a great conversion. Along the time, the quality's components are getting higher, so it would have reduced the failure rate but it hasn't been considered.

6. Conclusion learning objectives

The reliability field isn't a process that could be developed along the fix time. Instead reliability analysis must be developed and shortly after updated each time. Then reliability is a process that has to be carried out all the time and must be improved with time. Therefore when the maintenance plan will be done, the results will be improved and will be taken under consideration the logistic time, schedule maintenance time and the right reliability centered maintenance (RCM).