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Citation for the original published paper (version of record):

Hahn, B., Welte, T., Faulstich, S. et al (2017)
Recommended practices for wind farm data collection and reliability assessment for O&M optimization
Energy Procedia, 137: 358-365
http://dx.doi.org/10.1016/j.egypro.2017.10.360

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 137 (2017) 358–365

Energy Procedia

www.elsevier.com/locate/procedia

14th Deep Sea Offshore Wind R&D Conference, EERA DeepWind'2017, 18-20 January 2017, Trondheim, Norway

Recommended practices for wind farm data collection and reliability assessment for O&M optimization

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Abstract

The paper provides a brief overview of the aims and main results of IEA Wind Task 33. IEA Wind Task 33 was an expert working group with a focus on data collection and reliability assessment for O&M optimization of wind turbines. The working group started in 2012 and finalized the work in 2016. The complete results of IEA Wind Task 33 are described in the expert group report on recommended practices for "Wind farm data collection and reliability assessment for O&M optimization" which will be published by IEA Wind in 2017. This paper briefly presents the background of the work, the recommended process to identify necessary data, and appropriate taxonomies structuring and harmonizing the collected entries. Finally, the paper summarizes the key findings and recommendations from the IEA Wind Task 33 work.

Peer-review under responsibility of SINTEF Energi AS.

Keywords: IEA Wind; reliability data; reliability analyses; maintenance optimization; wind turbine

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Peer-review under responsibility of SINTEF Energi AS.
10.1016/j.egypro.2017.10.360

1. Introduction

As the global operational wind turbine fleet ages, pressure to reduce both the subsidies associated with wind energy and the Levelized Cost of Energy (LCoE) of wind energy continues. This confluence of events drives the need to improve the reliability of wind assets if profit margins are to be maintained while reducing costs. Reliability is a critical issue for the growing wind energy industry since it affects other areas such as safety, availability, maintenance, logistics and cost. Furthermore, reliability is dealt with during all phases of lifetime, from design via testing, to construction and operation until decommissioning.

To improve the reliability of wind assets, a detailed understanding of reliability characteristics of systems, components and subassemblies is required. This must be complemented by qualitative assessments and statistical analyses of operational and maintenance information sources. Currently, the wind industry lacks a common understanding and a uniform way of collecting and analyzing data from operation and maintenance for reliability analyses. Thus, databases of existing initiatives are often inconsistent and too small for sound statistical analyses and results are not comparable. However, a variety of respective guidelines already exists, and they should be the basis for harmonization, recommendations and standardization.

The paper is based on a final draft of the IEA Wind Task 33 expert group report on recommended practices for "Wind farm data collection and reliability assessment for O&M optimization" [1] (abbreviated as RP below). The paper provides a brief overview of the work and main results of IEA Wind Task 33. The Task and their aims are briefly presented in Section 2. The approach used by IEA Wind Task 33 is described in Section 3. In Section 4, the main findings and recommendations from the research task for the wind farm owners/operators and for the wider industry are summarized. Finally, conclusions are drawn in Section 5.

2. IEA Wind Task 33

The International Energy Agency Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Energy Systems (IEA Wind) is a vehicle for member countries to exchange information on the planning and execution of national, large-scale wind system projects and to undertake co-operative research and development projects called Tasks or Annexes. As a final result of research carried out in the IEA Wind Tasks, Recommended Practices, Best Practices, or Expert Group Reports may be issued. These documents have been developed and reviewed by experts in the specialized area they address. However, views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

IEA Wind sanctioned in 2011 the expert working group of Task 33 with a focus on reliability of wind turbines. IEA Wind Task 33 commenced in 2012 with the objective of elaborating recommendations to the wind industry for wind farm data collection and reliability assessment for O&M optimization. IEA Wind Task 33 focused on data collection from Supervisory Control And Data Acquisition (SCADA) systems, maintenance activities and reliability issues during operation and maintenance. Testing and design optimization, specialized inspections like vibration measurements and frequency analyses as well as the concatenation of reliability data with real cost were out of scope. Further, it is noted that this recommendation only partly can be applied to verify the requirements in IEC 61400-1:2005 to ensure acceptable safety of the structural components of the wind turbine.

The whole wind industry could benefit from O&M experience, but individual experience is often not systematically prepared and thus no universally valid information is available. Thus, IEA Wind Task 33 has strived at finding answers to the following questions:

- Which information do operators and other stakeholders need?
- What analyses can provide the requested information?
- Which data has to get recorded to feed these analyses?

The findings and recommendations from IEA Wind Task 33 are summarized in this paper and will finally be published by IEA Wind in the aforementioned RP [1] where also further details can be found. The intended audience for the RP are those working with reliability data and analysis mainly for existing plants. However, there will be value for other groups, including those setting up data collection and analysis for a new plant, developers exploring the possibility of a new plant, and researchers modelling theoretical plants or turbines.

The IEA Wind Task 33 workgroup had representation from industry and research, from OEMs to service providers, from research institutions to owner/operators. The following countries were represented in the workgroup: China, Denmark, Finland, France, Germany, Ireland, Netherlands, Norway, Sweden, UK, USA. Fraunhofer IWES from Germany was the task's operating agent.

Industry engagement in the task work has been a critical factor from the outset. In September 2015, an industry workshop with 40 representatives from industry and research discussed opportunities and barriers for collecting and analyzing reliability data from O&M of wind turbines. Additionally several intensive interviews with experts from industry were held in summer 2016. In general, these experts sanctioned the recommendations, provided in section 4. Thus, the IEA Wind Task 33 RP contains important contribution from research and industry as well.

3. IEA Wind Task 33 approach

Often the initial questions associated with reliability data are: What data to collect? What standard should be applied? In order to provide individual answers on these questions, it is important to firstly understand the stakeholders' individual circumstances and reliability objectives. Thus, the IEA Wind Task 33 approach (Fig. 1) starts with identifying relevant roles and possible objectives in the wind industry. Next, tasks and analyses which support those purposes are described and the input data (data groups and data entries) to drive these analyses are determined. Finally, standards and guidelines which provide categories and taxonomies or propose data sets are presented.

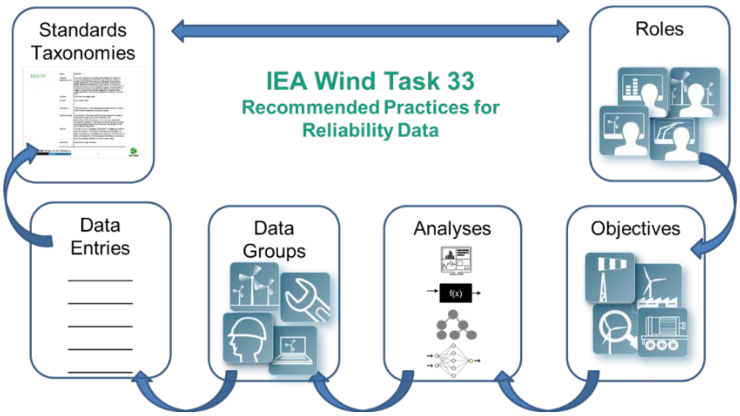

Fig. 1. The IEA Task 33 approach: From roles and objectives to data entries and standards/taxonomies.

In addition to the approach illustrated in Fig. 1, use cases have been described to illustrate how to individually apply the approach. The use cases are not further presented here, but can be found in the RP [1].

3.1. Roles, objectives and complexity levels

The key stakeholders and main roles with an interest in wind asset reliability and maintenance data are presented in Table 1. Furthermore, the table presents objectives which may serve the tasks of these roles. Even though the IEA Wind Task 33 RP are primarily directed at operators and service providers, all of the identified stakeholder groups benefit from the adoption of best practice. It is important to note that roles might be shared between companies or companies may take over several roles. Identification of roles and objectives is an important starting point for further steps to identify suitable data analysis methods and the need for different groups of reliability data.

Organizations have many stakeholders and individuals who will have varying views and requirements associated with the reliability of their assets. Depending on the size of their portfolio, on assigned responsibilities, or on purchase and maintenance contracts they will be able, and willing, to collect more or less detailed data and information. Furthermore, regional legislative or regulatory demands can influence reliability requirements.

Table 1. Most relevant stakeholders or roles in wind industry and their objectives for dealing with reliability and maintenance data.

Roles	Objective
Owner	Decisions support for investments
Operator	Reporting performance indicators
	Determining availability and weaknesses
	Identifying maintenance strategies
Service Provider	Maintenance optimization
	Optimizing spare part stock keeping
OEM/supplier	Design optimization
Financier/insurer	Risk assessment

Optimizing O&M procedures by building on the experience with historical faults and failures, maintenance effort and cost, is a complex and sophisticated task. This is particularly true when relating costs to the different efforts of maintaining and repairing, spare parts and logistics. Design optimization, monitoring and analyzing failure propagation or product degradation are a further set of complex tasks. In these cases failure and maintenance data often have to be collected from different sources and systematically archived. Monitoring and reporting the asset's performance with key performance indicators (KPIs) is a further activity, or series of tasks, associated when considering individual reliability ambition levels. While being less complex than the preceding tasks, for most KPIs the evaluation of automatically provided measurement data will be sufficient.

Table 2 presents three levels of ambition from relatively easy to achieve (A) to more laborious (C), which enable increasing complex applications. With each step one more data group has to get captured. The most ambitious level requires a high effort for achieving complete data sets of good quality and some noteworthy manual collection and verification.

Table 2. Different levels of complexity may lead to individually appropriate data collections and standards.

Level	Possible application	Possible analyses	Needed data groups	Requirement on organizational foundation of reliability
A	Performance, Availability	Statistical calculations (e.g. average values, Simple plots (such as histograms)	Equipment data, Operational data Measurement values	Assessment of assets is recognized as important.
B	Plus: Root cause analysis	Fault-Tree-Analysis, Pareto-Analysis, Basic physical models (e.g. Miner's rule)	Plus: Failure data	Reliability is recognized as important, some processes around reliability exist
C	Plus: Design optimization, Maintenance optimization, Degradation monitoring	Degradation models, Advanced physical models (e.g. modelling fluid structure interaction), Maintenance and logistics optimization, Data mining, Vibration analysis Optimized renewal Optimized stock keeping	Plus: Maintenance and inspection data (Costs)	A clear and formal reliability process is defined and regularly reviewed with stakeholders

3.2. Analysis methods

Different types of analysis methods have different requirements regarding degree of detail of the data sets and regarding length of data history. Thus, the objective of reliability data collection, and the analysis methods to be used to achieve these objectives, should be defined in the beginning of all data collection initiatives.

Different qualitative and quantitative methods serve the objectives of better understanding the reliability behavior of wind turbines and their components. A general model that suits all applications and is suitable for all types of decisions does not exist.

Currently, applying sophisticated reliability analyses seems still quite ambitious, because the needs for high quality data (in terms of accuracy, completeness and degree of detail) is difficult to serve with data currently available, and will also be difficult in the short and medium term. Collaborative data collection initiatives where many partners contribute with data will yield significant benefits, especially when statistical methods and models are used, since the associated increase of the sample size will improve the quality (accuracy) of estimates.

An improvement of the existing standards and initiatives aiming on estimating (constant) failure rates could be made by models as suggested in Table 3.

Table 3. Suggestions for improved reliability analyses.

Type of model	Comments/examples
Stochastic failure rate models for non-constant failure rates	e.g. non-homogeneous Poisson process (NHPP)
Lifetime distributions with non-constant failure/hazard rates	e.g. Weibull distribution. For components that are non-repairable.
Degradation models	Requires that degradation can be observed/measured and quantified. Well-suited for planning of condition-based maintenance.
Physical models	For applications where a good understanding of the physical mechanisms leading to failure as well as suitable models describing these mechanisms are available
Models for (continuous) condition monitoring data	Models capable for use with large amount of time series data. Well-suited for fault detection and predictive maintenance.

3.3. Data groups and sub-groups

Reliability analyses will aim at grouping similar technical concepts operated under similar conditions to find typical results. One aim is to identify frequent failures of a certain item and to find out whether they occur at similar ages of the affected turbines or if they occur randomly. Thus, data of the turbine type and operational conditions at the site as well as information on affected components, failure modes and causes and the dates of occurrence should be collected. These data types are of quite different characteristics and can get divided into four data groups. Table 4 provides these data groups and gives some indications which data or sub-groups / objects they consist of.

Table 4. Groups of reliability and maintenance data and sub-groups/objects.

Data groups	Sub-groups / objects
Equipment data (ED)	Identification
	Time data
	Technical information
Operating data / Measurement values (OP)	Time stamp
	Measurement values (SCADA, etc)
	Operational states
Failure data (FD)	Identification
	Time data
	Failure description
	Failure effect
	Failure detection
	fault properties
Maintenance & inspection data (MD)	Identification
	Time data
	Task / measure / activity
	Resources
	Maintenance results

A fifth data group would regard cost information. To optimize the financial benefit from running wind turbines it is essential to connect reliability and maintenance data with cost information. However, for most companies cost information is classified as competitively sensitive and confidential, and such the Task 33 recommendations do not cover cost data. Nevertheless, the objects ‘resources’, ‘failure impact’, ‘measurement values’, and ‘operational states’ provide information which will lead to financial assessments when connected with individual cost information.

3.4. Taxonomies

Several guidelines and standards from different industries deal with data and values and suggest varying degrees of granularity. For reliability analyses and O&M optimization none of these guidelines provides a complete scheme for all applications.

With table 5, the IEA Wind Task 33 RP present an overview of standards and guidelines providing lists of terms for categorizing aspects of components, failures, maintenance tasks etc. as ‘taxonomies’.

Table 5. Data groups and related taxonomies.

Data Groups / Taxonomies	Equipment data	Operating / Measurement data	Failure data	Maintenance & inspection data
RDS-PP® [3]	o			
GADS [4]	o	-		-
Reliawind [5]	o			
ISO 14224 [2]	(o)		(+)	(+)
ZEUS [6]		o	+	+
IEC 61400-25 [7]		+		
IEC 61400-26 [8]		o		

+ wind-specific entries with a high level of detail
o wind-specific entries with a medium level of detail
- wind-specific entries on a more general level
(+) entries with a high level of detail, not wind-specific
(o) entries with a medium level of detail, not wind-specific
(-) entries on a more general level, not wind-specific

A taxonomy that divides components of a wind power plant in hierarchical levels, i.e. a reference designation system, is the backbone for data collection, since for many analyses information collected has to be related to an item of one of the hierarchical levels. Furthermore, the hierarchical structure is important, when for example aggregating failure rates from items on a lower level to the failure rate of the respective item on the next higher level.

The recommendations of IEA Wind Task 33 broadly follow the hierarchy and the levels of detail of the industry standard ISO 14224 [2]. The recommended levels are (examples in brackets): 1. Plant (wind power plant), 2. System (wind turbine), 3. Sub-system (drive train), 4. Assembly (shaft assembly), 5. Maintainable item (bearing), 6. Part (roller).

4. IEA Wind Task 33 key findings and recommendations

IEA Wind Task 33 found that there is broad industry recognition of the relevance of reliability data collection and analyses for optimizing both profit margins and LCoE. However, the lack of standards associated with reliability data is adversely impacting industry progress in addressing reliability issues.

Historically, reliability data is rarely considered by the owners/operators at the early stages of wind asset development and warranty based operation. The owners'/operators' reliability ambitions range from those comfortable with a complete reliance on third parties, such as OEMs to manage asset reliability, to those seeking control of maintenance strategies and actively managing asset reliability. While ambitious owner/operators strive to benchmark reliability metrics against those of their peers, uptake is often restricted by the unavailability and inconsistency of reliability data.

From these key findings, recommendations as presented in Table 6 have been identified. The recommendations are divided in recommendations for developers, owners and operators, and in recommendations for the wider wind industry.

Table 6. Wind Task 33 Recommendations.

Developers / owners / operators	**1. Make sure you get access to all relevant data** Consider reliability data to be of high value from the early stages of wind asset development and a key operational factor throughout the life of the wind asset. Ensure that access to reliability data and required data are factored into negotiations with developers / OEMs / suppliers / service providers.
	2. Identify your use-case and be aware of the resulting data needs Identify use cases linked to your organizational reliability ambitions and use these to define data collection requirements.
	3. Map all wind turbine components to one taxonomy / designation system Map all wind asset components and maintenance activities to one of the taxonomies / designation systems identified in the Task 33 RP. This will allow for improvements in both the consistency and integrity of reliability data throughout an organization and at the interfaces with the supply chain.
	4. Align operating states to IEC 61400-26 Align operating states with those specified in IEC 61400-26 [8], the standard for a time- and production-based availability assessment for wind turbines.
	5. Train your staff understanding, what data collection is helpful for All staff engaged directly, or indirectly, in the production, collation and analysis of reliability metrics should be educated on the strategic significance of reliability data and empowered to improve related business processes and practices.
	6. Support data quality by making use of computerized means Whenever practical, seek to automate the data collection / collation process as a means of reducing efforts and the risk of human error as well as improving data quality.
	7. Share reliability data to achieve a broad statistical basis Wind farm owners / operators should engage in the external, industry-wide sharing of reliability and performance data. This will align data collection methodologies, drive organizational improvements and achieve statistically significant populations of data for reliability analyses.
Development of standards for the wider wind industry	**8. Develop comprehensive wind-specific standard based on existing guidelines/standards** Develop a comprehensive wind specific standard based on ISO 14224 [2], FGW ZEUS [6], and other existing guidelines/standard. This would provide a core standard for the language and scope of reliability and maintenance data for the wind industry (based on accepted reliability data best practice in oil and gas industry), while minimizing the time and cost associated with the development of the standard.
	9. Develop component- / material-specific definition of faults, location, and severity As a longer-term recommendation, there is a need to develop standard definitions for damage classification and severity for structural integrity issues.

The implementation of the above recommendations will improve the quality (accuracy, consistency and integrity) of reliability data and consequently the value derived from it for all stakeholders across wind asset investment, development, operation and insurance.

The development and adoption of reliability data collection standards and reporting across the industry will take time and the commitment of all stakeholders. The value, as realized in other industries such as oil and gas, lies in safer and more effective and efficient maintenance policies, strategies and practices. Failure to do this will restrict the pace at which opportunities to improve operations and maintenance costs can be identified and consequently implemented.

5. Conclusions

IEA Wind Task 33 found that there is a strong demand for making better use of operational experience to improve O&M as well as other applications from design optimization to risk management. However, up to now there is no international agreement or guideline about which data to collect and how to treat it. Thus, the recommended practices of IEA Wind Task 33 mean an important step towards making use of operational experience for reliability improvement.

The results have been developed and reviewed by experts from research and industry in the field of reliability. Even though the use of the results is of course voluntary and there is an initial effort for implementing a systematic approach of reliability assessment, the results may be adopted in part or in total by other standards developing organizations.

But nevertheless, since IEA Wind Task 33 has intended to identify appropriate guidelines and taxonomies instead of developing new ones, there still exist gaps, such as complete lists of data that should be collected and detailed descriptions of how to monitor initial faults in blades or other structural components. However, one of the IEC working groups dealing with availability and reliability has already announced to base their future work on these results. Addressing the topic by an international standard would increase the significance of reliability assessment much.

Acknowledgements

The authors would like to thank all supporters of IEA Wind Task 33. Nearly 40 people from 24 organizations from eleven member countries of IEA Wind have regularly contributed with important input to the RP. Numerous engaged experts from industry shared their knowledge in workshops and interviews. The executive committee of IEA Wind has always supported the team with valuable hints and comments. Last but not least many thanks to the secretariat of IEA Wind, who helped the team setting up and steering the whole project. Without this continuous support, the successful completion of the RP would not have been possible.

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