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.1.3

Report on Wind Turbine Reliability Profiles

Work package WP1 – Field Data Reliability Analysis

Deliverable leader: GH

Decisional Workflow		
Author(s)	Michael Wilkinson, Ben Hendriks - GH	**Approved by:** ☐ WP leader ☐ Task leader ☒ Scientific Director ☐ Project Technical Assessor (European Commission) ☐ Project Officer (European Commission)
Reviewer (s)	Prof. Peter Tavner	
Scientific Director		

Description of work

Objective of the WP:

The overall objective of this work package is to identify the critical failure modes at the component, sub-system and system scale within wind turbines based on the analysis of available long term operational data and fault records logged by SCADA systems operating on wind farms around the world.

Task description:

Quantification of failure rates and repair times will be attempted at a component and a sub-system and level but will also consider the following four overall wind turbine system fault categories:

Category 1: Manual restart

This requires the physical presence of crew at the turbine, in order to reset the turbine controller after it has been tripped by an alarm. This can occur relatively frequently, even in modern wind turbines, although once access to the machine has been secured, the duration of the visit is short. No actual repair operations to components are implemented for this category although some level of investigation as to the cause of the alarm will often be required, causing some delay in restarting the machine.

Category 2: Minor repair

This category describes turbine failures caused by minor faults, typically involving sensor or instrumentation failure. Replacement of small parts may be necessary as may some level of trouble-shooting in order to isolate the problem. This category of failure occurs at a similar level of frequency as manual restarts, but requires more crew-time at the turbine before the repair is complete. Some minor replacement parts may also be required.

Category 3: Major repair

Here, more extensive work is required, usually to one of the major mechanical components of the turbine such as the gearbox, shaft bearings, blades, control systems or to electrical components such as the generator, converter, transformer or switchgear. Although such failures will occur much less frequently than the previous two categories, in general they are likely to be relatively time consuming, with the turbine in question out of commission for multiple days.

Category 4: Major replacement

In the early years of a wind farm, any major component failures typically occur as a result of early life failures including perhaps some serial defects. Later in the project life, such occurrences are likely to be much less frequent. Lifting constraints will prevent the regular service crews from carrying out such operations and auxiliary plant and crew will be mobilised for the job. Typical operations include the replacement of gearboxes, generators and transformers.

Based on the analysis of the data available, each partner will derive reliability profiles at component, sub-system and system levels. These reliability profiles may be defined in terms of failure rates and, where possible, “Direct Time to Repair” (DTTR) statistics. An important aim of the work will be to establish objective indices to characterise these reliability profiles. The extent to which the component and sub-system reliability profiles can be determined with accuracy depends on the extent, nature and quality of the data available from the SCADA systems operating at the various wind farms. This information will also be supplemented with relevant results from a literature survey of previous publications relating to wind turbine reliability. GH will be responsible for undertaking this literature survey.

Document identifier

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Dependency

Delay in delivering ☒

Contractual deliverable : Y ☒ N ☐

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Access rights: Y ☐ N ☐

Archive on platform: Work Packages\WP1 - Field Reliability Analysis\T.1.3 - Derivation of reliability profiles

Workflow

When	Who	Registration	To do
04/08/2009	GH	Y ☐ N ☐	Initial issue of the deliverable D1.3
04/04/2010	GH UDUR	Y ☐ N ☐	revised by Michael Wilkinson in light of comments from peer review conducted by Durham University
14/03/2011	GH	Y ☐ N ☐	revised by Michael Wilkinson with additional data

Dissemination level:

PU	Public	☒
PP	Restricted to other programme participants (including the Commission Services)	☐
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

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
Resources shown in person-months	☐ ☐ GAMESA	7 MM	6.47 MM
☐☐ Partner X 0.5	☐ ☐ Ecotecnia	7 MM	9.61 MM
Peer reviews	☐ ☐ LM	MM	MM
Contributions	☐ ☐ Hansen	MM	MM
	☐ ☐ Drives	MM	MM
	☐ ☐ SKF	MM	MM
	☐ ☐ GH	5 MM	2.36 MM
	☐ ☐ Relex	0.12 MM	0.12 MM
	☐ ☐ UDUR	7 MM	4.28 MM
	☐ ☐ SZTAKI	MM	MM
	☐ ☐ Relex IT	1.33 MM	0.58 MM

Results achieved

Processing wind turbine historical operational data, the deliverable D.1.3 interpreted the results on critical failure modes at the component, sub-system and system scale within wind turbines. This work has resulted in a significant database of reliability information. The current deliverable is a new version of D.1.3 previously submitted to the EC with updated results after processing additional data.

The earlier deliverables D1.1 and D1.2 established the state of art and methodology for the analysis.

Contents

1 Introduction

1.1 Aims

Work Package 1 (WP1) of the EU Reliawind project was concerned with a Field Study of the reliability of operational wind turbines. The overall objective of this work package was to identify the critical failure modes at the component, sub-system and system scale within wind turbines based on processing wind turbine historical operational data. WP1 deliverables D.1.1 [1] and D.1.2 [2] have previously described the background to this work and the methodology employed; this third deliverable D.1.3 therefore focused on the presentation and interpretation of the results.

1.2 Context

Readers are encouraged to consider this deliverable in combination with the previous two WP1 deliverables to enable an appreciation of the justification for the work and the methodology employed to determine the results.

1.2.1 Publicly Available Data

The WP1 Literature Review D.1.1 [1] made an assessment of the current state of the art in measuring in measuring operational wind farm reliability. A number of quantitative studies of wind turbine turbine reliability have been carried out in the last 10 years. The Dutch research programme programme DOWEC, which has been among the pioneers of the quantification of wind turbine turbine reliability figures, has presented some interesting studies [3]–[7]. Further reliability analyses reliability analyses have used data from existing commercial and public databases. Relevant results Relevant results have been achieved by research carried out by various authors [8]–[11]. As an As an example,

Figure 1 shows the failure rate and downtime from two large reliability surveys LWK [12], WMEP [13].

The objectives of these studies have been to extract information from the field to understand wind turbine 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. [11] . The objective of the Reliawind Field Study was to build an exhaustive database of downtime events from a number of onshore wind farms.

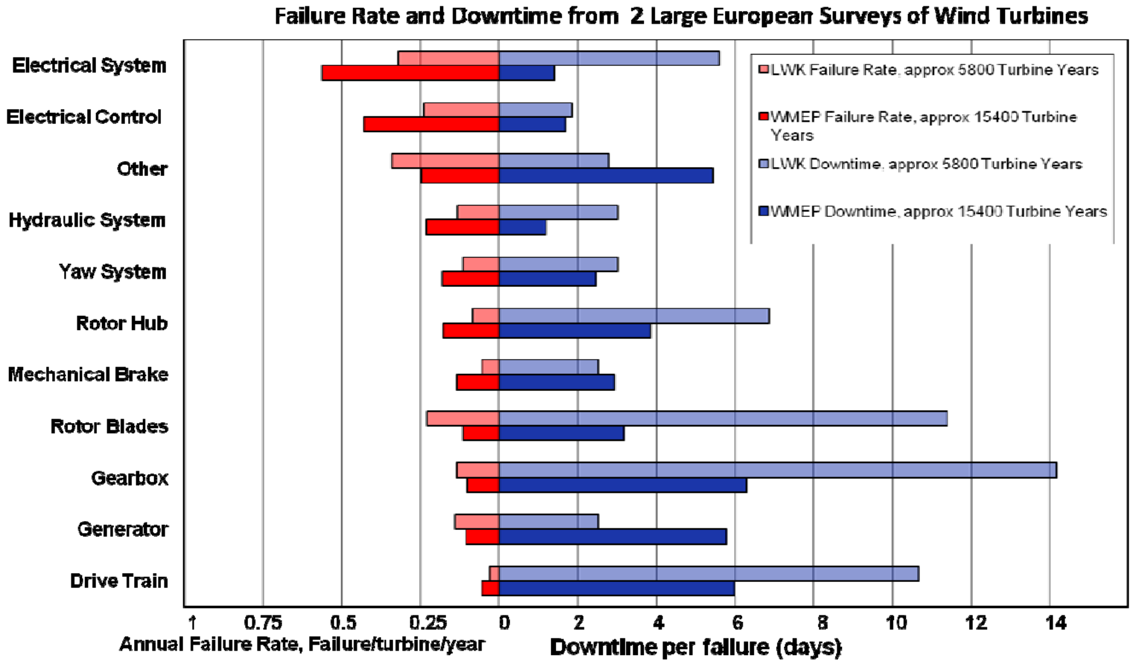

Figure 1. Results of two large of publicly available reliability surveys of onshore wind turbines[14].

1.2.2 Work Package 1 Field Study Data

The primary aim of this deliverable was to present the results of the WP1 field study. Deliverable D.1.2 Reliability Profiles (Methods) [2] has described the methods of the field study. The approach has been to take account of all operational data that is recorded at modern wind farms, 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 wind turbine in the study were identified and then tagged according to a common taxonomy [15].

Data for this study were provided by wind turbine manufacturers who were members of the Reliawind consortium and by the operator Falck Renewables who was a member of the Reliawind Users' Working Group.

1.2.3 Work Package 2 Field Study Data

Work Package 2 (WP2) of Reliawind was focused on reliability analysis, the outline method of which was described in Deliverable D.2.0.2 [16]. WP2 enabled the analysis of the failure rates of the generic Reliawind turbine according to the same taxonomy (structural breakdown) as the results from WP1. The results of this modelling were presented in Deliverable D.2.0.4 [17].

2 Reliability Profiles

2.1 Data Included in the Study

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

The data presented here are normalised relative to the overall failure rate / downtime, to show the percentage contribution to the overall failure rate / downtime of the analysis.

Faults from all severity categories were included in the results presented here.

2.2 Results

The results of the study to date are presented in the table below.

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%
AUXILIARY EQUIPMENT	COOLING SYSTEM	0.31%	0.12%
AUXILIARY EQUIPMENT	WTG 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	SENSORS	0.01%	0.00%

SYSTEM			

Note that the percent time lost shown in this table 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.

These data may be presented graphically as shown in Figure 2 and Figure 3. The large background blocks show sub-systems, the smaller foreground blocks show assemblies and the line shows the Pareto cumulative contribution.

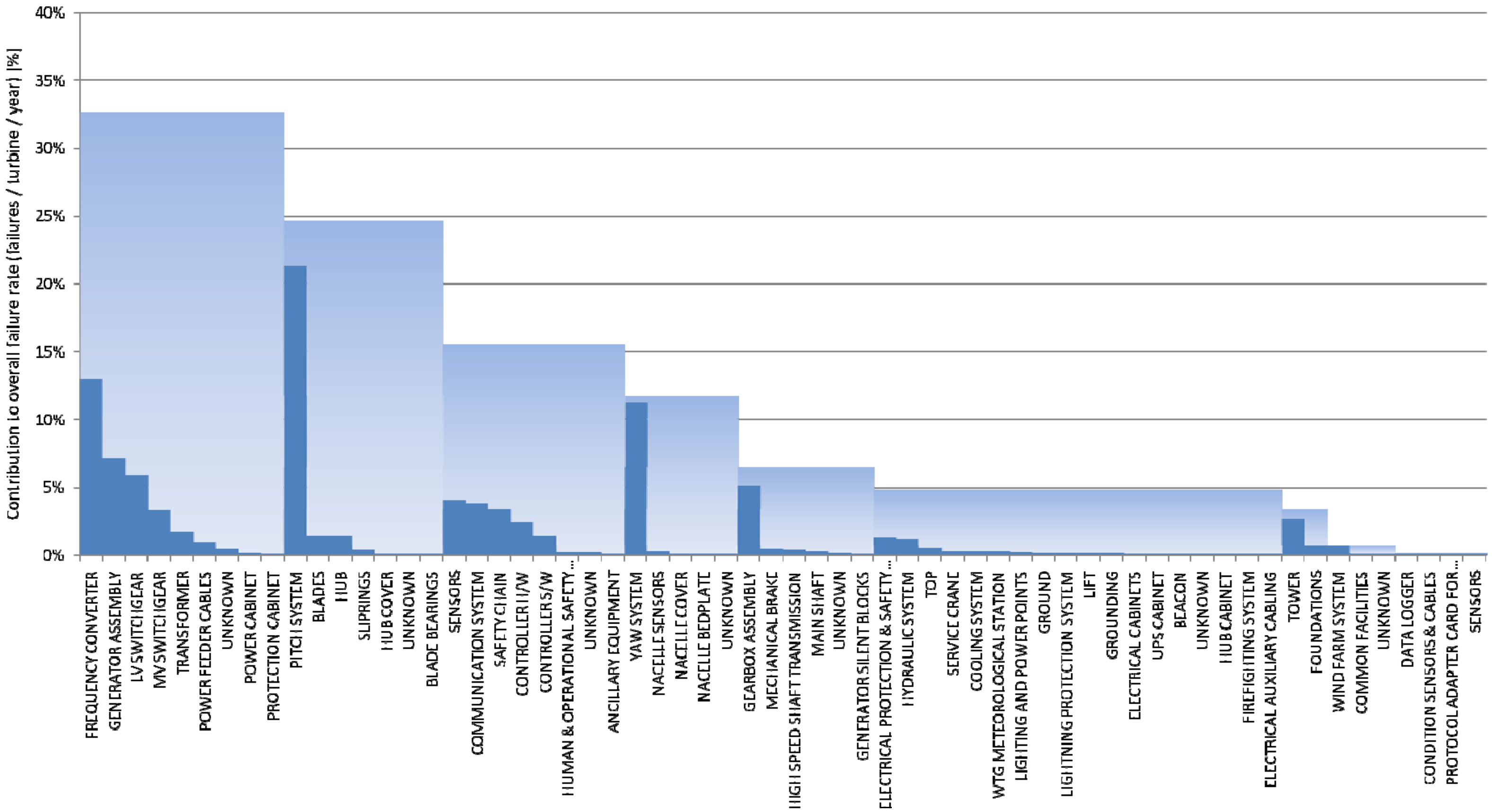

Figure 2. Normalised failure rate of sub-systems and assemblies for turbines of multiple manufacturers in the database.

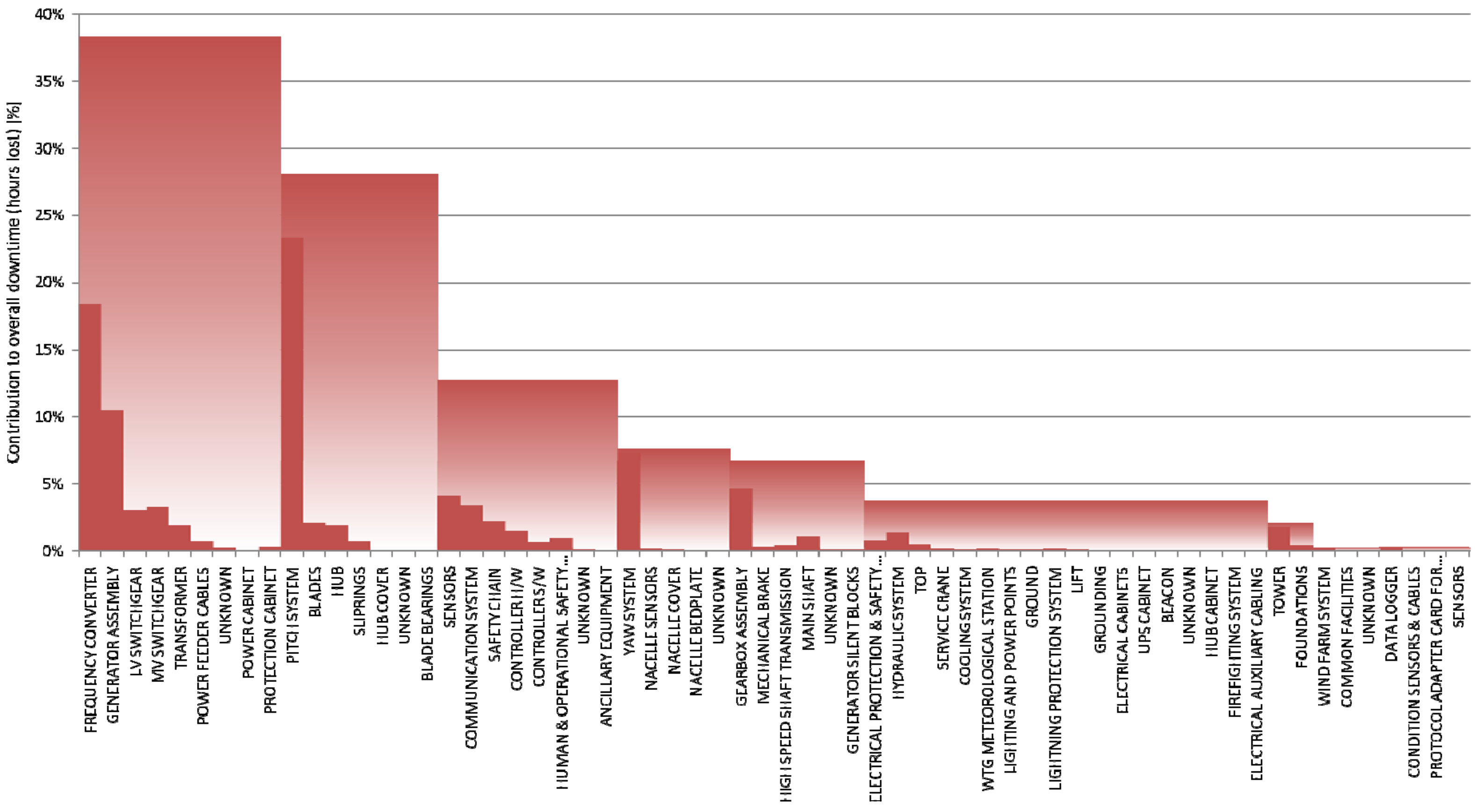

Figure 3. Normalised hours lost per turbine per year to faults in sub-systems and assemblies for turbines of multiple manufacturers in the database.

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