



Contract number 212966

# Reliawind

Reliability focused research on optimizing Wind Energy systems design, operation and maintenance: tools, proof of concepts, guidelines & methodologies for a new generation

Collaborative Project: Large Scale Integrated Project  
FP7-ENERGY-2007-1-RTD

## Deliverable D 6.7 – Report

### Recommendations from the ReliaWind Consortium for the Standardisation for the Wind Industry of Wind Turbine Reliability Taxonomy, Terminology and Data Collection

#### Workpackage WP 6 – Dissemination

#### Task T.6.7 – Establishment of a wind turbine reliability standard

Month of delivery: M36

Deliverable leader: UDUR

Decisional Workflow		
<b>Author(s)</b>	P J Tavner	<b>Approved by:</b> <input type="checkbox"/> WP leader <input type="checkbox"/> Task leader <input type="checkbox"/> Scientific Director <input type="checkbox"/> Project Technical Assessor (European Commission) <input type="checkbox"/> Project Officer (European Commission)
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<b>Description of work</b>
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**Objective of the WP:**

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The purpose of this Work Package is to disseminate the results of the Project to the wider Wind Industry in the European Union. This will be achieved through a variety of Conference, Workshop, Web site and Media initiatives but will be moderated by the experiences of the internal training of the Project partners. In this respect the experiences in the offshore oil and gas industry to disseminate methods to improve plant reliability will be emulated.

**Task description:**

To establish a draft future European wind turbine reliability standard, defining and codifying the collection of data for reliability analysis of wind turbine.

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PP	Restricted to other programme participants (including the Commission Services)	<input type="checkbox"/>
RE	Restricted to a group specified by the consortium (including the Commission Services)	<input type="checkbox"/>
CO	Confidential, only for members of the consortium (including the Commission Services)	<input type="checkbox"/>

**IP Management**

Is there any IP rights associated to this deliverable? Y  N

If yes, please fill-in the specific IP management file available on the project platform.

**Resources in person-months**

	Partner	Estimated Resources	Allocated Resources
<i>Resources shown in person-months</i> <input type="checkbox"/> <input type="checkbox"/> Partner X <input type="checkbox"/> <input type="checkbox"/> Peer reviews <input type="checkbox"/> <input type="checkbox"/> Contributions	<input type="checkbox"/> <input type="checkbox"/> GAMESA	3 MM	MM
	<input type="checkbox"/> <input type="checkbox"/> Ecotecnia	MM	MM
	<input type="checkbox"/> <input type="checkbox"/> LM	1.4 MM	MM
	<input type="checkbox"/> <input type="checkbox"/> Hansen	MM	MM
	<input type="checkbox"/> <input type="checkbox"/> Drives	MM	MM
	<input type="checkbox"/> <input type="checkbox"/> SKF	0.5 MM	MM
	<input type="checkbox"/> <input type="checkbox"/> GH	MM	MM
	<input type="checkbox"/> <input type="checkbox"/> Relex	MM	MM
	<input type="checkbox"/> <input type="checkbox"/> UDUR	4 MM	MM
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**If any difference between estimated resources and allocated resources, please justify:**

**Results achieved**

**Quality Assessment**

**Task Leader**

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## **Deliverable Technical Description**

This Deliverable is a recommendation from the ReliaWind Consortium to IEC National Committees and to International Committees associated with IEC 61400 Wind Turbine Standards for the standardisation of aspects of wind turbines associated with improving their reliability.

It is intended that this document will influence the content of IEC 61400 Parts 1, 3, 4, 25 and 26 where reliability is of particular importance.

The benefit of this document is that it can be used by Partners to influence their own IEC National Committees and, for those Partners who are members on the relevant IEC 61400 Standards International Committees, it will provide a direct briefing of recommendations from the ReliaWind Consortium.

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## **1. Introduction**

### **1.1 Background**

Wind turbine (WT) manufacturers, operators, maintainers and investors agree that it is essential for WTs to have a high Reliability to achieve a high Capacity Factor and Availability and thereby deliver electricity at a low Cost of Energy. An important factor in achieving those objectives is that WTs, when designed, should have the highest possible Reliability. Currently the European wind industry is achieving WT Availabilities onshore of 96-97% and offshore of 90-95%. It would be desirable to raise these availabilities and design for reliability would contribute to that aim.

An important requirement of design for reliability is to be able to measure, predict and analyse WT reliability using accurately defined Mean Time to Failure (MTTF), Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBF) data for WTs. These standard terms are defined by International Standards and are listed in Appendix 1.

The definition of the Terminology and Taxonomy of wind turbines and the collection of reliability data and its interrelationship with WT design, already defined by IEC 61400, needs to be standardised. It is also clear to the ReliaWind Consortium that in order to increase WT Reliability more and higher quality reliability data is needed by from the wind industry, within limits of commercial confidentiality.

This document aims to provide information to standards-makers to allow them to shape international standards for WTs to achieve the objective of standardising the reliability definitions and the methods of collecting reliability data.

These issues also affect other industries, including offshore oil & gas, power generation, transportation, military and aerospace.

An example of reliability data collected from the first of these industries, oil & gas, is shown by OREDA [1].

A standard for the collection of reliability data from that industry also exists, EN ISO 14224-2006 [2].

Where possible the ReliaWind Consortium recommends that the following Deliverable should be used to standardise issues associated with reliability in the wind industry, alongside proven, cost-effective and appropriate best practice, taken from the standards of those industries.

### **1.2 Relevant Standards**

The standards listed in the References at the end of this Report [2], [3], [4], [5], [6], [7] & [8] are relevant.

### **1.3 Relevant Literature**

A relevant textbook on reliability is [9]. Relevant recent publications by ReliaWind partners on the analysis and interpretation of WT reliability data are given in the ReliaWind Literature Survey [10] and in references [11], [12], [13] & [14].

#### **1.4 Previously Developed Methods for the Wind Industry**

The most detailed previous public domain WT data collection campaign was funded from 1996-2006 by the German Federal Ministry for Economics & Technology under the 250 MW Wind Test Programme, which included the Wissenschaftliche Mess- und Evaluierungsprogramm (WMEP), Scientific Measurement and Evaluation Programme, administered by the now Fraunhofer IWES Institute, [14]. A standard failure report form was used by WT operators for return to IWES and that is shown in Appendix 5. The proposals below have drawn from this experience.

## **2. Standardisation of WT Taxonomy-Proposed Guidelines**

### **2.1 Introduction**

Durham University were tasked in Work Package 6 of ReliaWind with defining the standardisation to come out of the project. Appendix 6 shows the standards committee representations of the Consortium Partners and their responses to a standardisation questionnaire from which the standardisation of Structure, Taxonomy and Terminology were ranked highest.

GL Garrad Hassan and Durham University were asked by the Consortium, at the Mid-Term Review Meeting in Brussels in 2009, to devise an updated WT Taxonomy or standard structure. That Taxonomy should draw on that previously developed by the ReliaWind Project and other taxonomies such as that derived by Sandia Laboratories, USA.

The Taxonomy should be adaptable for application to the common reliability analyses needed for WTs, such as Failure Mode and Effects Criticality Analysis [15], failure rate Pareto analysis, reliability growth analysis and Weibull analysis.

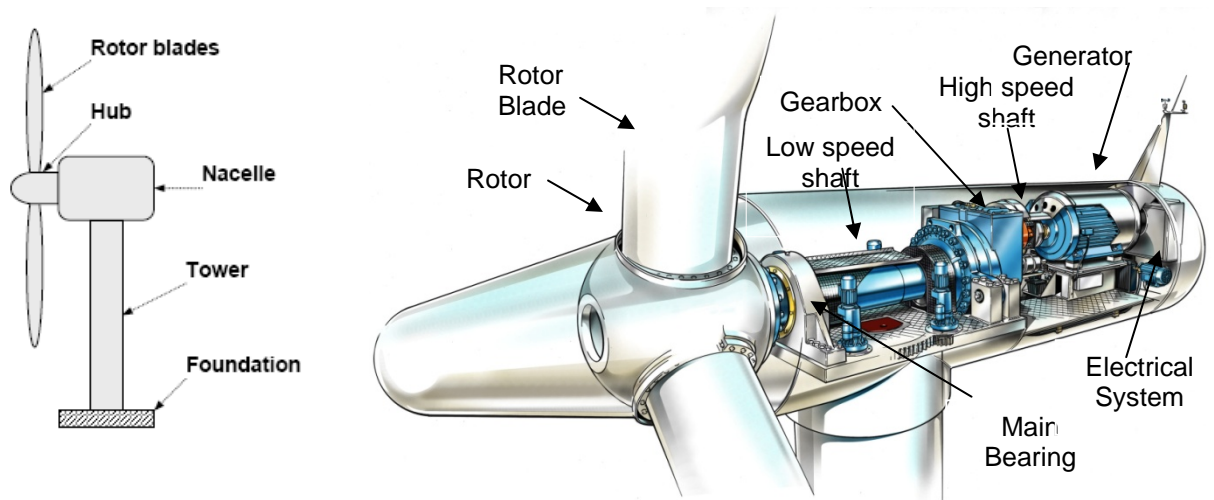
The intention of adopting such a Taxonomy would be to overcome current deficiencies of the data collection which can be summarised as follows:

- Consistency of naming of the systems, sub-systems, assemblies, sub-assemblies and components of WTs;
- Non traceability of the system monitored;
- Unspecified WT technology or concept;
- Problems of confidentiality between parties when exchanging data.

This document summarises the general principles and guidelines on which the Taxonomy will be based.

## 2.2 Taxonomy Guidelines

A WT Taxonomy is a structure which names the main features of a WT in a standardised terminology, such as exemplified in Figure 1.



**Figure 1. Example of a WT and its nacelle layout showing the terminology.**

- The Taxonomy must be reliability-oriented, particularly in respect of analysis. It is agreed that such an approach is the best compromise between the various industry needs, which leads to a different system breakdown, grouping and Terminology than would be achieved by simple components description.
- The Taxonomy will include all the WT concepts components in 5 levels. Data will be retrieved on the basis of a concept code, which allows WT model mapping within the Taxonomy for any given data set.
- The Taxonomy is based on the Danish Concept WT. That is an upwind, three-bladed, horizontal axis, un-ducted WT. Other concepts could be included upon achievement of significant industrial uptake by this Taxonomy.
- Outside the Taxonomy, at the highest level, it should be compulsory that the WT concept is identified by a code. For example indicating stall-, active stall- or pitch-regulated, fixed or variable speed, geared- or direct-drive, doubly-fed induction, induction or squirrel cage induction generator or wound or permanent-magnet synchronous generator. Therefore each item in the Taxonomy must clearly link to a listed code associated with each WT concept.
- The Taxonomy should also inform the structure of the monitoring Input/Output (I/O) applied to the WT, whether that is for Signal Condition and Data Acquisition (SCADA) or Condition Monitoring System (CMS) signals and alarms. The Taxonomy will be used to focus on SCADA and Service Log data available from operational wind farms. The Taxonomy shall be organised in 5 indented levels. Each level should be justified with a brief description that shall include the rationale for the level grouping and intended use.
- The first five indented levels of the Taxonomy must comply with the table given in Appendix 2. The Taxonomy may not reach the lower level components, for example to individual electronic capacitors, but the

analyst could add additional lower levels, if needed, but they must be compatible with the upper 5 levels of the Taxonomy. Analysts could also add additional elements in levels 1-5, if absolutely necessary for their purpose, denoted by the prefix CUSTOM, although this customization is strongly to be discouraged.

- The Taxonomy will have an alpha-numerical designation or short code for each item at each level. It is anticipated that the construction of the designation could follow the guidance of [7] which adopts an alpha-numeric code although some in the wind industry prefer a word code.
- The lowest level components will be grouped according to the following general concepts:
  - Functional grouping for the signalling, supervisory and control components, examples: pitch encoder grouped with Control and Communication System, LV electrical systems grouped together.
  - Positional grouping for mechanical components, examples: gearbox, pitch system, blade, frequency converter, generator, blade.

This is necessary due to the nature of WT systems that signalling, supervisory and control components tend to spread throughout the WT whereas mechanical devices are located in a specific position within the WT and is exemplified in Table 1.

- In case of ambiguity the designation will follow the order above: first functional grouping, second positional grouping. For example: generator temperature sensor and pitch encoder are both component of the monitoring system.
- At the lowest indented level the component name should have no ambiguity with similar components of different assemblies. For example: the pitch pinions and the yaw pinions.

**Table 1 Example of Grouping of Parts**

<b>Functional Grouping</b>	<b>Positional Grouping</b>
Control & Communication System	Generator
Lightning Protection System	Pitch System
110V Electrical Auxiliary System	Gearbox
220V Electrical Auxiliary System	Yaw System
400V Electrical Auxiliary System	Blade
WT Power System	Hub
SCADA System	Main Shaft Set
Collection System	Foundation
Grid Connection	Tower
Hydraulics System	

This table is not exhaustive.

**2.2 Standardisation of Control Input/Output List Structure for WTs**

The Terminology of components in the Input/Output (I/O) List of the SCADA should agree with the component names used in the Taxonomy above.

## 2. Standardising Methods for Collecting WT Reliability Data

In the ReliaWind Consortium the following method was used by the Work Package (WP) Leader of ReliaWind WP 1 where it was proposed that reliability data from WTs should be collected in 5 Tables as follows:

**Table 2 Events**

Wind Farm	Turbine ID	Date & Time of Event	Time to Repair TTR (hours)	Actual Repair Time ART (hours)	System	Sub-System	Assembly	Sub-Assembly	Component	Failure Mode	Root Cause	Maintenance Category	Severity Category	Additional information
A	1	2008-04-01 11:28:01	54.2	N/A	Wind Turbine	Drive train	Gearbox assembly	Gearbox	N/A	N/A	N/A	4	3	N/A
A	23	2008-04-24 01:56:11	168.4	3.5	Wind Turbine	Rotor	Pitch system	N/A	N/A	N/A	N/A	3	2	N/A
B	2	2008-04-25 08:43:24	2.5	1	Wind Turbine	Power	Generator assembly	Generator	Stator phase b winding	Open	Over current	1	1	Series failure
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table 2 fields are as follows:

Wind Farm	<i>Confidentiality will require that this be an anonymous identifier</i>
Turbine ID	<i>Turbine identifier within the wind farm</i>
Time of Event	<i>Time stamp in ISO form yyyy-mm-dd hh:mm:ss</i>
Mean Downtime (MDT)	<i>Total number of hours during which the turbine was not operational i.e. includes all the time needed to restore the WT to an operating condition.</i>
Time to Repair (TTR)	<i>Actual number of hours completing the repair i.e. excludes logistics associated with the repair action such as having the component delivered to site, arranging technicians' time.</i>
System Structure	<i>The system structure used is that set out in Appendix 2.</i>
Sub-System	<i>Select from an approved list, see Appendix 3. It should usually be possible to ascribe a failure to a particular sub-system.</i>

Assembly	<i>Select from an approved list Appendix 3. It should usually be possible to ascribe a failure to a particular assembly.</i>
Sub-Assembly	<i>Select from an approved list Appendix 3. It may not always be possible to ascribe a failure to a particular component.</i>
Part	<i>Select from an approved list. It may not always be possible to ascribe a failure to a particular component.</i>
Failure Mode	<i>The particular way in the failure occurred, independent of the reason for failure. This may be subjective, but very useful if available.</i>
Root Cause	<i>The cause of failure. This may be subjective, but very useful if available.</i>
Maintenance Category	<i>A description of the maintenance impact of the failure:</i> <ol style="list-style-type: none"> <li><i>1. Manual restart</i></li> <li><i>2. Minor repair</i></li> <li><i>3. Major repair</i></li> <li><i>4. Major replacement</i></li> </ol>
Severity Category	<i>A description of the severity of the failure based on MIL-STD-1629A Section 4.4.3 which relates to the ability of the system to carry out the function for which it was defined safely and efficiently</i> <ol style="list-style-type: none"> <li><i>1. Minor</i></li> <li><i>2. Marginal</i></li> <li><i>3. Critical</i></li> <li><i>4. Catastrophic</i></li> </ol>
Additional information	<i>Pertinent comments where available</i>

This list of events in this table will be exhaustive within the following criteria:

1. The event required manual intervention to restart the machine;
2. The event resulted in downtime  $\geq$  1 hour.

There will be no missing events or missing time periods; or if there are, the missing time periods will be noted and the reasons stated.

Every cell in the table should have either a data value or be filled with N/A, not available.

**Table 3 Failure Rates**

Wind Farm	Turbine	Sub-System	Assembly	Year			
				1	2	3	...
A	1	Drive Train	Gearbox	0	2	1	...
A	1	Power	Generator	2	1	2	...
A	1	Rotor	Pitch	1	2	1	...
...	...		...	...	...	...	...

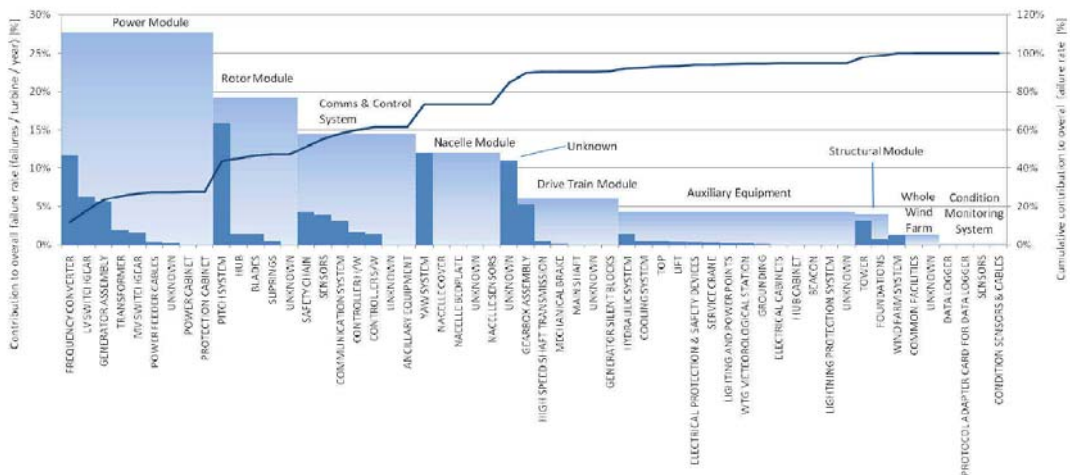
This table would be derived entirely from Table 2 and no new information is added.

It is thought unlikely that enough detail will be available in Table 2 to permit the calculation of failure rate on a per component basis.

Failure rates should be reported per year as standard but information from Table 6 will allow calculation per operational period in a year, per GWh in a year, per revolution, or some other metric, depending on what information is available for the particular wind farm.

Confidentiality may require that this information be aggregated on a wind farm, rather than WT basis.

This information could be presented graphically for example as shown in Figure 2.

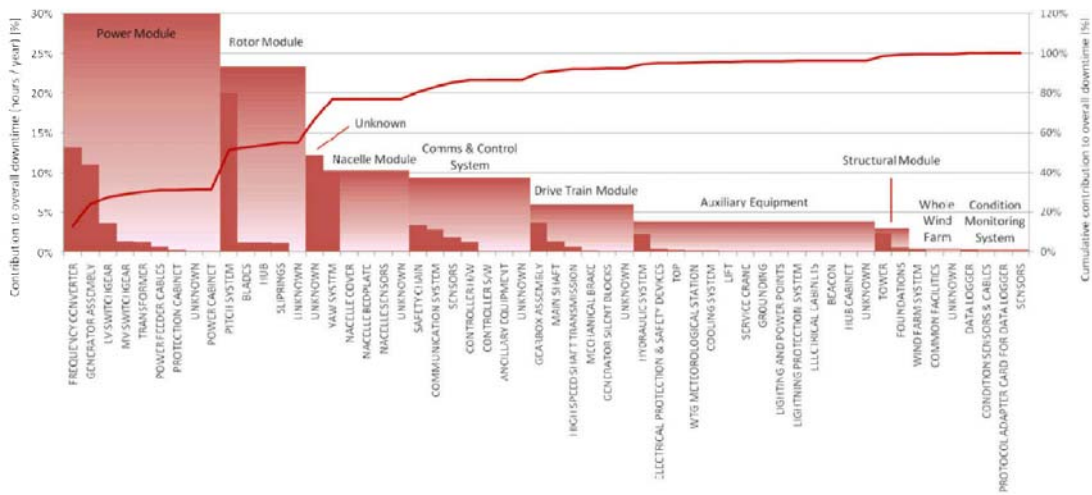


**Figure 2. Example of normalised failure rate for sub-systems and assemblies for turbines of multiple manufacturers in a database.**

**Table 4 Downtime**

Wind Farm	Turbine	Sub-System	Assembly	Year			
				1	2	3	...
A	1	Drive Train	Gearbox	24	5	1	...
A	1	Power	Generator	65	4	2	...
A	1	Rotor	Pitch	21	5	5	...
...	...		...	...	...	...	...

This table is derived entirely from Table 2 and no new information is added. The downtime will be given in units of hours. Confidentiality may require that this information be aggregated on a wind farm, rather than WT basis. This information could be presented graphically for example as shown in Figure 3.



**Figure 3. Example of normalised hours lost per turbine per year to failures in sub-systems and assemblies for turbines of multiple manufacturers in a database.**

**Table 5 Wind Farm Configuration**

Wind Farm	Turbines	Rated Power (MW)	Mean Wind Speed (m.s <sup>-1</sup> )	Mean Turbulence Intensity	Hub Height (m)	Rotor Diameter (m)	Terrain Type	Control Type	...
A	20 – 40	1 – 2	6 – 8	0.25 – 0.50	60	40	Offshore	A	...
B	0 – 20	2 – 3	8 – 10	0.50 – 0.75	55	30	Onshore Exposed	B	...
...	...	...	...	...	...	...	...	...	...

There would be two versions of this table:

- Table 5 (a) will have all values stated exactly and to maintain End User confidentiality will remain private; and
- Table 5 (b) will be available to a consortium but will be less specific about machine characteristics, with identifiable parameters categorised into appropriate ranges to make anonymous the data as shown in the example above.

The control type column will be populated from a standard list.

Further columns may be added to this table depending on what information is available for each wind farm.

**Table 6 Additional Turbine Information**

Wind Farm	Month	Energy Generated (GWh)	Revolutions	...
A	2008-01	50	$1.544 \times 10^5$	...
A	2008-02	70	$2.422 \times 10^5$	...
...	...	...	...	...

Confidentiality requirements may mean that the information in Table 6 could not be publicly available.

For a wind farm to be included in the survey it is desirable that the site contains at least 15 turbines that have been running for at least 2 years since commissioning.

Data for the tables above should be provided by WT operators.

### 3. Standardising Downtime Event Recording

The approach recommended by the ReliaWind consortium was to describe and classify downtime events as stoppages of duration  $\geq 1$  hour and requiring at least a manual restart. Downtime events can be categorised as follows:

- Category 1: manual restart
- Category 2: minor repair
- Category 3: major repair
- Category 4: major replacement

### 4. Standardising Failure Event Recording

#### 3.2 Failure Terminology

When a failure has occurred it is important to record the details of that failure. In the WMEP Failure Report Form shown in Appendix 5 a simple tick box approach was adopted.

This has proved to have insufficient detail for maintenance and root cause analysis purposes and the following approach is suggested for recording failures in detailed Fault or maintenance Logs, taken from the recommendations in IEC 61400-25-6 [8]. The terminology to be used should be that shown in Appendix 4, which is consistent with the proposed Structure Appendix 2 and overall Taxonomy Appendix 3. The Failure Modes suggested there include those identified by WP Partners of ReliaWind WP2.

#### 3.3 Failure Recording

The intention of this Section is to provide a broad method of failure recording, rather than trying to capture every different possible failure mode. For example a Bearing Failure could encompass:

- Inner Race Failures;
- Outer Race Failures;
- Cage Failures;
- Element Failures.

The recommended failure recording terminology is in part recursive, referring successively to the component, sub-assembly, assembly, sub-system, system, defined in Appendix 2, in turn.

For example using Appendix 4 for recording a gearbox epicyclic bearing failure the failure description should take the following format:

- Bearing Failure: Planet Bearing: Epicyclic Part: Gearbox: Drive-Train: Wind Turbine.

#### 3.4 Failure Location

Location indicators are needed for components, such as bearings, where several may be found in a single Assembly or Sub-Assembly, in that case the following rules could be followed, using the failure example above:

- If more than one epicyclic stage exists in a Gearbox, the 1<sup>st</sup> stage is that closest to the WT rotor and so on;
- In a parallel shaft gear train, the pinion drives and the gear is driven;
- The two ends of a Gearbox are the Rotor End or Generator End;

- Where there are two bearings on a Gearbox Shaft that closer to the gear should be referred to as the Inner Bearing, and that further from the gear as the Outer Bearing.
- Generator bearings should be defined as Drive End and Non-Drive End

## **5. Conclusions**

The above proposals from the EU FP7 ReliaWind Consortium represent a proposal for the standardisation of:

- Taxonomy of the wind turbine.
- Terminology used in English for the naming of components.
- Methods for collecting Reliability data from wind turbines in the field.
- Method for reporting failures from wind turbines in the field.

The purpose of these standardisations is for the improvement wind turbine Reliability in the field and thereby to raise wind turbine Availability and lower the consequent Cost of Energy.

## **6. Recommendations**

The Consortium recommends that:

- ReliaWind Partners named in the Table in Appendix 6 of this document should draw the attention of their IEC National Committees to this document.
- ReliaWind Partners named in the Table in Appendix 6 of this document should use it as a recommendation to the relevant IEC 61400 Committees on which they sit.
- The proposed standardisation is adopted by the European wind industry.

## **7. Acknowledgements**

The author acknowledges the assistance in preparing this Deliverable of ReliaWind Partners in particular GL Garrad Hassan and advice from Eon Climate and Renewables, WT Operators.

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## 8. Appendix 1-Definitions

The Consortium is aware that at the current time IEC 61400 Part 26 is being prepared to define precisely the Availability of WTs in terms of time and energy produced. In the mean time, however, for the purposes of this document the following definitions have been used:

- Reliability: the probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered
- Availability, the probability of finding a system in the operating state at some time into the future.

- Mean Time To Failure,  $MTTF$

- Mean Time to Repair, or Downtime  $MTTR$

The average time taken for a sub-assembly to be recovered from any failure

- Mean Downtime  $MDT$

Total number of hours during which the turbine was not operational i.e. includes all the time needed to restore the WT to an operating condition.

- Time to Repair  $TTR$

Actual number of hours completing the repair, excluding logistics associated with repair action such as having the component delivered to site or arranging the technicians' time.

- Mean Time Between Failures or Reliability:

$$MTBF=MTTF+MTTR=1/\lambda +1/\mu$$

The average period between unplanned stoppages of a sub-assembly.

In the event that a failure cannot be repaired immediately there may be a Logistic Delay Time,  $LDT$ , to carry out the repair, then:

$$MTBF=MTTF+MTTR+LDT=1/\lambda +1/\mu +LDT$$

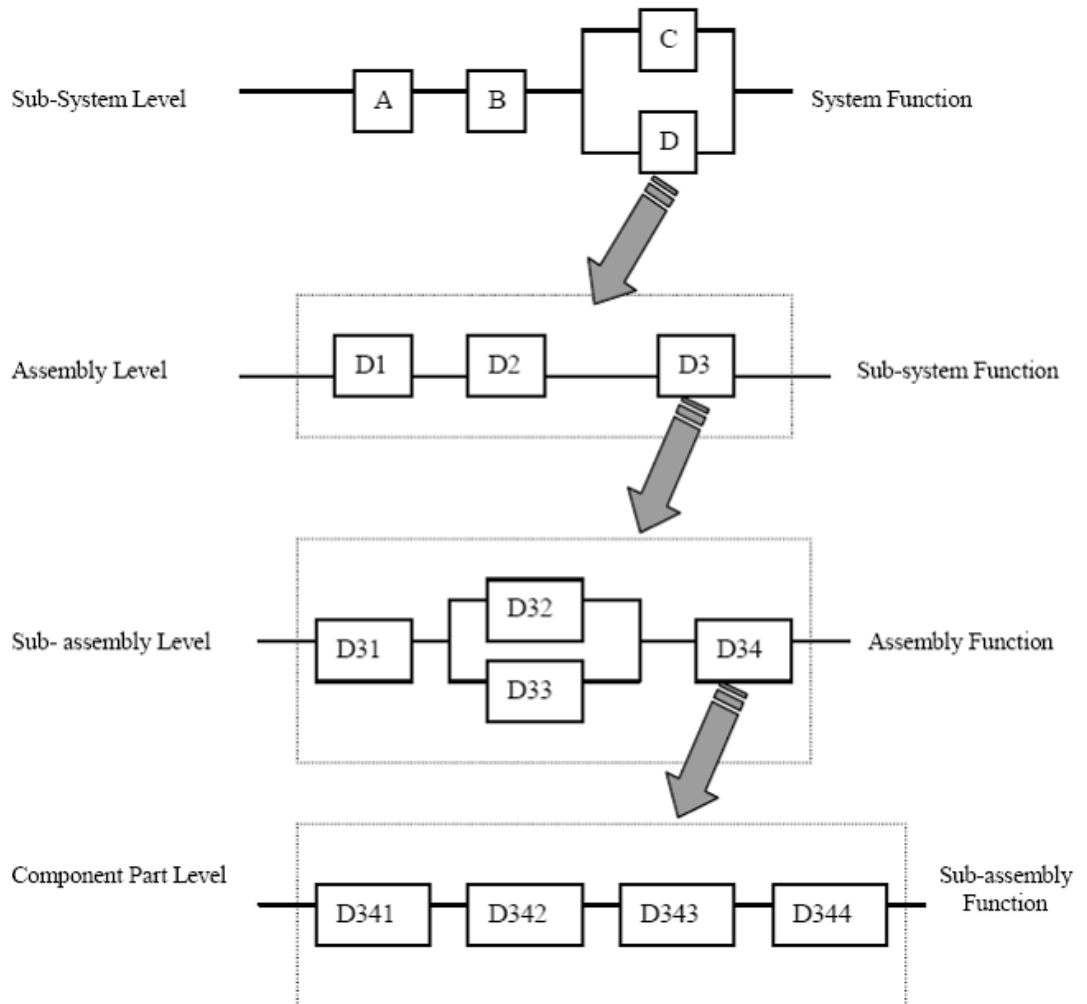
- Failure rate,  $\lambda = 1/MTBF$

- Repair rate,  $\mu=1/MTTR$

- Availability,  $A=(MTBF-MTTR)/MTBF=1-(\lambda/\mu)$

## 9. Appendix 2- System Structure

The structure of System, Sub-System, Assembly, Sub-Assembly and Component should be adopted as shown below:



Examples of this terminology are as follows:

System	Sub-System	Assembly	Sub-Assembly	Component
Wind Turbine	Rotor	Electrical Pitch System	Pitch motor	Brush
Wind Turbine	Drive Train Module	Gearbox	Gearbox	Stage 1 Planetary Wheel
Wind Turbine	Electrical Module	Frequency Converter	Power Electronics	IGBT

A full list of sub-systems, assemblies and sub-assemblies is provided in Appendix 3.

### 10. Appendix 3-Detailed Wind Turbine Taxonomy

<b>System</b>	<b>Sub-System</b>	<b>Assembly</b>	<b>Sub-Assembly</b>	<b>Component</b>
Wind Turbine	Drive Train Module	Gearbox	Bearings	Carrier Bearing
Wind Turbine	Drive Train Module	Gearbox	Bearings	Planet Bearing
Wind Turbine	Drive Train Module	Gearbox	Bearings	Shaft Bearing
Wind Turbine	Drive Train Module	Gearbox	Cooling System	Hose
Wind Turbine	Drive Train Module	Gearbox	Cooling System	Pump
Wind Turbine	Drive Train Module	Gearbox	Cooling System	Radiator
Wind Turbine	Drive Train Module	Gearbox	Gears	Hollow Shaft
Wind Turbine	Drive Train Module	Gearbox	Gears	Planet Carrier
Wind Turbine	Drive Train Module	Gearbox	Gears	Planet Gear
Wind Turbine	Drive Train Module	Gearbox	Gears	Ring Gear
Wind Turbine	Drive Train Module	Gearbox	Gears	Spur Gear
Wind Turbine	Drive Train Module	Gearbox	Gears	Sun Gear
Wind Turbine	Drive Train Module	Gearbox	Housing	Bushing
Wind Turbine	Drive Train Module	Gearbox	Housing	Case
Wind Turbine	Drive Train Module	Gearbox	Housing	Mounting
Wind Turbine	Drive Train Module	Gearbox	Housing	Torque Arm System
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Hose
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Motor
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Motor
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Primary Filter
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Pump
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Reservoir
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Seal
Wind Turbine	Drive Train Module	Gearbox	Lubrication System	Secondary Filter
Wind Turbine	Drive Train Module	Gearbox	Sensors	Debris
Wind Turbine	Drive Train Module	Gearbox	Sensors	Oil Level
Wind Turbine	Drive Train Module	Gearbox	Sensors	Pressure 1
Wind Turbine	Drive Train Module	Gearbox	Sensors	Pressure 2

Wind Turbine	Drive Train Module	Gearbox	Sensors	Temperature
Wind Turbine	Drive Train Module	Generator	Cooling System	Cooling Fan
Wind Turbine	Drive Train Module	Generator	Cooling System	Filter
Wind Turbine	Drive Train Module	Generator	Cooling System	Hose
Wind Turbine	Drive Train Module	Generator	Cooling System	Radiator
Wind Turbine	Drive Train Module	Generator	Lubrication System	Pump
Wind Turbine	Drive Train Module	Generator	Lubrication System	Reservoir
Wind Turbine	Drive Train Module	Generator	Rotor	Commutator
Wind Turbine	Drive Train Module	Generator	Rotor	Exciter
Wind Turbine	Drive Train Module	Generator	Rotor	Resistance Controller
Wind Turbine	Drive Train Module	Generator	Rotor	Rotor Lamination
Wind Turbine	Drive Train Module	Generator	Rotor	Rotor Winding
Wind Turbine	Drive Train Module	Generator	Rotor	Slip Ring
Wind Turbine	Drive Train Module	Generator	Sensors	Core Temperature Sensor
Wind Turbine	Drive Train Module	Generator	Sensors	Encoder
Wind Turbine	Drive Train Module	Generator	Sensors	Wattmeter
Wind Turbine	Drive Train Module	Generator	Stator	Magnet
Wind Turbine	Drive Train Module	Generator	Stator	Stator Lamination
Wind Turbine	Drive Train Module	Generator	Stator	Stator Winding
Wind Turbine	Drive Train Module	Generator	Structural & Mechanical	Front Bearing
Wind Turbine	Drive Train Module	Generator	Structural & Mechanical	Housing
Wind Turbine	Drive Train Module	Generator	Structural & Mechanical	Rear Bearing
Wind Turbine	Drive Train Module	Generator	Structural & Mechanical	Shaft
Wind Turbine	Drive Train Module	Generator	Structural & Mechanical	Silent Block
Wind Turbine	Drive Train Module	Main Shaft Set	High Speed Side	Coupling
Wind Turbine	Drive Train Module	Main Shaft Set	High Speed Side	Rotor Lock
Wind Turbine	Drive Train Module	Main Shaft Set	High Speed Side	Shaft
Wind Turbine	Drive Train Module	Main Shaft Set	High Speed Side	Transmission Shaft
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Axial Bearing
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Compression Coupling
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Connector Plate

Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Main Bearing Seal
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Main Bearing Temperature Sensor
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Main Shaft
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Radial Bearing
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Rotor Lock
Wind Turbine	Drive Train Module	Main Shaft Set	Low Speed Side	Slip Ring
Wind Turbine	Drive Train Module	Main Shaft Set	Mechanical Brake	Caliper
Wind Turbine	Drive Train Module	Main Shaft Set	Mechanical Brake	Disk
Wind Turbine	Drive Train Module	Main Shaft Set	Mechanical Brake	Pad
Wind Turbine	Drive Train Module	Main Shaft Set	Mechanical Brake	Tranmission Lock
Wind Turbine	Drive Train Module	Main Shaft Set	Sensors	High Speed Sensor
Wind Turbine	Drive Train Module	Main Shaft Set	Sensors	Low Speed Sensor
Wind Turbine	Drive Train Module	Main Shaft Set	Sensors	Position Sensor
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	24 Dc Feeder
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Auxiliary Transformer
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Breaker
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Cabinet
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Fan
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Fuse
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Grid Protection Relay
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Light
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Mechanical Switch
Wind Turbine	Electrical Module	Auxiliary Electrical	Electrical Services	Power Point

		System		
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Protection Cabinet
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Pushbutton
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Relay
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Space Heater
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Surge Arrester
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Thermal Protection
Wind Turbine	Electrical Module	Auxiliary Electrical System	Electrical Services	Ups
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Air Termination
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Bonding Element
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Earth Connector
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Earth Termination
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Sliding Contact
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Spark Gap System
Wind Turbine	Electrical Module	Auxiliary Electrical System	Lightning Protection System	Surge Arrester
Wind Turbine	Electrical Module	Control & Communication System	Ancillary Equipment	Breaker
Wind Turbine	Electrical Module	Control & Communication System	Ancillary Equipment	Cabinet Temperature Sensor

Wind Turbine	Electrical Module	Control & Communication System	Ancillary Equipment	Cable
Wind Turbine	Electrical Module	Control & Communication System	Ancillary Equipment	Contactor
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Analog I/O Unit
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Digital I/O Unit
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Ethernet Module
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Field Bus Master
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Field Bus Slave
Wind Turbine	Electrical Module	Control & Communication System	Communication System	Frequency Unit
Wind Turbine	Electrical Module	Control & Communication System	Condition Monitoring System	Condition Cables
Wind Turbine	Electrical Module	Control & Communication System	Condition Monitoring System	Data Logger
Wind Turbine	Electrical Module	Control & Communication System	Condition Monitoring System	Protocol Adapter Card For Data Logger
Wind Turbine	Electrical Module	Control & Communication	Condition Monitoring System	Sensors

		System		
Wind Turbine	Electrical Module	Control & Communication System	Controller Hardware	Controller Power Supply
Wind Turbine	Electrical Module	Control & Communication System	Controller Hardware	Cpu
Wind Turbine	Electrical Module	Control & Communication System	Controller Hardware	Internal Communication System
Wind Turbine	Electrical Module	Control & Communication System	Controller Hardware	Main I/O Unit
Wind Turbine	Electrical Module	Control & Communication System	Controller Hardware	Watch Dog Unit
Wind Turbine	Electrical Module	Control & Communication System	Controller Software	Closed Loop Control Software
Wind Turbine	Electrical Module	Control & Communication System	Controller Software	Supervisory Control Software
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Emergency Button
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Max Speed Switch
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Power Switch
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Short Circuit Switch

Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Vibration Switch
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Watch Dog Switch
Wind Turbine	Electrical Module	Control & Communication System	Safety Chain	Wind-Up Switch
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Auxiliary Power Supply
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Cabinet
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Cabinet Heating System
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Cabinet Sensor
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Communication And Interface Unit
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Control Board
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Generator Side Fan
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Grid Side Fan
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Measurement Unit
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Power Supply
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Power Supply 24v
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Tachometer Adapter
Wind Turbine	Electrical Module	Frequency Converter	Converter Auxiliaries	Thermostat
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Branching Unit
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Capacitor
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Contactora
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Generator Side Converter
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Generator Side Power Module
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Grid Side Converter
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Grid Side Power Module
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Inductor
Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Load Switch

Wind Turbine	Electrical Module	Frequency Converter	Converter Power Bus	Pre-Charge Unit
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Common Mode Filter
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Crowbar
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Dc Chopper
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Generator Side Filter
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Line Filter Assembly
Wind Turbine	Electrical Module	Frequency Converter	Power Conditioning	Voltage Limiter Unit
Wind Turbine	Electrical Module	Power Electrical System	Measurements	Ta
Wind Turbine	Electrical Module	Power Electrical System	Measurements	Tv
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Cables
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Machine Contactor
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Machine Transformer
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Mv Busbar / Isolator
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Mv Switchgear
Wind Turbine	Electrical Module	Power Electrical System	Power Circuit	Soft Start Electronics
Wind Turbine	Nacelle Module	Hydraulics System	Hydraulic Power Pack	Motor
Wind Turbine	Nacelle Module	Hydraulics System	Hydraulic Power Pack	Pump
Wind Turbine	Nacelle Module	Hydraulics System	Hydraulic Power Pack	Pressure Valve
Wind Turbine	Nacelle Module	Hydraulics System	Hydraulic Power Pack	Filter
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Bushing
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Cylinder
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Hose / Fitting
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Hydraulic Linear Drive
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Limit Switch
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Linkage

Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Miscellaneous Hydraulics System
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Position Controller
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Proportional Valve
Wind Turbine	Nacelle Module	Hydraulics System	Actuator	Pump
Wind Turbine	Nacelle Module	Hydraulics System	Torque Converter	
Wind Turbine	Nacelle Module	Hydraulics System	Differential	
Wind Turbine	Nacelle Module	Hydraulics System	Viscous Coupling	
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Meteorological Sensors	Anemometer
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Meteorological Sensors	Wind Vane
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Nacelle Sensors	Emergency Vibration Sensor
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Nacelle Sensors	Yaw Encoder
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Beacon
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Down Conductor
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Fall Arrester
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Firefighting System
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Nacelle Cover Metallic Mesh
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Lightning Protection Termination
Wind Turbine	Nacelle Module	Nacelle Auxiliaries	Safety System	Service Crane
Wind Turbine	Nacelle Module	Nacelle Structure	Bedplate	Bolts
Wind Turbine	Nacelle Module	Nacelle Structure	Bedplate	Cast or Welded Structure
Wind Turbine	Nacelle Module	Nacelle Structure	Cover	Fibreglass
Wind Turbine	Nacelle Module	Nacelle Structure	Cover	Hatch
Wind Turbine	Nacelle Module	Nacelle Structure	Generator Frame	Bolts
Wind Turbine	Nacelle Module	Nacelle Structure	Generator Frame	Cast or Welded Structure
Wind Turbine	Nacelle Module	Yaw System	Yaw Brake	Yaw Brake Calipers
Wind Turbine	Nacelle Module	Yaw System	Yaw Brake	Yaw Brake Disc
Wind Turbine	Nacelle Module	Yaw System	Yaw Brake	Yaw Brake Hoses
Wind Turbine	Nacelle Module	Yaw System	Yaw Brake	Yaw Brake Paths
Wind Turbine	Nacelle Module	Yaw System	Yaw Drive	Damper

Wind Turbine	Nacelle Module	Yaw System	Yaw Drive	Yaw Bearing
Wind Turbine	Nacelle Module	Yaw System	Yaw Drive	Yaw Gearbox
Wind Turbine	Nacelle Module	Yaw System	Yaw Drive	Yaw Motor
Wind Turbine	Nacelle Module	Yaw System	Yaw Drive	Yaw Pinion
Wind Turbine	Nacelle Module	Yaw System	Yaw Sensors	Wind-Up Counter
Wind Turbine	Nacelle Module	Yaw System	Yaw Sensors	Yaw Encoder
Wind Turbine	Rotor Module	Blade	Blade Lightning Protection Termination	Blade Lightning Protection Termination
Wind Turbine	Rotor Module	Blade	Blade Lightning Down-conductor	Blade Lightning Down-conductor
Wind Turbine	Rotor Module	Blade	De-Icing System	De-Icing System
Wind Turbine	Rotor Module	Blade	Leading Edge Bond	Leading Edge Bond
Wind Turbine	Rotor Module	Blade	Nuts And Bolts	Nuts And Bolts
Wind Turbine	Rotor Module	Blade	Paint And Coating	Paint And Coating
Wind Turbine	Rotor Module	Blade	Root Structure	Root Structure
Wind Turbine	Rotor Module	Blade	Sandwich Shell	Sandwich Shell
Wind Turbine	Rotor Module	Blade	Spar Box	Spar Box
Wind Turbine	Rotor Module	Blade	Spar Cap	Spar Cap
Wind Turbine	Rotor Module	Blade	Spar Web	Spar Web
Wind Turbine	Rotor Module	Blade	Trailing Edge Bond	Trailing Edge Bond
Wind Turbine	Rotor Module	Hub	Exit Hatch	Exit Hatch
Wind Turbine	Rotor Module	Hub	Nose Cone	Nose Cone
Wind Turbine	Rotor Module	Pitch System	Pitch Cabinet	Battery
Wind Turbine	Rotor Module	Pitch System	Pitch Cabinet	Battery Charger
Wind Turbine	Rotor Module	Pitch System	Pitch Cabinet	Heater
Wind Turbine	Rotor Module	Pitch System	Pitch Cabinet	Local Controller
Wind Turbine	Rotor Module	Pitch System	Pitch Cabinet	Switchboard
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Motor
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Motor Cooling
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Motor Cooling System
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Motor Drive

Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Pinion
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Pitch Bearing
Wind Turbine	Rotor Module	Pitch System	Pitch Drive	Pitch Gearbox
Wind Turbine	Rotor Module	Pitch System	Pitch Sensors	Position Encoder
Wind Turbine	Rotor Module	Pitch System	Pitch Sensors	Temperature Sensor
Wind Turbine	Rotor Module	Pitch System	Pitch Sensors	Voltmeter
Wind Turbine	Support Structure	Foundation	Gravity Based Foundation	Concrete
Wind Turbine	Support Structure	Foundation	Gravity Based Foundation	Steel Reinforcement
Wind Turbine	Support Structure	Foundation	Monopile	Corrosion Protection
Wind Turbine	Support Structure	Foundation	Monopile	Pile
Wind Turbine	Support Structure	Foundation	Monopile	Transition Piece
Wind Turbine	Support Structure	Foundation	Onshore	Concrete
Wind Turbine	Support Structure	Foundation	Onshore	Nuts & Bolts
Wind Turbine	Support Structure	Foundation	Onshore	Piles
Wind Turbine	Support Structure	Foundation	Onshore	Steel Reinforcement
Wind Turbine	Support Structure	Foundation	Space Frame / Tripod	Corrosion Protection
Wind Turbine	Support Structure	Foundation	Space Frame / Tripod	Piles
Wind Turbine	Support Structure	Foundation	Space Frame / Tripod	Structures
Wind Turbine	Support Structure	Tower	Access Equipment	Ladder
Wind Turbine	Support Structure	Tower	Access Equipment	Landing Pad
Wind Turbine	Support Structure	Tower	Access Equipment	Lightning Protection
Wind Turbine	Support Structure	Tower	Tower	Climb Assist
Wind Turbine	Support Structure	Tower	Tower	Maintenance Crane
Wind Turbine	Support Structure	Tower	Tower	Nuts & Bolts
Wind Turbine	Support Structure	Tower	Tower	Paint/Coating
Wind Turbine	Support Structure	Tower	Tower	Tower Section
Wind Farm	Collection System	Cable	Cable	Cable
Wind Farm	Meteorological Station	Meteorological Station	Meteorological Station	Meteorological Station
Wind Farm	Operational Infrastructure	Operational Infrastructure	Operational Infrastructure	Operational Infrastructure

Wind Farm	Substation	Grid Connection	HV Link	HV Link
Wind Farm	Substation	Grid Connection	Substation Transformer	Substation Transformer
Wind Farm	Substation	Grid Connection	Utility Communication & Control	Utility Communication & Control

## 11. Appendix 4- Wind Turbine Failure Terminology

Sub-System	Assembly,	Sub-Assembly or Component	Failure or Failure Mode from ReliaWind WP2
Foundation	Monopile		Scour; Erosion; Corrosion
	Tripod		Erosion; Corrosion
	Gravity Base		Scour; Erosion
	Transition Piece		Grout Slippage; Grout Loss;
	Jacking Brackets		Fatigue
	Bolts		Fatigue; Corrosion; Erosion
Tower	Structure		Fatigue; Corrosion
	Bolts		Corrosion; Overload; Fatigue
	Climbing System		Corrosion; Overload
	Lift		Motor failure; Interlock failure
Rotor Module	Rotor	Rotor Hub	Fracture; Corrosion
		Rotor Blade	Mechanical Imbalance; Aerodynamic Imbalance
		Spars	Cracking; Debonding From Skin
		Coating	Roughening Impact Damage
		Lamination	Debonding; Lightning Damage; Impact Damage
		Leading Edge	Erosion; Ice Build Up
		Trailing Edge	Debonding; Ice Build Up
		Tip Brake	Loss Of Tip
		Tip Brake Wire	Snagging Broken
Rotor Module	Pitch System		Pitch Bearing Failure; Seizure; Overload; Motor Failure
	Pitch System		Hydraulic Oil Contamination; Hydraulic Oil Leakage; Hydraulic Pump Failure
	Pitch System		Slip Ring Wear
	Pitch System		Blade Mismatch; Aerodynamic Imbalance
Nacelle Module	Yaw System		Yaw Bearing Failure;

			Yaw Ring Wear; Yaw Ring Distortion Or Damage; Yaw Motor Failure; Yaw Brake Failure; Yaw Brake Seizure; Yaw Alignment Error
	Hydraulics System	Hydraulic Power Pack; Motor	Winding failure; Overtemperature
		Hydraulic Power Pack; Pump	Overtemperature; Seal failure
		Hydraulic Power Pack; Pressure Valve	Seal failure
		Hydraulic Power Pack; Filter	Blockage
	Anemometer		Ice Build Up; Seizure; Calibration Drift; Impact Damage
	Wind Vane		Ice Build Up; Seizure; Calibration Drift; Impact Damage
	Electrical System		See Sub-systems
	Access System		Wear; Looseness; Breakage
	Generator Supports		Cracking; Bending; Looseness
Drive-Train	Main Bearing		Bearing Failure; Misalignment; Lubrication
	Main Shaft		Cracking; Permanent Bend
	Mechanical Brake		Pad Wear; Overheating; Disk Wear; Hydraulic Failure
	Gearbox	Gearcase	Fracture
		Suspension	Wear; Looseness
		Torque Arm	Wear; Looseness
		Lubrication System	Loss Of Lubricant; Contaminated Lubricant; Aged Lubricant; Lubricant System Failure; Lubrication Pump Failure; Blocked Lubrication Filters; Blocked Jets
		Epicyclic Part, Planet Carrier	Lubrication
		Epicyclic Part, Planet Bearing	Bearing Failure; Lubrication
		Epicyclic Part, Planet Gear	Tooth Failure; Lubrication
		Epicyclic Part, Internal Gear	Tooth Failure; Lubrication; Fracture
		Epicyclic Part, Sun Gear	Tooth Failure; Lubrication

		Epicyclic Part, Shaft	Cracking; Journal Damage
		Parallel Shaft Part, Gear	Tooth Failure; Lubrication
		Parallel Shaft Part, Bearing	Bearing Failure; Lubrication
		Parallel Shaft Part, Pinion	Tooth Failure; Lubrication
		Parallel Shaft Part, Shaft	Cracking; Journal Damage
		High Speed Shaft	Cracking; Permanent Bend
	Generator	Coupling	Misalignment; Perishing; Wear;
		Rotor	Fracture
		Rotor Windings	Shorted Turn; Earth Failure; Broken Bar
		Stator	Shorted Turn; Earth Failure
		Stator Windings	Shorted Turn; Earth Failure
		Bearings	Bearing Failure; Lubrication Failure
		Stator Cooling System	Blockage; Over-temperature
		Slip Rings	Brush Wear; Over-temperature
		Encoder	Encoder Failure
Electrical Module	Frequency Converter	Power Electronics	Component Failure; Joint Failure
		Grid-side Filter	Component Failure;
		Grid-side Inverter	IGBT Failure; Over-temperature
		DC Link	Capacitor Failure;
		Generator-side Inverter	IGBT Failure; Over-temperature
		Generator -side Filter	Component Failure
		Crowbar	Thyristor Failure
		Crowbar resistor	Over-temperature; Component failure; Fuse failure
		DC chopper	Component failure
		DC chopper resistor	Over-temperature; Component failure; Fuse failure
	Transformer	Windings	Winding Failure; Over-temperature
		Core	Over-temperature
		Oil System	Oil deterioration; Over-temperature
	Switchgear		Circuit Breaker Failure



# 13. Appendix 6-Standardisation Survey of ReliaWind Consortium Partners



Prepared by Dr Yanhui Feng, School of Engineering and Computing Sciences, Durham University  
**STANDARDISATION FROM RELIAWIND**

**INTRODUCTION:** As part of the Consortium's Work Plan WP6 we are required to initiate work on wind turbine standardisation for reliability and this needs to be done within the standard IEC 61400. UDUR as WP 6 Leader needs your assistance to participate in this survey and determine what the Consortium does in respect of standardisation. A number of Consortium Partner staff are members of IEC 61400 Working Groups, as set out in the attached document of previous email. Please will you complete the Survey as shown by the end of August 2010. If you are unable to complete it yourself please would you arrange for another member of staff in your organisation to complete the Survey. The Consortium's actions in this respect are most important.

Response	GAMESA	ALSTOM	LM	HANSEN	ABB	GH	SKF	RELEX	SZTAKI	UDUR
	Yes	Yes	No reply	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**QUESTION 1:** Please vote if you are prepared to participate in the following ReliaWind Activities, as required by the ReliaWind work plan?

**QUESTION 2:** Please vote to confirm that you agree that ReliaWind should not contribute to the definition of Wind Turbine & Wind Farm Availability in IEC61400 Parts 26, as this important work is already proceeding involving staff from some ReliaWind Partners.

**QUESTION 3:** Do you agree that ReliaWind propose to the Working Group for IEC61400 Parts 26, that the reliability of wind turbines should be included in Part 26 and particularly it should include:

- Standardisation of the WT Taxonomy (naming of parts)
- Standardisation of the classification of WT parts within that Taxonomy
- Standardisation of the structure of the Control Input/Output list for WTs so that it conforms to the above Taxonomy
- Standardisation of methods for collecting reliability data from WTs and the methods for analysing them.

**QUESTION 4:** Taxonomy and the I/O list are already considered in IEC61400 Part 25 so there will need to be some interaction between these Part 25 and 26. Do you agree that the standardisation should also consider Part 25?

**QUESTION 5:** Please confirm that, if your answers to the above are yes, you are prepared to contribute to Consortium meetings to work with the IEC 61400 Part 26 Working Group?

**QUESTION 6:** Who in your organisation will contribute to this activity, which will be led by UDUR as Work Package 6 Leader? Please identify the email address of contact person?

	GAMESA	ALSTOM	LM	HANSEN	ABB	GH	SKF	RELEX	SZTAKI	UDUR
Q1	No reply	Yes	No reply	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q2	No reply	Yes	No reply	Yes	No	No	Yes	Yes	No	Yes
Q3	Yes	Yes	No reply	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q4	Yes	No	No reply	Yes	Yes	No	Yes	Yes	Yes	Yes
Q5	Yes	Yes	No reply	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Q6	Eugenio Gomez : <a href="mailto:egomez@gamesa-corp.com">egomez@gamesa-corp.com</a>	<a href="mailto:juan-ignacio.lopez@power.alstom.com">juan-ignacio.lopez@power.alstom.com</a>	No reply	Dr. Ir. Kris Smolders <a href="mailto:kris.solders@hansepowertransmissions.com">kris.solders@hansepowertransmissions.com</a> Dr. Ir. Wim Meertzen <a href="mailto:wim.meertzen@hansepowertransmissions.com">wim.meertzen@hansepowertransmissions.com</a>	Mikael Aulinke <a href="mailto:mikael.aulinke@fi.abb.com">mikael.aulinke@fi.abb.com</a> Aarti Vinke <a href="mailto:aarti.vinke@fi.abb.com">aarti.vinke@fi.abb.com</a>	Fabio Spinato <a href="mailto:fabio.spinato@garradhassan.com">fabio.spinato@garradhassan.com</a>	<a href="mailto:par.malmberg@skf.com">par.malmberg@skf.com</a> <a href="mailto:john.skillemis@skf.com">john.skillemis@skf.com</a>	Luca Barbieri	<a href="mailto:gabor.ecdes@sztaki.hu">gabor.ecdes@sztaki.hu</a> <a href="mailto:zoltan.boros@sztaki.hu">zoltan.boros@sztaki.hu</a>	<a href="mailto:peter.trnsek@durham.ac.uk">peter.trnsek@durham.ac.uk</a>



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**STANDARDS COMMITTEE MEMBERSHIP:** Following the Durham General Assembly Meeting, May 2010, UDUR has collected the information of the ReliaWind Partners involved in IEC 61400 standardisation. UDUR, RELEX, SZTAKI have no representation in Standards Committee.

The proposal is that we should communicate with these contacts to further the standardisation objectives of ReliaWind

		Main Parts Associated with Reliability & Availability				
		Part 1	Part 3	Part 4	Part 26	
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	<b>Other parts( including IEC61400 Part 5, 12, 21, 24, 25, 27, EN50308)</b>					
	GAMESA	Part 5: Part 11: Part 12-1: Part 12-2 & 12-3: Part 25: Part 27: EN50308 Personal Safety:	Alejandro Saez Moreno Millan Esteba Cornejo Roberto Gutierrez Ardanaz Millan Esteba Cornejo Nerea Perez Garcia Javier Perez-Jacoiste Asin Millan Esteba Cornejo	<a href="mailto:alsaez@gamesa-corp.com">alsaez@gamesa-corp.com</a> <a href="mailto:mecornejo@gamesa-corp.com">mecornejo@gamesa-corp.com</a> <a href="mailto:rgutierrez@gamesa-corp.com">rgutierrez@gamesa-corp.com</a> <a href="mailto:mecornejo@gamesa-corp.com">mecornejo@gamesa-corp.com</a> <a href="mailto:nperez@gamesa-corp.com">nperez@gamesa-corp.com</a> <a href="mailto:jperezjacoiste@gamesa-corp.com">jperezjacoiste@gamesa-corp.com</a> <a href="mailto:mecornejo@gamesa-corp.com">mecornejo@gamesa-corp.com</a>		
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