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Wind Energy Computerized Maintenance Management System (CMMS): Data Collection Recommendations for Reliability Analysis

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Abstract

This report addresses the general data requirements for reliability analysis of fielded wind turbines and other wind plant equipment. The report provides a rationale for why this data should be collected, a list of the data needed to support reliability and availability analysis, and specific data recommendations for a Computerized Maintenance Management System (CMMS) to support automated analysis.

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Executive Summary

This data collection recommendations report was written by Sandia National Laboratories to address the general data requirements for reliability analysis of operating wind turbines. This report is intended to help develop a basic understanding of the data needed for reliability analysis from a Computerized Maintenance Management System (CMMS) and other data systems. The report provides a rationale for why this data should be collected, a list of the data needed to support reliability and availability analysis, and specific recommendations for a CMMS to support automated analysis. Though written for reliability analysis of wind turbines, much of the information is applicable to a wider variety of equipment and analysis and reporting needs.

The “Motivation” section of this report provides a rationale for collecting and analyzing field data for reliability analysis. The benefits of this type of effort can include increased energy delivered, decreased operating costs, enhanced preventive maintenance schedules, solutions to issues with the largest payback, and identification of early failure indicators.

The “Data Requirements” section outlines the field maintenance data required to support reliability and availability analysis and reporting. The data requirements include:

- Machine ID
- Event Type
- Failure Mode ID and Name
- Equipment Status
- Event Date and Time
- Man Hours
- Total Downtime
- Monitoring Period
- Operational Time
- Equipment Configuration
- Cost Data (optional)
- Lost Production Data (optional)

The “Recommendations” section presents specific recommendations that address common issues Sandia has seen in CMMS design and implementation. These recommendations are grouped into “process” suggestions on *how* the data is tracked and “data” suggestions on *what* data is tracked.

Process Suggestions

- Develop a detailed taxonomy
- Fill in all the data fields – accurately
- Integrate ease of use into data recording
- Assign dedicated data entry and quality assurance staff

Data Suggestions

- Identify equipment status
- Track equipment downtime
- Identify maintenance action performed
- Record inspections and other scheduled maintenance events
- Identify the affected equipment/area for all maintenance actions
- Identify which part caused the maintenance
- Track maintenance and parts cost
- Identify source of parts

Acronyms and Definitions

- CMMS: Computerized Maintenance Management System. A software system that tracks work orders and/or maintenance performed.
- Failure Mode: Any maintenance-related event, including failure, inspection, scheduled maintenance, etc.
- EBS: Equipment Breakdown Structure
- MDT: Mean Downtime
- MTBF: Mean Time Between Failure
- MTTR: Mean Time To Repair
- O&M: Operations and Maintenance

Introduction

This data collection recommendations report was written by Sandia National Laboratories to support high-quality reliability tracking and process improvement. The report describes the data collection requirements that enable a Computerized Maintenance Management System (CMMS) and related systems to provide the data needed for reliability analysis of fielded wind turbines.

This report is intended to provide the reader with a basic understanding of what data are needed for reliability analysis of wind turbines. The report does not describe the technical details of implementing a CMMS, nor does it detail state-of-the-art CMMS systems. The report was written for *reliability* analysis of *wind turbines*, though much of the information is applicable to a wider variety of equipment and a wider variety of analysis and reporting needs.

In addition to enabling analysis, there are many other reasons why a company would implement a CMMS. Formalizing communication within the company, enabling consistent external communication (with suppliers or financial partners, for example), and providing historical documentation are just a few of the benefits. Sandia's reliability work has led to the identification of some common CMMS setup and implementation questions. This report was written to provide answers to these common questions and address common gaps in operations and maintenance (O&M) data collection.

The "Motivation" section of this report provides a rationale for collecting and analyzing field data for reliability monitoring and improvements. The "Data Requirements" section outlines the field maintenance data required to support reliability and availability analysis and reporting. The "Recommendations" section presents detail on specific recommendations that address common issues Sandia has seen in CMMS design and implementation. These recommendations are grouped into "process" suggestions on *how* the data is tracked and "data" suggestions on *what* data is tracked. "Appendix A" contains a list of definitions and acronyms used in the report.

Motivation[1]

Wind plant operators interested in understanding and improving reliability will need to capture high-quality data to reap the benefits of reliability analysis. When O&M data are readily available for analysis, the potential improvements in operational efficiency include increases in energy delivery and decreases in costs. Identifying top drivers of unreliability and root causes of those faults and failures can result in a variety of improvements, including enhancing preventive maintenance schedules, addressing the issues with largest payback potential, moving from reactive to proactive maintenance, and identifying trends and early failure indicators. The costs associated with data collection and analysis are not trivial, but are far outweighed by the benefits gained through an ability to predict future failures and minimize their impact.

One of the key reasons to track and improve reliability is to enhance the plant's financial performance. Reliability can improve financial performance through cost avoidance, including O&M and overhead costs, thus reducing the cost of energy. Reductions in O&M costs can come from a variety of activities, such as decreasing unscheduled maintenance and translating costly parts replacements into less costly scheduled maintenance. Overhead decreases can result from benefits such as reduced insurance costs based on decreased performance uncertainty and reduced investment in spare parts inventories. Improvements in reliability can also benefit the bottom line by increasing revenue through increased turbine availability during useful wind, thus maximizing the plant's capital investment. Secondary financial impacts can include such varied benefits as freeing up capital to allow investments in other programs and providing more accurate input to inform long-term investment decisions. For example, a good understanding of the impact of curtailment may impact the location choice for a company's next wind plant or understanding the causes of plant-to-plant variability could inform the next turbine selection.

Capturing high-quality reliability data has benefits beyond the plant. It enables automated reporting to various regulatory entities and creates a foundation for reporting to partners. In addition to the benefits for an individual plant or operator, collective reliability data for the industry can bolster support for wind-friendly policy from federal and states government, public utility commissions, tax and rate payers, and the insurance and investment community. Also, an understanding of national wind industry reliability performance can guide standards and research and development investments.

[1] Excerpted from "Using Wind Plant Data to Increase Reliability." McKenney, Ogilvie, and Peters; Sandia National Laboratories. Albuquerque, NM. January 2011. SAND2010-8800

Data Requirements

This section outlines the field maintenance data required to support reliability and availability analysis and reporting. In a typical maintenance data system, there is usually one record for each event in a main "Events" database table. Supporting data (such as additional parts needed to correct the failure event, employee time expended for maintenance, part costs, or system operating hours) may be stored in one or many other tables and/or databases. Each element of the basic data needs is listed below. Note that frequently these items are not stored in the system as they are described here; instead, multiple data fields may be required to create each of these items.

1. Machine ID: Links the maintenance event with a specific system or piece of equipment.
2. Event Type: Type of maintenance event (e.g., component failure, preventative maintenance, inspection).
3. Failure Mode ID and Name: A unique identifier or code for each failure mode, along with a unique descriptive label for each failure mode. (Here, "failure mode" refers to any maintenance-related event, not just failures.) The failure mode may come from one or more of the following:
   - A breakdown of the system (e.g., taxonomy or equipment breakdown structure)
   - A brief description of the failure mechanism
   - A description of an external event that causes downtime or maintenance
   - A description of how the system reacts to the failure
4. Equipment Status: The status of the equipment or system during the maintenance event (e.g., offline, degraded, online, etc.).
5. Event Date and Time: Date and time when the status of the equipment changes (or, if the equipment status does not change due to the event, the date and time the maintenance event begins).
6. Man Hours: The total number of person-hours required to complete the maintenance action. Note that this may be very different (greater than *or* less than) total downtime.
7. Total Downtime: The amount of time the equipment was down or offline due to the event (or, if the equipment was not down due to the event, the duration of the maintenance event), ideally with each of the following recorded individually:
   - Active maintenance time
   - Time spent waiting for a part from supply
   - Time spent waiting for a piece of support equipment to become available
   - Time spent waiting for a technician to become available
   - Time spent waiting for other delays

In addition to the data that is needed for each maintenance or downtime event, supplemental system information is also needed. This information may or may not be captured in the Computerized Maintenance Management System (CMMS).

8. Monitoring Period: This is the total time over which the reliability of the equipment is evaluated. (For example, most plants are run such that turbines should be available around-the-clock.)
9. Operational Time: This is the total amount of time that the turbine is operational. This may only include time when the power generation is positive, or it may include anytime that the rotor is moving.
10. Equipment Configuration: A qualitative or quantitative understanding of how the equipment functions, and how failure modes combine to cause or avoid an overall equipment failure. In the case of a standard wind turbine most events that require maintenance cause turbine downtime, but others do not (e.g., some preventive maintenance and inspection work). A list of maintenance events that do not bring down the turbine may suffice for this data requirement, or, if the system has complex redundancy, a reliability block diagram or a fault tree may be needed.
11. Cost Data: Cost information is usually obtained from a different source than the reliability field data. Cost data is not strictly necessary for reliability analysis, but including the following can greatly enhance reporting and insights:
    - Nominal cost: Typically, this is the component-level repair/replace cost.
    - Cost per hour: Cost of the maintenance event in terms of penalty per downtime hour. Examples include maintenance man-hour cost, lost revenue, lost opportunity cost, or a customer-imposed penalty.
    - Fixed cost per failure: Recurring cost per maintenance event, independent of nominal and hourly costs. Examples include a fixed trip charge, an administrative cost, or a paperwork cost.
12. Lost Production Data: Like cost data, lost production data is typically obtained from a different data source and is also not strictly necessary. Reference information, such as a power curve or generation from a similar turbine, is needed to determine what the turbine could have produced while it was down.

Gathering the data as described above will allow for calculation of many different measures of system reliability performance, including Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), Mean Downtime (MDT), and various measures of Availability. With these reliability measures, the components, failure modes, and maintenance events that contribute most to system unreliability, downtime, cost, and production loss can be identified.

Recommendations

This section outlines specific recommendations for the design and implementation of a CMMS. These recommendations are made based on Sandia's experience in reliability modeling and analysis for wind turbines and plants, in addition to Sandia's extensive experience performing reliability analysis on a wide variety of systems.

The recommendations provided here will help provide an accurate set of data that supports reliability analysis for a variety of purposes. The data should be able to describe the activities of the equipment 24 hours a day, 7 days a week, and should include failure events, parts replacements, scheduled downtime, and other maintenance actions. Establishing a system-of-record and ensuring that this system is easily integrated into maintenance processes is the key to collecting and recording high-quality data.

Processes – How to track data

1. Develop a detailed taxonomy

Developing a detailed equipment breakdown structure (EBS) or taxonomy helps ensure that maintenance data is captured with enough detail to be useful. Using a breakdown of the equipment that provides a unique assessment opportunity for each component or part ensures greater insight in determining which assemblies, subassemblies, or components significantly affect reliability and availability performance. (For example, "Drivetrain-Gearbox-Bearings-Planetary Bearing" provides much more information than just "Gearbox".)

2. Fill in all the data fields – accurately

With any data collection system, one of the biggest challenges is ensuring that data is entered for every applicable data field. In addition to entering all the relevant information, ensuring that standard and correct information is entered is also essential. There is often a trade-off to be made when weighing the value of data collected against the cost of collecting it. With the right hardware and smart software, it should be possible to help technicians record data quickly and accurately without adding an unnecessary burden. Additionally, ensuring that the user interface evolves with the business is critical. For example, allowing technicians to suggest new items for a taxonomy dropdown box can help prevent "Miscellaneous" from being the most frequent problem. A well-designed CMMS can greatly reduce the amount of follow-up data entry and quality assurance required.

3. Integrate ease of use into data recording

To have an accurate and consistent CMMS, it is important to limit the amount of time spent entering and updating records. This can be achieved by incorporating automated data collection and validation into maintenance processes. In addition to automated validation, use of handheld devices can decrease entry error and allow for automated capture of many data elements (for example: date, time, and technician).

Frequently, all the ways that maintenance data will be used are not known at the time the CMMS is implemented. Modern software systems can provide an interface that makes data entry easy and accurate, and they can also store information in a way that facilitates later use by the various groups who need to access the data.

4. Assign dedicated data entry and quality assurance staff

The simplest method for improving data collection is to obtain data as close to the maintenance activity as possible. Individuals specifically responsible for data entry and accuracy can be a real asset. An assigned data collector needs to ensure that the information is both complete and correct; this may involve interaction with technicians. Part of the solution may be to provide portable computing equipment for technicians to record and manage day-to-day operations. Another part of the solution may be to ensure the data collection system is easy to use and has "smart" capabilities (e.g., flagging missing or inconsistent data).

Data – What data to track

1. Identify equipment status

Equipment status is a crucial part of understanding reliability and availability. For all failure or maintenance events, the equipment's status (Online, Degraded, Non-Operational, etc.) should be clearly indicated for the duration of the event. Capturing when the equipment is not Online is critical to identifying key drivers of availability and reliability performance.

2. Track equipment downtime

In addition to tracking the man-hours associated with each maintenance event, the total equipment downtime should also be recorded. This downtime should include the entire duration the equipment was not Online, and ideally would distinguish between time spent performing active maintenance, parts delays, support equipment delays, technician delays, and any other downtime contributors.

3. Identify maintenance action performed

Depending on the definition of availability used, various event types will or will not be included in the calculation. For example, scheduled maintenance may be included in availability metrics used at the plant, but typically not in the availability metrics used by turbine manufacturers. Additionally, the maintenance type has a direct effect on cost. For example, if only an inspection is performed, there may not be a parts cost and the equipment may remain Online, but a personnel cost may still be incurred. Tracking the type of maintenance performed for each maintenance event will allow for flexibility and precision in calculating reliability metrics.

4. Record inspections and other scheduled maintenance events

Even inspections and scheduled maintenance that are relatively short in duration, relatively infrequent, and/or can occur while the system is running are crucial to understanding the availability and reliability performance of a system. All scheduled events form a part of the maintenance history of the system and should be recorded in the CMMS to capture the associated man-hours and the impact on availability and cost.

5. Identify the affected equipment/area for all maintenance actions

A simple way to clearly identify the area of the equipment where a maintenance action occurs is to use a taxonomy or EBS to determine the affected part for all maintenance actions. In addition to parts replacements, this should be captured for all types of events, including scheduled maintenance, inspections, and repairs.

6. Identify which part caused the maintenance

To truly understand the impact each part has on overall reliability and availability, it is important to distinguish between parts that caused a failure ("primary failures"), parts that failed as a result of the primary failure ("secondary failures"), and other parts that need to be repaired/replaced in the process of performing maintenance on parts with primary and secondary failures ("ancillary failures"). For example, if a power spike from a power supply causes the power supply to fail and also shorts out a circuit board under a console panel, then the power supply has a primary failure, the circuit board has a secondary failure, and the console panel has an ancillary failure. If multiple parts are worked on for the same maintenance action, a "Failed Part" field could be used to identify parts with primary failures and distinguish them from those with secondary or ancillary failures. Additionally, parts are sometimes opportunistically replaced when other maintenance events are underway, thus significantly reducing their replacement time and/or cost compared to their usual replacement time and/or cost. These opportunistic replacement activities should also be captured.

In some cases, the part with a primary failure may not be obvious at the time of the maintenance event. In these cases, returning to the maintenance record after the root cause is discovered will be important, to create an accurate and complete assessment of the maintenance event.

7. Track maintenance and parts cost

While Availability and Reliability are key metrics in assessing equipment performance, understanding what is driving maintenance costs can be just as valuable. Typically, the parts and personnel costs are stored outside the maintenance system, and the relevant information from the maintenance system (including parts replaced and man-hours) is used to calculate the total cost for each maintenance event.

8. Identify source of parts

For relevant event types, the source of parts should be clearly captured. This includes parts cannibalized from other equipment, purchased outside the main supply system, and acquired by others means (including parts machined on site). Identifying the source of parts (including those exchanged between equipment) will allow for accurate cost calculations, in addition to setting the stage for advanced CMMS uses such as parts and inventory tracking; this can be accomplished through a "Parts Source" field.

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