Final Publishable Summary of Results of Project ReliaWind

PROJECT FINAL REPORT

Grant Agreement number: 212 966

Project acronym: RELIAWIND

Project title: Reliability-focused research on optimizing Wind Energy system design, operation and maintenance: Tools, proof of concepts, guidelines & methodologies for a new generation

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

Period covered: from 15 March 2008 to 14 March 2011

Name of the scientific representative of the project's co-ordinator[1], Title and Organisation:

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Project website Error! Bookmark not defined. **address:** www.ReliaWind.eu

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

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ReliaWind

More efficient and reliable wind turbines by 2011

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

1 Executive Summary

ReliaWind investigated the current reliability of large wind turbines and recommended methods of measuring reliability and processing data from wind turbines and wind farms that will raise overall Wind Turbine (WT) availability and lower the cost of energy from wind. The project ran from March 2008 to March 2011 with active involvement of 10 partners. The main results of the project can be summarized as:

- Benchmarking past failure rate and downtime data from operational WTs;
- Measuring current failure rate and downtime data from WTs, their sub-systems' assemblies, subassemblies and components in operational Wind Farms (WFs), comparing those results with the public domain benchmark;
- Identification of 6 critical sub-systems in a modern WT;
- Identification of 5 failure modes in those 6 critical sub-systems;
- Understanding failures and failure mechanisms in a modern WT.
- Definition of a logical architecture for the detection, location, diagnosis and prognosis of failures in critical systems of a modern WT;
- Demonstrating the project findings in a WF maintenance model;
- Carried out a Training Needs Analysis and prepared Training Materials presented at 13 sessions to more than 240 wind industry professionals;
- Prepared a programme of standardisation and specification for the collection and analysis of reliability information in the wind industry to IEC Committees;
- Disseminated Consortium knowledge through a website, posters, conference and journal papers at the EWEC 2009, 2010 and 2011, visual media and at more than 18 other international events;
- Completed 78 internal deliverables.

2 Project Context and Objectives

On 8 & 9th March 2007 the EU Council of Ministers agreed:
"Renewable energy will supply at least 20 % of the EU's energy demand by 2020".
Provided sufficient emphasis is placed on technological, R&D and market development, wind power can make the most substantial contribution to this target. The geography of Europe and current technological evolution towards 2020 mean that offshore wind energy will play a key role in achieving this target.

Current offshore wind operation & maintenance (O&M) costs are too high, requiring high feed-in tariffs to encourage private investors to make the business case to enter the market. This project aims to change this paradigm by encouraging offshore wind to be deployed with similar operational performance and O&M costs as onshore through better availability and lower cost of energy.

Based on successful experience in the aerospace sector, the ReliaWind Consortium has changed that paradigm by jointly & scientifically studying how reliability affects the design, operation and maintenance of WTs, leading to a new generation of offshore, and onshore WTs for the market beyond 2015.

Ten top partners took part in this ambitious project, each of them leaders in technical and operational disciplines in the wind power generation value chain:

- This included the wind Industry itself, Gamesa (project coordinator), Alstom Wind Power, LM Wind Power, Hansen Transmissions, ABB and SKF.
- Technology experts were GL Garrad Hassan and PTC-Relex Reliability Software and Services.
- Academia was represented by Durham University, UK and SZTAKI, a Research Institute of the Hungarian Academy of Sciences in Budapest.

The project aimed to achieve better availability and lower cost of energy for WTs, through the deployment of new systems with reduced maintenance requirements and increased availability. To this end, the project proposes an architecture directed at a modular design more immune to environmental conditions, permitting the replacement of components simply and quickly; to improve component monitoring systems and achieve more accurate component diagnosis; and to develop preventive maintenance algorithms for failure anticipation. These new technologies will be integrated in future generations of WT components, WTs and WFs.

3 Main Scientific & Technological Results and Foreground

The main results of the project can be summarized as follows:

- Benchmarking from the public domain the normalised failure rate (λ) and downtime ($1/\mu$) of operational WTs and their major assemblies in the field (Work Package 1: Field Reliability Analysis).
- Measurement of WT normalised Mean Times Between Failure ($MTBF=1/\lambda$) and Mean Times to Repair ($MTTR=1/\mu$) for WTs, their sub-systems, assemblies, subassemblies and components, in operational WFs and comparing those results with the public domain benchmark (Work Package 1: Field Reliability Analysis).
- Identification of 6 critical sub-systems in a modern WT (WP1: Field Reliability Analysis).
- Understanding failures of sub-systems, assemblies, sub-assemblies and components in a modern WT and their mechanisms (WP2: Design for Reliability).
- Identification of 5 failure modes for each of the 6 critical sub-systems (WP2: Design for Reliability).
- Definition a logical architecture for the detection, location, diagnosis and prognosis of failures critical sub-systems, assemblies, sub-assemblies and components in a modern WT and specification of a modern WT Health Monitoring System (WP3: Algorithms).
- Demonstration of the principles of the project findings in a WF maintenance model (WP4: Applications).
- Carried out a Training Needs Analysis and on that basis prepared Training Materials which were presented at 13 sessions to more than 240 wind industry professionals who were internal and external partners of the Consortium (WP5: Training).
- Prepared a programme of standardisation and detailed specification for the collection and analysis of reliability information in the wind industry and forwarded that proposal to National and International IEC Committees (WP6: Dissemination).
- Dissemination of new knowledge generated by the Consortium in posters and conference papers at the European Wind Energy Conferences of 2010 and 2011, in journal articles, on the web site, through visual media and at more than 18 other international events, including cooperation with other international initiatives such as Sandia working group (WP6: Dissemination).

With **78 internal deliverables completed**, the ReliaWind project's main goal was to usher in a new generation of more efficient and reliable WTs, providing practical results to be used WT design, operations and maintenance. The work of the consortium was divided into six Work Packages (WP) as follows.

3.1 WP 1, Identification of Critical Failures and Components

3.1.1 Aims

The overall objective was to identify the critical sub-systems, assemblies, sub-assemblies and components of WTs and their failure modes based on processing WT historical operational data and carrying out a Failure Modes Effects & Criticality Analysis (FMECA). The first work consisted of establishing the state of art and the methodology to be employed. Using the established methodology the field data was analysed and interpreted.

3.1.2 Context

Public Domain Data

An assessment of the current state of the art in measuring operational WF reliability [1] showed that a number of quantitative studies of WT reliability have been carried out in the last 10 years. The Dutch research programme DOWEC, which has been among the pioneers of the quantification of WT reliability figures, has presented some interesting studies [2]–[6]. Further reliability analyses have used data from existing commercial and public databases. Relevant results have been achieved by research carried out by various authors [7]–[10]. As an example,

Figure **1** shows the failure rate and downtime from two large reliability surveys LWK [11], WMEP [12].

The objectives of these studies have been to extract information from the field to understand WT reliability from a statistical point of view and provide a benchmark for further analysis. These previous works have presented relevant results; however consideration must be made to the method of recording and reporting these data, which are discussed by Spinato et al. [10]. The objective of the ReliaWind Field Study was to build a database of downtime events from a number of WFs containing a large number of WTs [13].

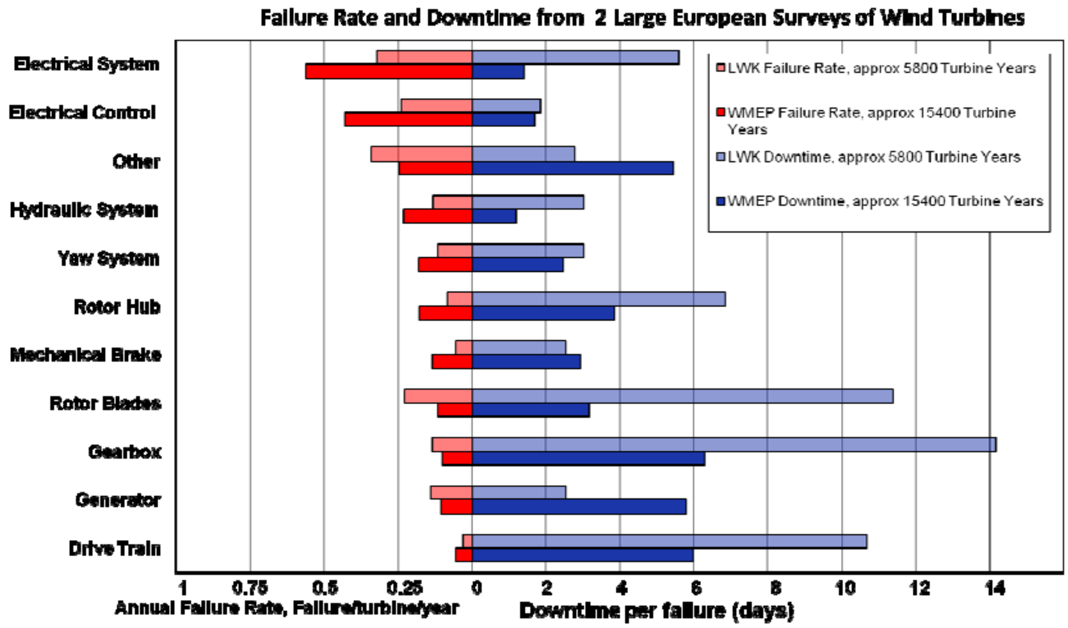

Figure 1. Failure rate and downtime results for onshore WTs from two large public domain reliability surveys [13].

Field Study Data

The primary aim was to present the results of the project field study. The methods of the field study were established and the approach was taking account of all operational data that is recorded at modern WFs, including:

- 10-minute average SCADA data;
- Fault / alarm logs;
- Work orders / service reports; and
- O&M contractor reports.

These sources are discrete and are not designed to easily allow reliability information to be extracted; a substantial effort was invested in connecting these sources. All the downtime events at each WT in the study were identified and then tagged according to a common taxonomy [15].

Data for this study were provided by WT manufacturers who were members of the ReliaWind consortium and by others operators who were members of the ReliaWind Users' Working Group.

Relex Field Study Data

The FMECA allowed an analysis of the failure rates for the generic ReliaWind WTs, carried out according to the taxonomy used for the FMECA as the results of the above-mentioned field data. This modelling described the procedure, method and data sources needed to build a WT reliability database and then to predict the WT reliability and FMECA of different designs using Relex Studio software.

Reliability Profiles

Data Included in the Study

450 wind-farm months' of WT data were added to the field study database, comprising around 350 WTs operating for varying lengths of time. This is in the form of 35,000 downtime events, each one tagged within the standard taxonomy.

3.1.3 Results

The results of WP1 are presented graphically in Figure 1 and Figure2 and are normalised relative to the overall failure rate / downtime, to show the percentage contribution to the overall failure rate / downtime of the analysis. The large background blocks show sub-systems, the smaller foreground blocks show assemblies and the line shows the Pareto cumulative contribution. Faults from all severity categories were included in the results presented here.

Note that the percent time lost shown in these tables is the distribution of the total expected downtime each year and as such, an assembly with a high failure rate will have a larger total downtime than an assembly with a low failure rate but the same mean time to repair per failure (MTTR). The total downtime may be regarded as a criticality metric equivalent to an availability measure.

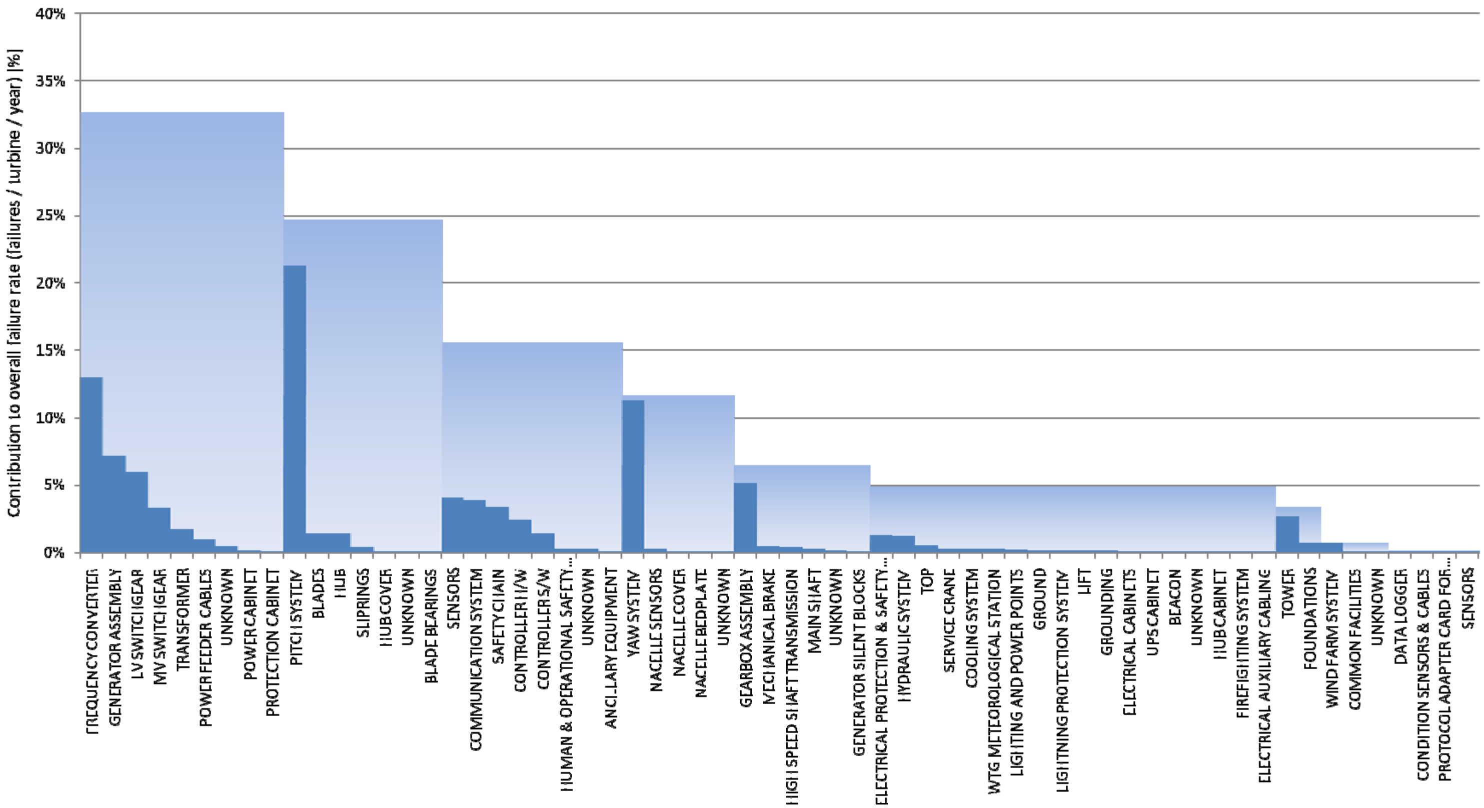

Figure 1. Normalised failure rate of sub-systems and assemblies for turbines of multiple manufacturers in the database.

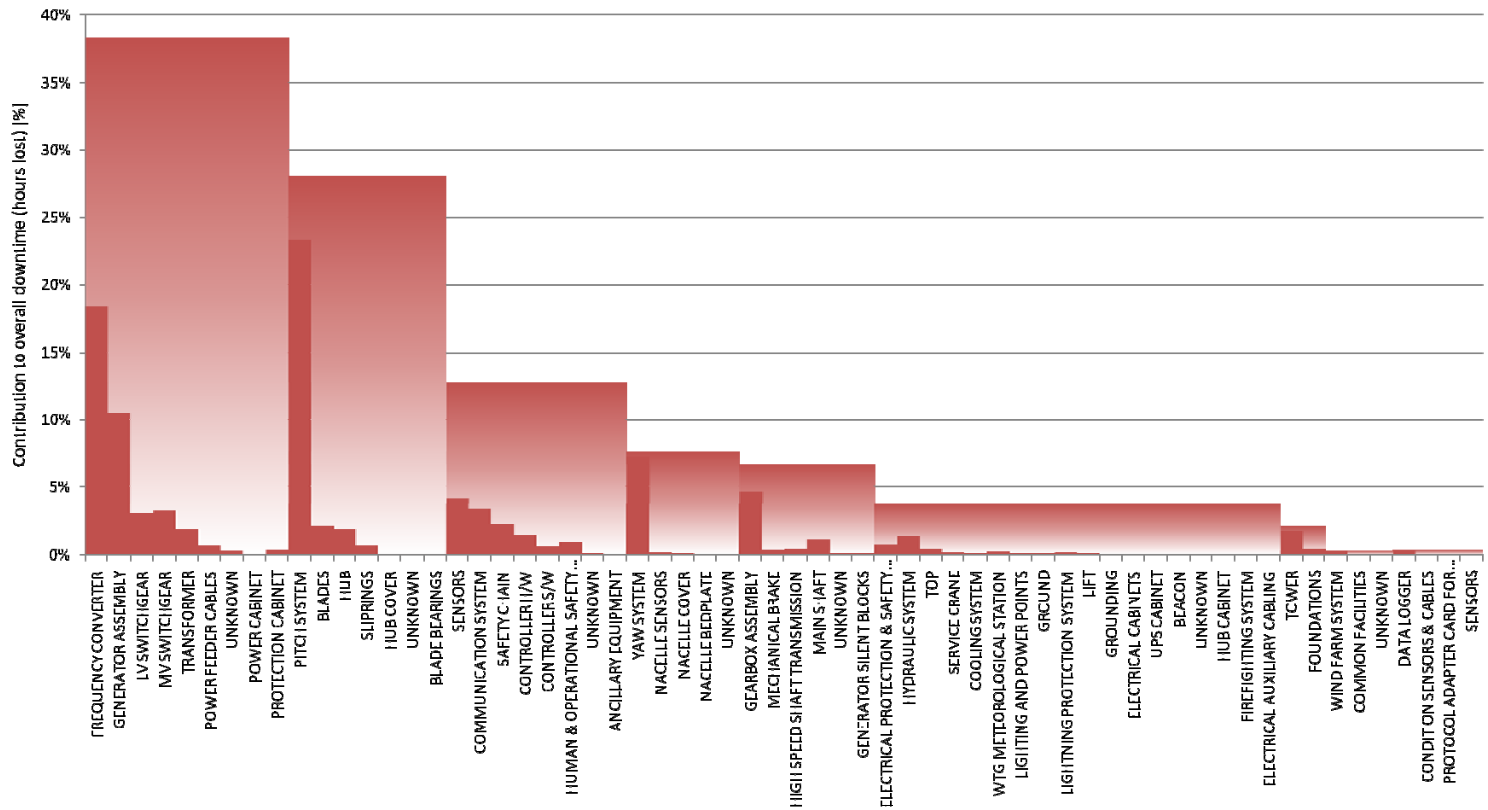

Figure2. Normalised hours lost per turbine per year to faults in sub-systems and assemblies for turbines of multiple manufacturers in the database

3.2 WP2, Understanding Failures & their Mechanisms, Design for Reliability

3.2.1 Aims

This part of work aimed at identifying best design practices and providing guidelines that can enhance overall WT reliability and availability, namely describing the procedure, method and data sources needed to build a WT reliability database and then predict WT reliability by means of a Failure Modes Effects & Criticality Analysis (FMECA) of different WT designs using Relex Studio software.

3.2.2 Context

Reliability Model

The WT Reliability Prediction & Reliability Block Diagram (RBD) models presented in the analysis are based on two generic WT configurations, R80 & R100 as listed in Table I. For the R100, a component FMECA was also performed.

Table I. WT Specifications

Configuration Criteria	**These 2 configurations are both pitch-regulated, upwind, variable speed WTs. Their sub-systems include hydraulic pitch, 3-stage gearbox, DFIG, active yaw and three-blade rotor.**	
	R80 A general 2MW WT is illustrated in Figure 2.	**R100**
Frequency	50/60Hz	50/60Hz
Nominal Power	1.5—2 MW	3—5 MW
Rotor Diameter	80—90 m	120—130 m
Hub height	60—100 m	100—120 m
Rotational Speed	10—20 rpm	12—14 rpm
Aerodynamic Brakes	Full feather	Full feather
Number of blades	3	3
Class	IIA	IIA
Operating Temperature	-25—40 ^{o}C	-25—40 ^{o}C
Altitude	0—1500 m	0—1500 m
Analysis	Reliability Prediction & RBD	Reliability Prediction & RBD results not shown
		FMECA

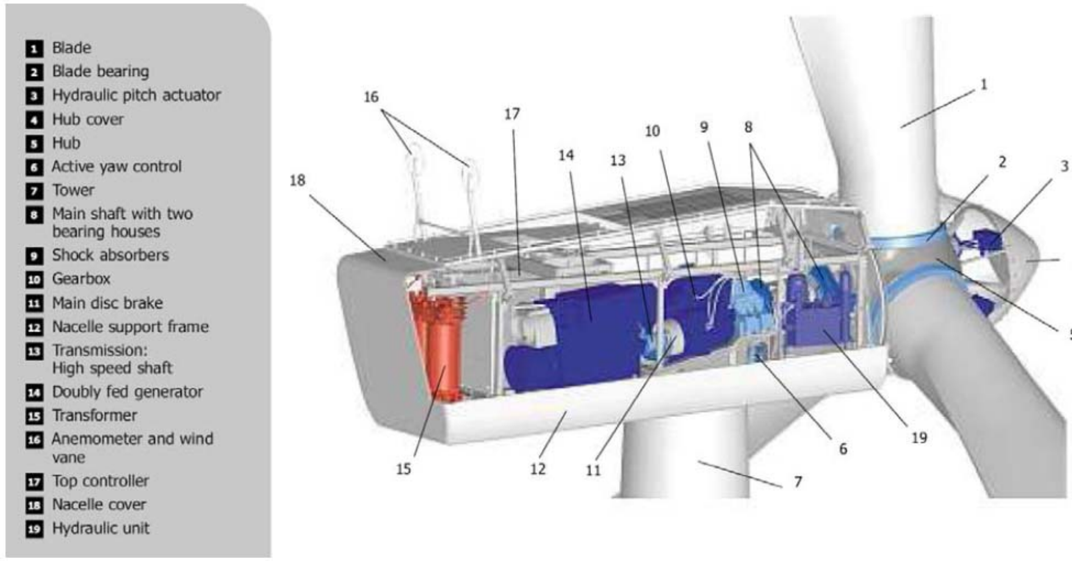

Figure 2. General Structure for the R80 2MW WT

Reliability Analysis Procedure

The procedure for WT design for reliability analysis was applied to the WT in Figure 2 and can be used as a classical reliability design analysis during the *Design* and *Redesign* Phases. The reliability design analysis can be performed on the *overall systematic level* as well as *the sub-system levels*.

The aim of overall systematic level reliability analysis was to integrate the whole system reliability model using common reliability analysis procedures which require a WT system functional block diagram specification and sub-system reliability model specifications.

The sub-system level reliability analysis builds a reliability model for each sub-system in order to analyze the sub-system reliability to:

- Investigate the interaction of the sub-system models on the whole system;
- Develop a design guideline for sub-system design teams;
- Define optimum sensing devices and locations for characterising sub-system failures.

The taxonomy used for the FMECA is shown in Figure 3.

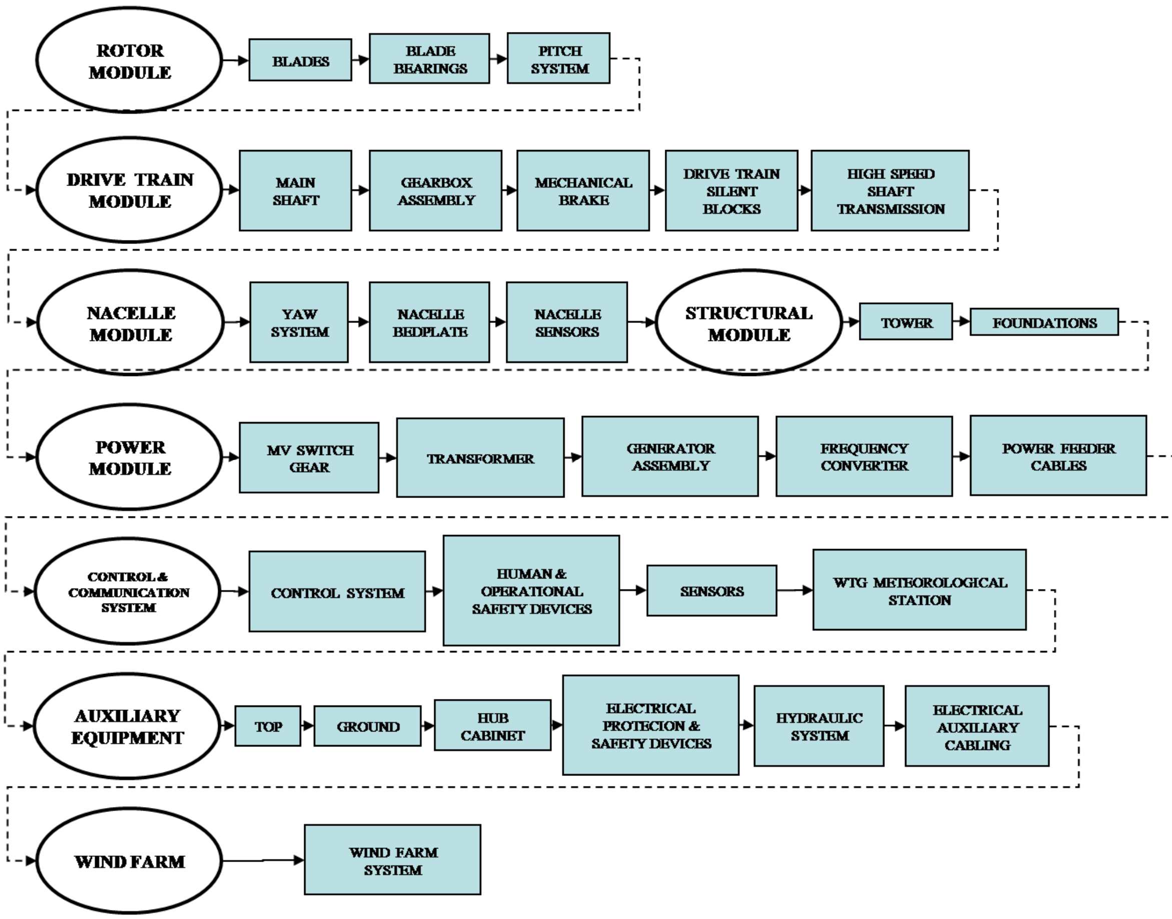

Figure 3. Taxonomy used for the FMECA of the R80 & R100 WTs

3.2.3 Results

The results of the FMECA study are presented in the Table Annex 1. The Critical sub-systems of the WT are shown in Figure 4. The most important Failure Modes identified by WP2 in the Critical sub-systems is shown in Figure 5.

Sub-system / Assembly	Total Failure Rate %	Medium Time Lost %
Pitch System	16%	20%
Frequency Converter	12%	13%
Yaw System	12%	10%
Control System	14%	9%
Generator Assembly	6%	11%
Gearbox Assembly	5%	4%

Figure 4. Critical Sub-systems identified in WP2

Sub-system/ Assembly		Failure Mode 1	Failure Mode 2	Failure Mode 3	Failure Mode 4	Failure Mode 5
Pitch System	Electrical (5 out of 13)	Battery Failure	Pitch Motor Failure	Pitch Motor Converter Failure	Pitch Bearing Failure	Temperature or Humidity Sensor Failure
	Hydraulic (5 out of 5)	Internal leakage of proportional valve	Internal leakage of solenoid valve	Hydraulic cylinder leakage	Position sensor degraded or no signal	Pressure control valve sensor degraded signal
Frequency Converter (5 out of 18)		Generator-side or Grid-side Inverter Failure	Loss of Generator Speed Signal	Crowbar Failure	Converter Cooling Failure	Control Board Failure
Yaw System (5 out of 5)		Yaw gearbox and pinion lubrication out of specification	Degraded wind direction signal	Degraded guiding element function	Degraded hydraulic cylinder function	Brake operation valve does not operate
Control System (5 out of 5)		Temperature sensor modules Failure	PLC analogue input Failure	PLC analogue output Failure	PLC digital input Failure	PLC In Line Controller Failure
Generator Assembly (5 out of 11)		Worn slip ring brushes	Stator winding temperature sensor Failure	Encoder Failure	Bearing Failure	External fan Failure
Gearbox Assembly (5 out of 5)		Planetary Gear Failure	High Speed Shaft Bearing Failure	Intermediate Shaft Bearing Failure	Planetary Bearing Failure	Lubrication System Failure

Figure 5. Most important Failure Modes identified in the Critical Sub-systems by WP2

3.3 WP3, Logical Architecture Definition for Advanced WT Health Monitoring

3.3.1 Aims

Using the results of the field data in WP1 and design analysis in WP2, WP3 has targeted the critical sub-assemblies identified in WP2 to develop algorithms for the detection, location, diagnosis and prognosis of faults in those sub-systems designed to raise WT reliability and availability.

3.3.2 Context

WP3 identified the vital need to simplify and aggregate the valuable data coming from WTs and unlock a data overload stasis that is gripping the industry. That can initially be done by developing algorithms for the detection, location, diagnosis and prognosis of faults in those sub-systems shown to be unreliable to operate on the data collected from WT SCADA and CMS systems to raise reliability and availability.

3.3.3 Results

A number of algorithms were developed to detect, locate, diagnose and prognose the fault behaviour in the 6 sub-systems described above. Software systems were developed to apply these algorithms to data made available by Partners to demonstrate their fault detection efficacy. A number of monitoring processes were thereby developed.

First, the Logical Architecture of an Advanced WT Health Monitoring System was defined. This architecture meets the related wind industry and other standards; moreover improvements for the wind industry related standard were suggested. The most critical failures for the most critical components were defined and possible controller mitigating actions have were described.

Next a practical approach to visualise the SCADA signals and alarms on time domain was devised. A specific algorithm to evaluate the Mean Residual Life (MRL) for the WT components was developed. As a result of establishing new algorithms for failure detection, location and prognosis, improved FMECA applications were developed.

A Maintenance Task Description Template (MTDT) was developed that includes all the variables that have influence on the Availability / Maintainability.

The algorithm for planning maintenance activities based on the previous tasks was developed in order to achieve the maximum operational availability with the pre-defined resources and logistical constraints. Aspects like weather conditions, spare parts availability, or capacity of maintenance teams, were taken into account when preparing the schedule. SCADA based data reports were defined to support maintenance related decision making at an operator and WF owner level. Establishment and direct ordering of SCADA reports to different WT working situations, e.g., failure cases.

Consequently a set of maintenance decision-making tools were defined based on the failure detection, location, and prognosis. These tools will enable maintenance planners to feedback the maintenance schedule and optimize maintenance resources on the short-term and medium-term horizons.

3.4 WP 4, Demonstration of the Principles of Project Findings

3.4.1 Aims

The algorithms developed in WP3 were then applied to information collected from WT SCADA and Maintainer information and applied to the maintenance strategy developed in WP3 to allow incipient faults in key WT sub-assemblies to be identified early and preventative maintenance to be scheduled appropriately so that downtime is reduced and availability raised. A set of software for this purpose has been developed by SZTAKI.

3.4.2 Context

The wind industry is currently collecting an enormous amount of data from WFs in the field but to date very little has been done to process and use this data to improve operational performance. The stimulus to this appears to be the migration of WTs offshore where access costs are high and downtimes extended. It is clear that if a method can be developed to process the large amount of data available from WTs in WFs against an ordered maintenance strategy then substantial improvements in reliability and availability should be achievable.

3.4.3 Results

Under this task the tools and algorithms developed in WP3, based on the principles of WP2, were integrated to establish a practicable condition monitoring system. This system was to be suitable for application to a WT unit, manageable by the operator and suitable for integration into existing SCADA products, which delivers genuine potential for planning Condition Based Maintenance.

The system was developed as a software platform for the multi-agents developed in WP3. It was designed using software components to include the new functionalities and technologies and to be capable of being subjected to overall system tests based on real turbine experience collected in WP1. The multi-agent platform was developed for the coexistence and exchange of information among the different agent types: failures detection, location, diagnosis and maintenance generation and maintenance sequencing. Next the platform coordinating agents were developed. The consistent Software (SW) platform demonstrator is able to simulate and optimize the operation and maintenance concept, by maximizing WT availability and optimizing CoE for WFs.

The ultimate aim was to devise practical applications to validate the developments against well-known cases that allow evaluating the capacities of the methodology, to identify the necessary improvements and to compare them against the results obtained nowadays by other methods. This feedback allowed fitting / calibrating the performance of the multi-agent platform.

In this task four types of applications of the platform were defined and realized:

- Wind Turbines,
- Multiple Wind Turbines in diverse locations,
- WFs and

• Several WFs connected to a net of transport.

The work included study, design and development of the graphical user interface (GUI) that provides information of the state and the results of the system of detection of anomalies and diagnostics for equipment. The system Man Machine Interface (MMI) as well as the user graphical interfaces for the supervision, management and control of the multi-agent system were developed.

An important interface with a decisions making support system was established. This interface includes the following principal characteristics: graphical support to the different alternatives for decision making, simulator of results depending on every solution that a decision maker considers, comparator of results of the simulations, intelligent adviser in line, continuous scanner of the system data bases to show the previous situations most similar to the current one and the solutions that were adopted, and capacity of interaction with the Man Machine Interface of the system.

3.5 WP 5, Training Internal & External Partners

3.5.1 Aims

To train Internal and External Partners within the Consortium in the methods being developed by the Consortium.

3.5.2 Context

It has been clear in the work of this project of the importance of making design, manufacturing, operations and maintenance staff aware of the importance of raisning WT reliability and the methods by which it may be done. The Consortium developed a set of Training Materials which were aimed at these staff and deployed in the offices of Consortium Partners.

3.5.3 Results

Consortium has energetically trained its own Partners, including more than 240 engineers directly involved in WT design, but also business development managers and sales staff who see the commercial benefits of high reliability products.

The evaluation feedbacks collected have shown that the trainings were well received by the audiences, see Figure 6.

Partner	Date	No. of Participants	Location of Training	Feedback Poor/Satisfactory/Good
Durham	15 Oct 2008	4	Durham	Satisfactory/Good
GL Garrad Hassan	15~26 Nov 2008 **13~14 Jan 2011**	3 **8**	Durham **Bristol**	Good **Good**
HANSEN	11~12 March 2009 **18 January 2011**	10 **20**	Lommel **Lommel & Kontich**	Good **Good**
Alstom-Ecotecnia	30 Mar ~ 1 Apr 2009	8	Barcelona	Satisfactory/Good
ABB	2 June 2009	60 ~ 70	Helsinki	Good
SZTAKI	18 Sept 2009	2	Durham	Good
Gamesa	12~13 Jan 2010	28	Pamplona	Satisfactory/Good
Gamesa & Relex	13~14 Jan 2010	6	Madrid	Satisfactory/Good
SKF	10-11th Feb 2010 4-5 Oct 2010	21 15~20	Nieuwegein Hamburg	Good Good
LM	**24 January 2011**	**40+**	**Kolding**	**Good**

Figure 6. Summary of Training undertaken by ReliaWind

3.6 WP 6, Dissemination of New Knowledge

3.6.1 Aims

To disseminate the results of the Consortium as widely as possible.

3.6.2 Context

The issues developed in this Consortium are well-known in other industries, such as Aerospace and Automotive. Therefore a key outcome from the Consortium was to ensure that reliability and availability was as well-publicised in the wind Industry as those topics are in the Aerospace and Automotive industries.

3.6.3 Results

The Consortium disseminated its results to the European Wind Industry through:

- A website;
- Publication of 25 Conference Papers, particularly at EWEC2009, Marseille, EWEC2010, Warsaw and EWEA2011, Brussels;
- Publication of 12 Papers in international Journals
- Delivery of 17 presentations at International Conferences, Seminars or Workshops addressing more than 500 wind industry professionals;
- Preparation of a ReliaWind video available on the ReliaWind website.

The Consortium also interacted with the wider industry through its Users Group, who contributed operational results, and through a Reliability Panel, consisting of wind industry colleagues outside Europe, where the results of the work to date have been received with great interest and augur well for the development of international standardisation in the areas of WT availability, taxonomy and data standardisation.

Finally the Consortium developed the following documents which are available to the industry on the website:

- Literature Survey on Reliability of Wind Turbines;
- Monograph of all publications, see Section 6 below;
- Final publishable set of Training Materials;
- Standardisation recommendation to the industry for IEC 61400.

4 Dissemination Measures (Templates A1 and A2)

This section describes the dissemination measures, including scientific publications relating to foreground.

ReliaWind produced a Research Monograph, downloadable from its website, which lists all the research publications of the Consortium over the project period as follows:

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
1	*Wind power as a clean energy contributor*	*Tavner P J,*	*Journal Energy Policy, 2008,*	*2008*	*Elsevier*	*Amsterdam, Netherlands*	*2008*	*pp 1-4*	*Digital Object Identifier 10.1016/j.enpol.2008.09.033*	*Yes In The Journal*
2	*Condition monitoring and fault diagnosis of a wind turbine synchronous generator drive train*	*Yang, W, Tavner, P J, Wilkinson, M.R.*	*IET Renewable Power Generation Proceedings, Vol. 3, No. 1,*	*2008*	*Institution of Engineering Technology*	*London, UK*	*2008*	*pp. 1–11*	*Digital Object Identifier 10.1049/iet-rpg:20080006*	*Yes In The Journal*
3	*Reliability analysis for wind turbines with incomplete failure data collected from after the*	*H. Guo, S. J. Watson, P. J. Tavner,*	*Journal of Reliability Engineering*	*January 2009*	*Elsevier*	*Amsterdam, Netherlands*	*2009*	*pp 1057-1063*	*Digital Object Identifier 10.1016/jress.2008.12.004*	*Yes In The Journal*

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
	date of initial installation	*J. Xiang,*	*and System Safety, Vol 94*							
4	*Reliability of wind turbine subassemblies*	*F. Spinato, P.J. Tavner, G.J.W. van Bussel, E. Koutoulakos,*	*IET Renewable Power Generation Proceedings, Vol. 3, Iss. 4, pp. 1–15.*	*September 2009*	*Institution of Engineering Technology*	*London, UK*	*2009*	*pp 1-15*	*Digital Object Identifier 10.1049/iet-rpg:20080060*	*Yes In The Journal*
5	*Condition Monitoring Of The Power Output Of Wind Turbine Generators Using Wavelets*	*S.J. Watson, B.J. Xiang, W. Yang, P.J. Tavner, C.J. Crabtree,.*	*IEEE Transactions On Energy Conversion, Vol. 25, No. 3,*	*September 2010*	*Institution Of Electrical & Electronic Engineers*	*Piscataway, USA*	*2010*	*pp 715-721*	*Digital Object Identifier 10.1109/TEC.2010.2040083*	*Yes In The Journal*
6	*Condition Monitoring Of The Power Output Of Wind Turbine Generators Using Wavelets*	*Yang, P.J. Tavner, C.J. Crabtree,*	*IEEE Transactions On Industrial Electronics, Vol. 57, No. 1,*	*January 2010*	*Institution Of Electrical & Electronic Engineers*	*Piscataway, USA*	*2010*	*pp 263-271*	*Digital Object Identifier 10.1109/TIE.2009.2032202*	*Yes In The Journal*
7	*Early Experiences of UK Round 1 Offshore Wind Farms*	*Y. Feng, P.J. Tavner, H. Long,*	*Proceedings of the Institution of Civil Engineers – Energy, Energy 163,*	*Nov 2010*	*Institution of Civil Engineers*	*London, UK*	*2010*	*pp 167-181*	*Digital Object Identifier 10.1680/ener.2010.163.4.167*	*Yes in the Journal*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
			Issue EN4							
8	*Wind Turbine Gearbox Bearing Fatigue Life Prediction by using SCADA Data and Miner's Rule*	*H. Long, J. Wu, F. Matthew and P. J. Tavner,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*-*	*None*	*Yes on EWEA2011 website*
9	*Effects of Wind Speed on Wind Turbine Availability*	*S. Faulstich, P. Lyding, B. Hahn, P. J. Tavner,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*-*	*None*	*Yes on EWEA2011 website*
10	*A Parametric Investigation of Generator Misalignment upon Bearing Fatigue Life in Wind Turbines*	*M Whittle, Won Shin, Jon Trevelyan, Junjie Wu,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*-*	*None*	*Yes on EWEA2011 website*
11	*The Correlation Between Wind Turbine Turbulence And Pitch Failure,*	*P Tavner, Y Qiu, A Korogiannos, Y Feng,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*-*	*None*	*Yes on EWEA2011 website*
12	*SCADA Alarm Analysis For Improving Wind Turbine Reliability,*	*Y Qiu, P Richardson, Y Feng, P Tavner, G Erdos*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*-*	*None*	*Yes on EWEA2011 website*
13	*Use Of SCADA And CMS*	*Y Feng, Y*	*EWEA 2011*	*Mar 2011*	*European*	*Brussels,*	*2011*	*-*	*None*	*Yes on*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
	Signals For Failure Detection & Diagnosis Of A Wind Turbine Gearbox,	*Qiu, C Crabtree, H Long, P Tavner,*			*Wind Energy Association*	*Belgium*				*EWEA2011 website*
14	*Influence of DFIG rotor fault severity on stator current and power spectral content,*	*C Crabtree, S. Djurovic,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	-	*None*	*Yes on EWEA2011 website*
15	*Wind Turbine Blade Reliability,*	*M Philipsen,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
16	*Fatigue Analysis of Wind Turbine Gearbox Bearings using SCADA Data and Miner's Rule,*	*H Long,etc.*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
17	*Condition Based Maintenance Tools for Wind Turbines,*	*E Gomez,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
18	*Design for Reliability – A Reliability Assessment Model for a Wind Turbine,*	*S Barbati, L Barbati,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
19	*Identifying Downtime Events in Operational Wind Farm Data,*	*M Wilkinson, T Delft,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
20	*Control Actions for Failure Mitigation in Wind Turbines,*	*E Echavarria,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*

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21	*A Parametric Investigation of Generator Misalignment upon Bearing Fatigue Life in Wind Turbines,*	*M Whittle, Won Shin, Jon Trevelyan, Junjie Wu,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
22	*Use Of SCADA And CMS Signals For Failure Detection & Diagnosis Of A Wind Turbine Gearbox,*	*Y Feng, Y Qiu, C Crabtree, H Long, P Tavner,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
23	*Logical Architecture of an Advanced WTG Health Monitoring System,*	*Z Viharos, etc.,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
24	*Evaluation of Dual Axis Resonant Testing of Wind Turbine Blades,*	*P Greaves, etc.,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
25	*A System for the Detailed Scheduling of Wind Farm Maintenance,*	*A Kovacs, etc.,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
26	*SCADA Alarm Analysis For Improving Wind Turbine Reliability,*	*Y Qiu, P Richardson, Y Feng, P Tavner, G Erdos,*	*EWEA 2011*	*Mar 2011*	*European Wind Energy Association*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011 website*
27	*Wind Turbine Gearbox Bearing Fatigue Life Prediction by using*	*H. Long, J. Wu, F.*	*EWEA 2011*	*Mar 2011*	*European Wind Energy*	*Brussels, Belgium*	*2011*	*1 page poster*	*None*	*Yes on EWEA2011*

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	SCADA Data and Miner's Rule,	*Matthew and P. J. Tavner,*			*Association*					*website*
28	*Scheduling the Maintenance of Wind Farms for Minimizing Production Loss,*	*A Kovacs, G Erdos, L Monostori, Z Viharos,*	*IFAC 2011*	*Sep 2011*	*IFAC*	*Milano, Italy*	*2011*	*6 page*	*None*	*Yes on IFAC WC 2011 website*
29	*Artificial intelligence applications for maintenance oriented health monitoring of wind turbines,*	*Viharos, Zs. J.; Erdos, G; Kovács, A.; Monostori, L.:*	*7th International conference on mechanical engineering, Special scope of Advanced Technologies,*	*May 2010*	*7th International conference on mechanical engineering*	*Budapest, Hungary*	*2010*	*pp. 403-413*	*None*	*Yes*
30	*Methodology and Results of the ReliaWind Reliability Field Study*	*Wilkinson, M.R.et al*	*Scientific Track, European Wind Energy Conference, Warsaw, 2010.*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*6 page paper*	*None*	*Yes on EWEC2010 website*
31	*Reliability Analysis and Prediction for Wind Turbine Gearboxes*	*K Smolders, H Long, Y Feng, P J Tavner,*	*Scientific Track, European Wind Energy Conference,*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*6 page paper*	*None*	*Yes on EWEC2010 website*

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			Warsaw, 2010							
32	*Study of Effects of Weather & Location on Wind Turbine Failure Rates*	*P J Tavner, R Gindele, S Faulstich, B Hahn, M W G Whittle Energy Conference, Warsaw, 2010.*	*Scientific Track, European Wind Energy Conference, Warsaw, 2010*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*6 page paper*	*None*	*Yes on EWEC2010 website*
33	*Detecting Incipient Gearbox Failure in Wind Turbines: A New Signal Analysis Method for On-line Condition Monitoring*	*C Crabtree, Y Feng, P J Tavner*	*Scientific Track, European Wind Energy Conference, Warsaw, 2010*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*6 page paper*	*None*	*Yes on EWEC2010 website*
34	*AI Supported Maintenance and Reliability System in Wind Energy Production*	*Zs. J. Viharos, L. Monostori, G. Erdős, A. Kovács,*	*European Wind Energy Conference, Warsaw, 2010.*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*1 page poster*	*None*	*Yes on ReliaWind website*
35	*Use of the FMEA to Wind Turbine Availabilities*	*P J Tavner, A Higgins, H Arabian, H Long, Y Feng*	*European Wind Energy Conference, Warsaw, 2010*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*1 page poster*	*None*	*Yes on ReliaWind website*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
36	*A Design Software Tool for Conceptual Design of Wind Turbine Gearboxes*	*A Firth, H Long,*	*European Wind Energy Conference, Warsaw, 2010*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*1 page poster*	*None*	*Yes on ReliaWind website*
37	*Prognosis from SCADA data in Wind Turbines,*	*Luis Cárceles, Juan I. Lopez,*	*ReliaWind-SuperGen Side Event, European Wind Energy Conference, Warsaw, 2010.*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*1 page poster*	*None*	*Yes on ReliaWind website*
38	*Design for Reliability*	*Eugenio Gómez Santiago*	*ReliaWind-SuperGen Side Event, European Wind Energy Conference, Warsaw, 2010.*	*March 2010*	*ReliaWind*	*Warsaw*	*2010*	*1 page poster*	*None*	*Yes on ReliaWind website*
39	*Review of Early Operation of UK Round 1 Offshore Wind Farms*	*Y Feng, P J Tavner, H Long, J Bialek,*	*IEEE Power Engineering Society 2010 General*	*July 2010*	*Institution Of Electrical & Electronic Engineers*	*Piscataway, USA*	*2010*	*pp 1-8*	*Digital Object Identifier 10.1109/PES.2010.5590159*	*Yes on IEEEXplore*

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NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
			Meeting							
40	*Derivation of wind turbine reliability profiles from operational data,*	*M. R. Wilkinson, K. Harman, P. J. Tavner, B. Hendriks,*	*European Wind Energy Conference and Exhibition*	*Mar 2009*	*European Wind Energy Association*	*Marseille, France*	*2009*	*1 page poster*	*None*	*Yes on ReliaWind website*
41	*An intelligent approach to the condition monitoring of large scale wind turbines,*	*W Yang, P. J. Tavner C. J. Crabtree,*	*European Wind Energy Conference and Exhibition*	*Mar 2009*	*European Wind Energy Association*	*Marseille, France*	*2009*	*6 page*	*None*	*Yes on ReliaWind website*
42	*Condition monitoring artefacts for detecting winding faults in wind turbine DFIGs*	*S. Djurovic S. Williamson, P.J. Tavner, W. Yang,*	*European Wind Energy Conference and Exhibition*	*Mar 2009*	*European Wind Energy Association*	*Marseille, France*	*2009*	*pp 1-6*	*None*	*Yes on ReliaWind website*
43	*Condition Monitoring of a Wind Turbine Doubly-fed Induction Generator,*	*S. Watson, B. Xiang, W. Yang, P. Tavner, C. Crabtree,*	*European Wind Energy Conference and Exhibition*	*Mar 2009*	*European Wind Energy Association*	*Marseille, France*	*2009*	*-*	*None*	*Yes on ReliaWind website*
44	*Derivation Of Wind Turbine Reliability Profiles From Operational Data*	*Chris Elkinton, Michael Wilkinson, Keir Harman,*	*Windpower 2009 Conference organised by American Wind Energy Association*	*May 2009*	*American Wind Energy Association*	*Chicago, USA*	*2009*	*1 page poster*	*None*	*Yes on ReliaWind website*

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			(AWEA)							
45	*AI supported maintenance and reliability system in wind energy production,*	*Monostori L, Viharos ZJ, Erdős G, and Kovács A,*	*International Symposium on Methods of Artificial Intelligence, AI-METH*	*Nov 2009*	*International Symposium on Methods of Artificial Intelligence*	*Gliwice, Poland*	*2009*	*11 page*	*None*	*Yes on ReliaWind website*
46	*Reliability of different wind turbine concepts with relevance to offshore application,*	*Tavner, P J, Spinato, F, van Bussel, G J W, Koutoulakos, E,*	*European Wind Energy Conference*	*Apr 2009*	*European Wind Energy Conference*	*Brussels, Belgium*	*2009*	*9 page*	*None*	*Yes on ReliaWind website*
47	*Condition monitoring and fault diagnosis of a wind turbine with a synchronous generator using wavelet transforms*	*W Yang, P. J. Tavner and M. R. Wilkinson,*	*IET Power Electronics, Machines and Drives (PEMD2008)*	*Apr 2009*	*Institution of Engineering Technology*	*York, UK*	*2009*	*pp 1-11*	*None*	*Yes on ReliaWind website*
48	*Wind turbine condition monitoring and fault diagnosis using both mechanical and electrical signatures*	*W Yang, P. J. Tavner and M. R. Wilkinson*	*IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM2008)*	*Jul 2009*	*Institution Of Electrical & Electronic Engineers*	*Xi'an, China*	*2009*	*6 page*	*None*	*Yes on IEEE website*
49	*Research on a simple, cheap*	*W Yang, P. J.*	*XVIII*	*Sep 2008*	*International*	*Vilamoura,*	*2008*	*5 page*	*None*	*Yes on*

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	but globally effective condition monitoring technique for wind turbines,	*Tavner, C. J. Crabtree,*	*International Conference on Electrical Machines (ICEM'08)*		*Conference on Electrical Machines*	*Portugal*				*ReliaWind website and IEEE website*
50	*Monitoring wind turbine condition by the approach of empirical mode decomposition*	*W Yang, J Jiang, P. J. Tavner, C. J. Crabtree,*	*The 11th International Conference on Electrical machines and Systems (ICEMS 2008)*	*Oct 2008*	*International Conference on Electrical machines and Systems*	*Wuhan, China*	*2008*	*5 page*	*None*	*Yes on ReliaWind website*

Below the list of all ReliaWind dissemination activities:

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[4]	Main leader	Title	Date	Place	Type of audience[5]	Size of audience	Countries addressed
1	*Conference*	*UDUR & SKF*	*SKF Wind O&M Conference*	*March 2009*	*Hamburg, Germany*	*Industry*	*200*	*Germany, EU*
2	*Conference*	*UDUR & Gamesa*	*Sandia Reliability Conference*	*May 2009*	*Albuquerque, USA*	*Industry*	*500*	*US, Canada, EU*
3	*Conference*	*UDUR*	*Wind Farm O&M*	*May 2010*	*Glasgow, UK*	*Industry*	*60*	*UK, Ireland, EU*
4	*Conference*	*UDUR*	*Operation & Maintenance Forum*	*May 2010*	*London, UK*	*Industry*	*60*	*UK, Ireland, EU*
5	*Conference*	*UDUR*	*Offshore Wind Conference of Renewables*	*June 2010*	*Liverpool, UK*	*Industry*	*200*	*UK, Ireland, EU, World*
6	*Conference*	*UDUR*	*International Conference of Electrical Machines*	*Sep 2010*	*Rome, Italy*	*Industry*	*500*	*EU, World*
7	*Conference*	*UDUR*	*European Academy of Wind Energy Seminar*	*Sep 2010*	*Trondheim, Norway*	*Industry*	*100*	*EU*
8	*Conference*	*UDUR*	*IMechE Ocean Power Fluid Machinery Seminar*	*Oct 2010*	*London, UK*	*Industry*	*50*	*UK*
9	*Conference*	*UDUR*	*Narec Offshore Wind Conference*	*Oct 2010*	*Sedgefield, UK*	*Industry*	*200*	*UK*

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date	Place	Type of audience[5]	Size of audience	Countries addressed
10	*Conference*	*UDUR*	*IQPC Drive Train Innovation for Wind Turbines Seminar*	*Oct 2010*	*Hamburg, Germany*	*Industry*	*100*	*EU*
11	*Standards Meeting*	*Gamesa, GH*	*10th IEC 61400-26 Meeting Availability of wind turbines and wind turbine plants*	*Oct 2010*	*Feldkirch, Austria*	*Standardisation*	*40*	*EU*
12	*Conference*	*UDUR*	*Renewables – UK Conference*	*Nov 2010*	*Glasgow, UK*	*Industry*	*150*	*UK, EU*
13	*Seminar*	*UDUR*	*Renewables Seminar*	*Jan 2011*	*Lloyds of London, UK.*	*Insurance*	*200*	*EU*
14	*Standards Meeting*	*Gamesa, GH*	*11th IEC 61400-26 Meeting on Availability of wind turbines and wind turbine plants*	*Feb 2011*	*Oslo, Norway*	*Standardisation*	*40*	*EU*
15	*Conference*	*UDUR*	*Wind Farm O&M*	*May 2011*	*Glasgow, UK*	*Industry*	*150*	*UK, EU*
16	*Conference*	*UDUR, ECOT*	*Operation & Maintenance Forum*	*May 2011*	*Barcelona, Spain*	*Industry*	*30*	*UK, EU*
17	*Conference*	*UDUR*	*WT Condition Monitoring Workshop*	*Sept 2011*	*NREL Labs, Golden Colorado, USA*	*Industry*	*100*	*US*
18	*Conference/workshop*	*UDUR*	*Reliawind-Supergen Wind Side Event*	*Mar 2010*	*Warsaw, Poland*	*Industry*	*15-25*	*EU*
19	*Conference/*	*UDUR*	*Reliawind Side Event*	*Mar 2011*	*Brussels, Belgium*	*Industry/Policy*	*75*	*EU*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date	Place	Type of audience[5]	Size of audience	Countries addressed
	presentations/ exhibitions					*Makers/Media/ Scientific Community*		
20	*Video*	*UDUR*	*Reliawind Project*	*Mar 2011*	*Brussels Side Event, Reliawind Website, Youtube*	*Industry/Policy Makers/Media/ Scientific Community/Civil Society*	*-*	*World wide*
21	*Sandia Reliability Expert Meeting*	*UDUR, GH*	*The current issue of Reliability Data Collection and Analysis*	*Jun 2009*	*Sheraton Uptown, Albuquerque USA*	*Industry*	*40*	*US, EU*
22	*Recommendation*	*UDUR*	*D 6.7 Recommendations from the ReliaWind Consortium for the Standardisation for the Wind Industry of Wind Turbine Reliability Taxonomy, Terminology and Data Collection*	*Mar 2011*	*Reliawind partners circulated, Reliawind Website*	*Industry/Policy Makers/ Scientific Community*	*-*	*EU*
23	*Web*	*UDUR*	*Reliawind Reports, Monograph, Presentations, Publications*	*2011*	*Reliawind Website-Dissemination*	*Industry/Policy Makers/Media/ Scientific Community/Civil Society*	*-*	*World wide*

5 Potential Impact and Results Exploitation

5.1 Expected Project Impact as stated in the Description of Work

- Reduction of manufacturing, logistics and maintenance costs combined with increased power-to-weight ratio, reliability and robustness should lead to lower production costs for wind generated electricity.
- Cost reductions through improvements in technology, up-scaling of turbines, large-scale deployment (including offshore) and grid connection should lead to a cost below 0.04 €/kWh in 2020.
- Develop robust, reliable, cost effective and low maintenance onshore and offshore wind energy systems which are easy to transport and to install.
- Development of individual components and aggregate sub-systems (e.g. rotors, drive trains, controls) using advanced materials, design tools and validation models, and the development of innovative manufacturing procedures.
- Innovative large scale on and off-shore wind power plants based on improved technologies, more robust, reliable and low-maintenance multi-MW turbines, combined with dependable output forecasting tools as well as with standards and certification schemes should bring wind power to higher levels of market penetration.

5.2 Potential Users of Results

The main beneficiaries of the ReliaWind project outcomes will be WF operators, WT producers, WT designers and other supply chain members of WT production. The results enable the industry to focus on significant aspects of reliability. The outcomes have also pronounced somewhat different view as compared to previous studies, showing that the gearbox problems are not dominating faults at least for relatively young installations.

Results of ReliaWind project **may encourage other manufacturers to share fault statistic information**. Results may have impact on how different events are recorded, e.g. not all events leading to downtime are perceived as faults (to be reported further to component supplier for instance). It can give an objective view on the actual reliability and associated downtime of different components. Today, reliability related discussions are dominated by some issues, such as the gearbox, while the actual reliability of some components is overseen. Using these data, a more accurate return on investment calculation can be made for new projects, and O&M can be optimised to further reduce the cost of energy produced by WTs.

Other potential beneficiaries and stakeholders include standardisation organisations, engineers, researchers, designers of asset management tools and systems, IT industry; more generally also environmental organisations and NGOs who have interest in more reliable renewable energies and energy control experts to achieve more balanced wind energy production.

The project considered fully the requirements of users. However, as in the case of most innovative projects, the results drove to technical or behaviour breakthrough that in some cases indicated significant changes in the users norms and values.

5.3 Exploitation of Results

5.3.1 Exploitable Results

There are a number of outcomes that are relevant for exploitation and the following list is not exhaustive:

WP1 Field survey

- Literature Review on the reliability and availability of WTs;
- Identification of public domain data on failure and downtime rates for WT sub-systems;
- Standardized WT taxonomy;
- Standardized reliability data collection templates;
- Identification of the most critical sub-systems of WTs;
- Establish risks levels for the principal components and identify the critical system
- Comparable failure and downtime rates for WT sub-systems, assemblies and sub-assemblies.

WP2 Reliability analysis

- A reliability model that was built for the R80 and R100 WTs;
- Understanding the usage of reliability calculations for WTs;
- Use of the FMECA analysis to identify the key risks in current and future technology WTs;
- Identification of the most important Failure Modes in the most critical sub-systems of WTs;
- The possibility to simulate the reliability related results of the design changes in the WT structure;
- Work done to identify the importance of systematic reliability design methods in WT development, including the use of the FMECA and reliability testing like HALT.

WP3 Algorithm development

- Understanding the structure of SCADA data in WTs and the related technical-IT issues;
- Understanding the influence of control on the WT reliability and its potential for providing solutions to mitigate faults;
- Analysis and validation of possible advanced WT control methods;
- Developments of new algorithms for failure detection, location and prognosis for the critical failure modes of the 6 most critical sub-systems, including:
    - Engineering knowledge based solutions
    - Alarm sequence analysis
    - Data-cleaning
    - Probabilistic methods for the alarm sequences
    - Detection of non-conform situations
    - SCADA data based failure detection

        - Close to real-time component residual life cycle estimation
- Harmonized and integrated handling of different maintenance activities, e.g. retrofit, failure prognosis;
- Structured specification of WF maintenance constraints and expected key performance indicator calculations;
- Algorithm development for finding the optimal short term scheduling of WFs and zones;
- Definition of SCADA database reports to support maintenance related decision making at operator and at WF owner level;
- Establishment and direct ordering SCADA reports to different WT working situations, e.g. failure cases;
- A concept for integrating all the above results in one framework system.

WP4 Demonstration

- Specification of a comprehensive software system realizing the results of WP3 in an integrated manner
- Definition of interfaces between WF operator's software systems and the newly established software solution
- Development of user surfaces of the system, like web based usage and mobile equipment based access
- Implementation of failure lifecycle handling and maintenance scheduling related business processes and the database structure of the system
- Set up of a demo application to represent all the steps of an integrated failure lifecycle handling solution
- Verification of the solution based on data from the field

WP5 Training

- General introduction to WTs and their reliability issues;
- Reliability calculation and modelling;
- Demonstration of the power of the FMECA to reveal reliability issues in a WT;
- Demonstration of the effectiveness of various algorithms to detect WT faults in advance from SCADA signal data;
- Demonstration of the importance of SCADA alarm data in terms of the very high alarm rates being experienced by WTs and the potential for using these alarms to warn of incipient faults;
- Demonstration of the impact on WT reliability and availability of systematic reliability design during development using the FMECA and reliability testing like HALT.

WP6 Dissemination

- Scientific papers;
- Establishment of recommendation of a standard;
- Participation and presentation at various EWEC & EWEA events;
- Project website;

- Project video;
- Dissemination of training materials.

5.3.2 Exploitation Strategy

The ReliaWind Partners' exploitation plans are as follows.

Some of the know-how and methodology developed can be directly distributed to the users, such as normalized fault rates, fault distribution, downtime distribution, training materials and courses, software model for reliability and reliability calculations. , software prototype for failure lifecycle handling and maintenance scheduling. The software developed to demonstrate the principles of the project findings or algorithms could be distributed as software or could be a basis to develop a customized programme. The results could be even more widely used providing specific implementation support to users.

The recommendations from the Reliability Debate at the ReliaWind Side Event at EWEA2011 were:

- That the he ReliaWind reliability database should be expanded;
- Data sharing about WT reliability and availability is to be encouraged in the Wind Industry but involves major issues of confidentiality;
- In order to aid the development of more reliable WTs pre-normative research is needed into:
    - Definitions of wind turbine sub-assembly loadings taking account of the wind's stochastic nature;
    - The influence of wind resource and weather on reliability results;
    - Development of knowledge management systems for large wind farms, particularly those offshore.

In order to build user capacity to make continued use of the ReliaWind results, some of the next steps could be:

- More training of Wind Industry users in reliability techniques;
- Realization of the changes in WT and WF company software environments to permit greater data exchange;
- Continuous improvement of the currently available results;
- Continue to gather and record fault information on the original group of turbines to see if the reliability of components will change over time e.g. gearbox faults;
- Setting up a uniform and anonymous field intervention database;
- Implementation of the methodologies developed in ReliaWind;
- Assessment of the improvements made by the use of ReliaWind outcomes in availability and in cost of energy;
- Standardisation of reliability and downtime related definitions;

- Standardisation of the WT taxonomy for the purposes of more accurate data collection;
- Standardisation of the reliability data collection methods;
- Standardisation of service intervention reporting;
- Standardisation of reliability analysis tools.

5.4 Exploitation Plans

This section specifies the exploitable foreground and provides partners' plans for exploitation.

5.4.1 Applications for patents, trademarks, registered designs (Template B.1)

The partners of Reliawind project have not submitted any applications for patents, trademarks or registered designs (template B1). However, Garrad Hassan and Durham University developed a recommendation for Wind Turbine Taxonomy.

Durham University sent a questionnaire to the standards committee representations of the Consortium Partners. In their replies the standardisation of Structure, Taxonomy and Terminology were ranked highest. Consequently Garrad Hassan and Durham University devised a **Recommendation on an updated WT Taxonomy**. The recommendation drew on the taxonomy 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, failure rate Pareto analysis, reliability growth analysis and Weibull analysis.

The intention of adopting such 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 recommendation was sent to all the Consortium members who are members of Standardisation Committees of International Electrotechnical Commission (IEC). It is also available on the ReliaWind website and was advertised at the Side Event of EWEA2011 in Brussels.

5.4.2 Partners Exploitation Plans (Template B.2)

The following partners have prepared exploitation plans: Alstom Wind, LM Windpower, SKF, Garrad Hassan and UDUR. For the question of confidentiality LM is sending its exploitation plan directly to the EC Project Officer. The other mentioned partners' plans are included below.

Partner Nr 2 Alstom Exploitation Plan

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Develop a new offshore platform	YES	Prototype in November 2011	Offshore WTG	C27. Manufacture of Wind Turbine Generators	- Prototype 2011 - Commercial 2012	Several patents are being under study	Alstom Wind
Exploitation of R&D results via internal standards	Implement a new interactive software to adquire information and optimize the O&M resources	YES	First two Wind Farms in the US at the end of 2011	Current Eco74/80 platform	C33. Repair and installation of Wind Turbine Generators	- Test during first 6 months - Extend to others Wind Farm during 2012	No	Alstom Wind

<u>Offshore project</u>

The purpose is to develop a new platform of Wind turbine generator to gain access to the offshore market.

The Reliawind foreground is currently being exploited by the Design Department of Alstom Wind introducing RAMS in the design of the new platform.

IPR exploitable measures: Several patents are being under study.

[1] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[7] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Further research: future new platforms

Potential/expected impact: Gain access to the offshore market where in the next 3 years several Wind Farms will be located.

Optimize resources of O&M

The purpose is to implement new software. This software will be interactive help to the Manpower to identify the best action when a fault in the wind turbine generator (WTG) appears. Also the software will be fed with the actions taken in the WTG by the Manpower and will help for further actuations.

The foreground is currently being exploited by the O&M department of Alstom.

IPR exploitable measures: No measures are so far taken.

Further research: Make prognosis to anticipate the failure of the WTG and implement a predictive maintenance.

Potential/expected impact: Optimize the O&M resources reducing the CoE.

SKF Exploitation Plan

Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
1. General advancement of knowledge	wind turbine reliability	no	n.a.	knowledge and appreciation of end-user requirements.	NACE codes C28.1.5 C33	2011 onward	n.a.	Sales and account managers needing to interface with business relations on basis of common terminology & understanding.
2. Commercial exploitation of R&D results	Reliability analysis method	no	n.a.	capability to perform reliability analysis	NACE codes C28.1.5 C33	2011 onward	n.a.	Engineers involved with technical assessment and system selection. Designers of asset management tools and systems.

[1] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[9] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Partner Nr 7 Garrad Hassan Exploitation Plan

Type of Exploitable Foreground[10]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date	Exploitable product(s) or measure(s)	Sector(s) of application[11]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge, AND Commercial exploitation of R&D results	Appointment of the most critical components of wind turbines; Establish risks levels for the principal components and identify the critical system; Comparable failure and downtime rates of the wind turbine components	No	N.A.	Consultancy services for operators, developers and manufacturers	M71.1.2 - Engineering activities and related technical consultancy	2011 and forward	No	-
General advancement of knowledge, AND Commercial exploitation of R&D results	systematic reliability design method, including FMEA	No	N.A.	Consultancy services for operators, developers and manufacturers	M71.1.2 - Engineering activities and related technical consultancy	2011 and forward	No	-
General advancement of knowledge, AND Commercial exploitation of R&D results	Options for reconfiguration and fault tolerant control	No	N.A.	Consultancy services for operators, developers and manufacturers	M71.1.2 - Engineering activities and related technical consultancy	2011 and forward	No	-

[1] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[11] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Partner Nr 9 University of Durham Exploitation Plan

Type of Exploitable Foreground[12]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[13]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Going to collaborate with SZTAKI in further research on WTG failures	Yes	31/12/2011	Developments of new algorithms for failure detection, location and prognosis: - Engineering knowledge based solutions - Probabilistic methods for the alarm sequences	Wind Farm Management	2011, 2012, 2013	Patents are possible	SZTAKI
Commercial exploitation of R&D results	Going to collaborate with Garrad Hassan in further research on WTG failures	Yes	31/12/2011	A knowledge management system for offshore WTG to handle scada and cms and present to operation and maintenance manager	Wind Farm Management	2012, 2013	Patents are possible	GL Garrad Hassan
Commercial exploitation of R&D results	Going to collaborate with SKF in further research on WTG failures	Yes	31/12/2011	Insert new algorithms into existing commercial CMS system	Wind Farm Management	2012,2013, 2014	Patents are possible	SKF

[8] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[13] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Partner Nr 10 Sztaki Exploitation Plan

Type of Exploitable Foreground[14]	Description of exploitable foreground	Confidential YES /NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [15]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	Strive to Introduce a benchmark project for Hungarian WTG operators	Y		- Standardized WTG structure - Standardized data collection templates - Comparable failure and downtime rates of the wind turbine components	Wind industry, Hungary	2011, 2012		
General advancement of knowledge	Strive to Explore the Hungarian WTG supply chain and support them to improve their efficiency	Y		- Exploration of the Hungarian wind business suppliers	Wind industry, Hungary	2011, 2012		
General advancement of knowledge	Strive to Introduce trainings on wind turbines in Hungary	N		- General introduction training on wind turbines - Reliability calculation and modelling training - University training materials	Wind industry, Hungary	2011		
General advancement of knowledge	Going to collaborate with wind turbine control solution producers, especially Gamesa	Y		- Appointment, analysis and validations of possible, advanced wind turbine control methods - Under-standing of the wind turbine control methods and solutions	Wind industry	2011, 2012	Patents are possible	
Commercial exploitation of R&D results	Strive to Improveme the IT infrastructure of WTGs	Y		- Under-standing the structure of SCADA data in wind turbines and the related technical-IT issues	Wind industry	2011, 2012, 2013	Patents are possible	
General	Going to	Y		Developments of new algorithms for failure	Academic	2011,	Patents	University of

[1] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[15] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[14]	Description of exploitable foreground	Confidential YES /NO	Foreseen embargo date dd/mm/ yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [15]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
advancement of knowledge	collaborate with University of Durham in further research on WTG failures			detection, location and prognosis: - Engineering knowledge based solutions - Probabilistic methods for the alarm sequences		2012, 2013	are possible	Durham
General advancement of knowledge Commercial exploitation of R&D results	Going to collaborate with WTG producers and operators, especially with Gamesa	Y		Developments of new algorithms for failure detection, location and prognosis: - Engineering knowledge based solutions - Alarm sequence analysis - Data cleaning - Detection of non-conform situations - SCADA data based failure detection	Wind industry	2011, 2012	Patents are possible	
General advancement of knowledge Commercial exploitation of R&D results	Collaboration Strive to collaborate with companies from other businesses, especially in manufacturing	Y		Developments of new algorithms for failure detection, location and prognosis: - Engineering knowledge based solutions - Alarm sequence analysis - Data cleaning - Detection of non-conform situations - SCADA data based failure detection - Close to real-time component residual life cycle estimation	Manufacturing	2011, 2012, 2013	Patents are possible	
Commercial exploitation of R&D results	Going to Introduce the developed solution in wind business, especially at Gamesa	Y		- Template and algorithm development for describing a general case for a maintenance request for wind turbines - Harmonized and integrated handling of different maintenance activities (e.g. retrofit, failure prognosis) - Structured specification of wind farm's maintenance constraints and expected key performance indicator calculations - Algorithm development for finding the optimal short term scheduling of wind farms and zones	Wind industry	2011, 2012, 2013	Patents are possible	Gamesa

Type of Exploitable Foreground[14]	Description of exploitable foreground	Confidential YES /NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[15]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
				- Definition of SCADA data based reports to support maintenance related decision making at operator and at wind farm owner level - Establishment and direct ordering SCADA reports to different wind turbine working situations, e.g. failure cases - A concept for integrating all the above results in one framework system - Specification of a comprehensive software system realizing the results of WP3 in an integrated manner - Definition of interfaces between wind farm operator's software systems and the newly established software solution - Development of user surfaces of the system, like web based usage and mobile equipment based access - Implementation of failure lifecycle handling and maintenance scheduling related business processes and the database structure of the system				
General advancement of knowledge Commercial exploitation of R&D results	Strive to Introduce maintenance scheduling solutions for other industries, especially for manufacturing	Y		- Set up of a demo application to represent all the steps of an integrated failure lifecycle handling solution	Manufacturing	2011, 2012	Patents are possible	
exploitation of results through (social)	Strive to Disseminate the results in the "green field"	Y		- Set up of a demo application to represent all the steps of an integrated failure lifecycle handling solution - Project website	Manufacturing	2011, 2012, 2013		

Type of Exploitable Foreground[14]	Description of exploitable foreground	Confidential YES /NO	Foreseen embargo date dd/mm/ yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [15]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
innovation exploitation of results through EU policies				- Project video				
General advancement of knowledge	Going to publish further scientific papers	N		- Scientific papers - Participation and presentation at various events, like fairs and EWEC	Many industries	2011, 2012, 2013		
General advancement of knowledge	Strive to start new EU FP7 R&D project in the field of flexible SCADA solution introduction (e.g. for offshore turbines, e.g. FlexSeeWind proposal), especially with Gamesa	Y		- All the reliawind results are applied	Wind inductry	2011, 2012, 2013, 2014	Patents are possible	

5.5 Impact at European Policy Level

A wider impact at the European level lies in promoting renewable energy and in the proof that efficient green energy solutions are available. It equally encourages further investment in related R&D. There is better return on investment calculations for new wind projects, representing the improved efficiency of WFs operations. It can open up new opportunities for creating new expertise and jobs in the wind energy sector, favouring also rural areas. In addition ReliaWind contributed a lot of material for possible standardisation of WTs. ReliaWind consortium members participating IEC standardization will strive for common turbine taxonomy and fault event classification.

5.6 Report on Societal Impacts

A **General Information** *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	212966
Title of Project:	RELIAWIND
Name and Title of Coordinator:	
B **Ethics**	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	No
• Did the project involve patients?	No
• Did the project involve persons not able to give consent?	No
• Did the project involve adult healthy volunteers?	No
• Did the project involve Human genetic material?	No
• Did the project involve Human biological samples?	No
• Did the project involve Human data collection?	No
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	No
• Did the project involve Human Foetal Tissue / Cells?	No
• Did the project involve Human Embryonic Stem Cells (hESCs)?	No
• Did the project on human Embryonic Stem Cells involve cells in culture?	No
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	

DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator		1
Work package leaders		5
Experienced researchers (i.e. PhD holders)	2	17
PhD Students	1	3
Other		

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**0**
Of which, indicate the number of men:	0

D Gender Aspects		
5. Did you carry out specific Gender Equality Actions under the project?	○ ⦿	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective … Very effective
❑	Design and implement an equal opportunity policy	○○○○○
❑	Set targets to achieve a gender balance in the workforce	○○○○○
❑	Organise conferences and workshops on gender	○○○○○
❑	Actions to improve work-life balance	○○○○○
○	Other:	

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

- ○ Yes- please specify
- ⦿ No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- ⦿ Yes- please specify: Supergen-wind consortium, European Academy Wind Energy
- ○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ⦿ Yes- please specify: Website, Training Material in booklet and Powerpoint format & a Video,
- ○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- ⦿ Main discipline[16]: Engineering & Technology
- ⦿ Associated discipline[16]: Natural Sciences
- ○ Associated discipline[16]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ ⦿	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ⦿ No
- ○ Yes- in determining what research should be performed

[16] Insert number from list below (Frascati Manual).

○	Yes - in implementing the research
○	Yes, in communicating /disseminating / using the results of the project

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ⦿	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

○	No
⦿	Yes- in framing the research agenda
⦿	Yes - in implementing the research agenda
⦿○	Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

○	Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
⦿	Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
○	No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs	Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid	Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport

13c If Yes, at which level?

- ○ Local / regional levels
- ⦿ National level
- ⦿○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**50**
To how many of these is open access[17] provided?	**43**
How many of these are published in open access journals?	**0**
How many of these are published in open repositories?	**43**
To how many of these is open access not provided?	**7**
Please check all applicable reasons for not providing open access:	
☒ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[18]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		Not known
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	Not known
	Registered design	Not known
	Other	Not known
17. How many spin-off companies were created / are planned as a direct result of the project?		None
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

☒ Increase in employment, or	☒ In small & medium-sized enterprises
❑ Safeguard employment, or	☒ In large companies
❑ Decrease in employment,	❑ None of the above / not relevant to the project
❑ Difficult to estimate / not possible to quantify	

[17] Open Access is defined as free of charge access for anyone via Internet.
[18] For instance: classification for security project.

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* *6FTEs*
Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ⊙ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ⊙ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☒	Press Release	☒	Coverage in specialist press
☒	Media briefing	☒	Coverage in general (non-specialist) press
❑	TV coverage / report	☒	Coverage in national press
❑	Radio coverage / report	☒	Coverage in international press
☒	Brochures /posters / flyers	☒	Website for the general public / internet
☒	DVD /Film /Multimedia	☒	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

☒	Language of the coordinator	☒	English
☒	Other language(s)		

6 Contact Information

Address of the project public web site: www.ReliaWind.eu

Contact details:

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Annex 1. Table comparing the contribution of failure rate and downtime calculated from the R80 FMECA.

Sub-System	Assembly	Contribution to Total Failure Rate % [failures/ turbine/ year]	Contribution to Average Time lost % [hours/year]
POWER MODULE	FREQUENCY CONVERTER	12.96%	18.39%
POWER MODULE	GENERATOR ASSEMBLY	7.16%	10.47%
POWER MODULE	LV SWITCHGEAR	5.88%	3.03%
POWER MODULE	MV SWITCHGEAR	3.32%	3.27%
POWER MODULE	TRANSFORMER	1.71%	1.84%
POWER MODULE	POWER FEEDER CABLES	0.97%	0.67%
POWER MODULE	UNKNOWN	0.45%	0.30%
POWER MODULE	POWER CABINET	0.12%	0.03%
POWER MODULE	PROTECTION CABINET	0.09%	0.30%
ROTOR MODULE	PITCH SYSTEM	21.29%	23.32%
ROTOR MODULE	BLADES	1.45%	2.13%
ROTOR MODULE	HUB	1.40%	1.84%
ROTOR MODULE	SLIPRINGS	0.43%	0.67%
ROTOR MODULE	HUB COVER	0.05%	0.04%
ROTOR MODULE	UNKNOWN	0.01%	0.01%
ROTOR MODULE	BLADE BEARINGS	0.01%	0.05%
CONTROL & COMMUNICATION SYSTEM	SENSORS	4.06%	4.12%
CONTROL & COMMUNICATION SYSTEM	COMMUNICATION SYSTEM	3.83%	3.41%
CONTROL & COMMUNICATION SYSTEM	SAFETY CHAIN	3.34%	2.21%
CONTROL & COMMUNICATION SYSTEM	CONTROLLER H/W	2.43%	1.44%
CONTROL & COMMUNICATION SYSTEM	CONTROLLER S/W	1.42%	0.62%
CONTROL & COMMUNICATION SYSTEM	HUMAN & OPERATIONAL SAFETY DEVICES	0.23%	0.91%
CONTROL & COMMUNICATION SYSTEM	UNKNOWN	0.22%	0.07%
CONTROL & COMMUNICATION SYSTEM	ANCILLARY EQUIPMENT	0.02%	0.02%
NACELLE MODULE	YAW SYSTEM	11.28%	7.30%
NACELLE MODULE	NACELLE SENSORS	0.29%	0.18%
NACELLE MODULE	NACELLE COVER	0.06%	0.11%
NACELLE MODULE	NACELLE BEDPLATE	0.04%	0.06%
NACELLE MODULE	UNKNOWN	0.01%	0.00%
DRIVE TRAIN MODULE	GEARBOX ASSEMBLY	5.13%	4.66%
DRIVE TRAIN MODULE	MECHANICAL BRAKE	0.47%	0.33%
DRIVE TRAIN MODULE	HIGH SPEED SHAFT TRANSMISSION	0.41%	0.41%
DRIVE TRAIN MODULE	MAIN SHAFT	0.29%	1.09%
DRIVE TRAIN MODULE	UNKNOWN	0.10%	0.12%
DRIVE TRAIN MODULE	GENERATOR SILENT BLOCKS	0.02%	0.08%
AUXILIARY EQUIPMENT	ELECTRICAL PROTECTION & SAFETY DEVICES	1.32%	0.73%
AUXILIARY EQUIPMENT	HYDRAULIC SYSTEM	1.19%	1.42%
AUXILIARY EQUIPMENT	TOP	0.53%	0.44%
AUXILIARY EQUIPMENT	SERVICE CRANE	0.32%	0.15%

Sub-System	Assembly	Contribution to Total Failure Rate % [failures/ turbine/ year]	Contribution to Average Time lost % [hours/year]
AUXILIARY EQUIPMENT	COOLING SYSTEM	0.31%	0.12%
AUXILIARY EQUIPMENT	WT METEOROLOGICAL STATION	0.30%	0.22%
AUXILIARY EQUIPMENT	LIGHTING AND POWER POINTS	0.18%	0.10%
AUXILIARY EQUIPMENT	GROUND	0.15%	0.09%
AUXILIARY EQUIPMENT	LIGHTNING PROTECTION SYSTEM	0.15%	0.17%
AUXILIARY EQUIPMENT	LIFT	0.12%	0.09%
AUXILIARY EQUIPMENT	GROUNDING	0.11%	0.06%
AUXILIARY EQUIPMENT	ELECTRICAL CABINETS	0.09%	0.05%
AUXILIARY EQUIPMENT	UPS CABINET	0.03%	0.02%
AUXILIARY EQUIPMENT	BEACON	0.02%	0.01%
AUXILIARY EQUIPMENT	UNKNOWN	0.02%	0.03%
AUXILIARY EQUIPMENT	HUB CABINET	0.02%	0.00%
AUXILIARY EQUIPMENT	FIREFIGHTING SYSTEM	0.01%	0.03%
AUXILIARY EQUIPMENT	ELECTRICAL AUXILIARY CABLING	0.01%	0.02%
STRUCTURAL MODULE	TOWER	2.66%	1.75%
STRUCTURAL MODULE	FOUNDATIONS	0.70%	0.37%
WIND FARM	WIND FARM SYSTEM	0.71%	0.27%
WIND FARM	COMMON FACILITIES	0.01%	0.00%
WIND FARM	UNKNOWN	0.01%	0.01%
CONDITION MONITORING SYSTEM	DATA LOGGER	0.06%	0.27%
CONDITION MONITORING SYSTEM	CONDITION SENSORS & CABLES	0.03%	0.07%
CONDITION MONITORING SYSTEM	PROTOCOL ADAPTER CARD FOR DATA LOGGER	0.01%	0.00%
CONDITION MONITORING SYSTEM	SENSORS	0.01%	0.00%

References

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