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Condition monitoring and diagnostics of wind turbines —

Part 1: General guidelines

Surveillance et diagnostic d'état des éoliennes de production d'électricité —

Partie 1: Lignes directrices générales

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machine systems*.

A list of all parts in the ISO 16079 series can be found on the ISO website.

Introduction

General

This document is the first in a series of International Standards covering the application of condition monitoring to wind turbines. It is an application of the recommendations and best practices described in the generic standards developed under ISO/TC 108.

Background

Power production from wind turbines is growing exponentially on the global energy market. As a consequence, predictability of the production from wind power plants has become as crucial as predictability of power production from conventional power plants. As for conventional power plants, an efficient maintenance programme for wind power plants adds significant value to the reliability and predictability of the supply of energy. An efficient condition monitoring system is an important part of such a programme in order to achieve the following:

a) obtain predictability in power production, thus avoiding penalties from grid authorities if the quoted amount of power is not delivered;

b) maintain the confidence of investors by providing a stable power production, thus motivating future investments;

c) lower turbine maintenance costs by

   1) avoiding development of failures to a serious state,

   2) avoiding consequential or subsequent failures, and

   3) being able to plan service months ahead;

d) reduce the through life cost by

   1) avoiding loss of availability,

   2) allowing continued operations under fault conditions (perhaps with appropriate restrictions), and

   3) supporting failure investigations to prevent repetitive events.

Condition monitoring, in general, requires:

— Reliable alarms. An alarm is triggered only when the confidence level of the diagnosis and prognosis is high. Wind turbines are placed in remote locations and many wind turbines are located offshore where access is limited and costly.

— An estimated time to failure. This is for supporting efficient maintenance planning and utilization of cranes, staff, ordering of spare parts, etc.

— Reliable descriptor measurements. In addition to self-excited forces, a wind turbine is also subject to environmental occurrences. The compact structure can cause measurement readings from one machine part to be affected by other machine parts.

— Detection of faulty monitoring. A working data acquisition system is the basis of a reliable monitoring systems. Any equipment can fail. It is essential that faulty equipment is detected to ensure a reliable condition monitoring process.

— Complex IT landscape. A monitoring system is required to monitor thousands of wind turbines connected to a central server via complex worldwide data networks. (This requirement is outside the scope of this document.)

Condition monitoring of wind turbines presents some challenges compared to condition monitoring of other machinery.

— Access to the nacelle is difficult and potentially dangerous and in many countries is not allowed during operation, so online systems are likely to be required for measurements which have traditionally used hand-held methods.

— Wind turbine loading varies significantly with time and cannot be influenced; some extra measures need to be taken to ensure repeatability of measurements.

— Self-excitation of the structures, extremes of ambient temperature and the likelihood of lightning strikes present a severe test of the robustness of all systems.

— Since wind turbines are often in remote locations, the monitoring systems need to be able to function in the face of loss of network connectivity.

Aims of the ISO 16079 series

This document and subsequent documents in the ISO 16079 series have the following aims:

a) to allow manufacturers of wind turbines, operators of wind turbines and manufacturers of condition monitoring systems for wind turbines to share common concepts and terminology;

b) to provide a methodology whereby users of this document can prioritize and select which components shall be monitored and which failure modes shall be detected, in order to obtain the most efficient condition monitoring system with regard to

1) cost,

2) detection capability,

3) complexity of monitoring system and methods, and

4) available resources and skill level of staff in the monitoring body.

It is NOT the intention of this document or subsequent documents in the ISO 16079 series to cover any aspects of safety monitoring systems.

Time-proven experience

The monitoring strategies presented in the ISO 16079 series are based on time-proven experience. Only conservative, well-proven methods and best practices are applied. This means that detection of certain failure modes may be left out if the behaviour of the failure modes and their related symptoms are not well-documented. As new monitoring techniques mature, this document will be updated accordingly.

Relation to the generic standards of ISO/TC 108

ISO 17359 is a parent standard of this document. It presents an overview of a generic procedure recommended to be used when implementing a condition monitoring programme and provides further details on the key steps to be followed. It introduces the concept of directing condition monitoring activities towards root cause failure modes and describes the generic approach to setting alarm criteria, carrying out diagnosis and prognosis and improving confidence in diagnosis and prognosis, which are developed further in other documents. Particular techniques of condition monitoring are introduced briefly.

The concept of condition monitoring itself and the measurement techniques involved are presented in other generalized condition monitoring guidelines such as ISO 13373 (all parts), ISO 13374 (all parts) and ISO 13379-1. Those guidelines are considered as foundations of this document. Figure 1 illustrates how this machine-specific document is linked to other generic guidelines of condition monitoring and measurement techniques.

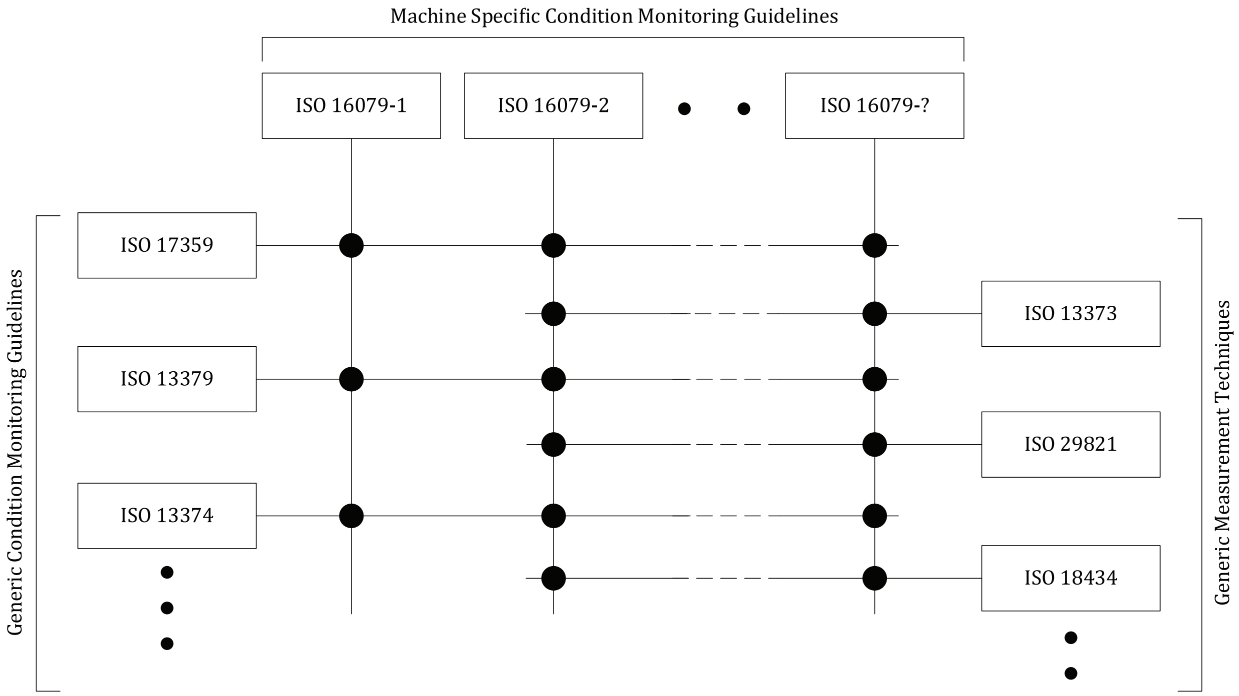


Figure 1 — Links between the machine-specific International Standards and the generic International Standards

Other documents and guidelines for wind turbines

The documents and guidelines listed here are not within the scope of this document. However, a brief introduction is relevant as they are often referenced.

— ISO 10816-21[1] specifies broadband measurements to be applied for the evaluation of mechanical vibrations of wind turbine using zone boundaries. Examples of zone boundaries for onshore wind turbines below 3MW are provided in an annex. The aim of ISO 10816-21 is to standardize vibration measurements, to assist in their evaluation and to make possible a comparative evaluation of the vibration measured in wind turbines and their components. For long-term condition monitoring and diagnostics, more advanced techniques are required which are outside the scope of ISO 10816-21.

— IEC 61400-25-6[10] in the IEC 61400-25 series specifies the information models related to condition monitoring for wind power plants and the information exchange of data values related to these models. The purpose of the ISO 16079 series is to define the descriptors for detection of various failure modes. IEC 61400-25-6 complements this document by specifying how to organize these descriptors in a data model.

  A data model organizes data elements and standardizes how the data elements relate to one another. The data model allows a single computer program to retrieve wind turbine data from several different condition monitoring systems where the data model is implemented. IEC 61400-25-6 describes notation for identifying sensors and sensor locations, sensor types, operational states and proposes a systematic naming of descriptor types.

— The DNV·GL guideline[11] specifies requirements for the certification of condition monitoring systems for wind turbines and the associated monitoring bodies. The guideline specifies requirements to the documentation of the condition monitoring system and requirements to associated procedures which are applied by the staff of the monitoring body. The guideline specifies sensor location and required frequency ranges as well as requirements to the presence of certain analysis procedures. The guideline does not propose any requirements to which failure modes shall be detected, nor to the capability of measuring related descriptor types.

Relation to the ISO 55000 series

The requirement of the ISO 55000 series is straightforward and has a direct link to condition monitoring. An organization, a company, a wind power plant, etc. has a portfolio of assets. It has a corporate strategy that provides overall objectives for the entire organization. Those assets are intended to deliver part of those objectives. Effective control and governance of assets by organizations is essential to realize value through managing risk and opportunity, in order to achieve the desired balance of cost, risk and performance.

For a wind power plant, condition monitoring is a key risk-handling element of the asset management program by avoiding that wind turbines fail unexpectedly, keeping the cost of operation under control and ensuring a high performance.

Condition monitoring and diagnostics of wind turbines —

Part 1: General guidelines

1 Scope

This document gives guidelines which provide the basis for choosing condition monitoring methods used for failure mode detection, diagnostics and prognostics of wind power plant components.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Mechanical vibration, shock and condition monitoring – Vocabulary*

ISO 13372:2012, *Condition monitoring and diagnostics of machines — Vocabulary*

ISO 13379-1:2012, *Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and ISO 13372 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
alarm
operational signal or message designed to notify personnel when a selected *anomaly* (3.2) or a logical combination of anomalies, which requires a corrective action is encountered

[SOURCE: ISO 13372:2012, 4.2, modified — “requiring” has been replaced by “which requires”.]

3.2
anomaly
irregularity or abnormality in a system

[SOURCE: ISO 13372:2012, 4.4]

3.3
component
sub-component
component part
part of a geared wind turbine, typically the main bearing, gearbox and generator

Note 1 to entry: Each of these components in the strictest sense of the definition can also contain several sub-components or component parts such as a generator bearing or a planet gear.

3.4
consequential damage
phenomena whereby degradation of one *component* (3.3) can cause *failures* (3.7) in other components

Note 1 to entry: This is also often referred to as secondary damage or subsequent damage.

3.5
descriptor
data item derived from raw or processed parameters or external observation

Note 1 to entry: Descriptors are used to express *symptoms* (3.15) and *anomalies* (3.2). The descriptors used for monitoring and diagnostics are generally those obtained from condition monitoring systems. However, operational parameters, like any other measurement, can be considered as descriptors.

Note 2 to entry: Descriptors are also referred to as “condition monitoring descriptors”.

[SOURCE: ISO 13372:2012, 6.2, modified — the admitted term "feature" has been deleted and the Notes to entry have been added.]

3.6
estimated time to failure
ETTF
lead time
estimation of the period from the current point in time to the point in time where the monitored machine has a *functional failure* (3.8)

[SOURCE: ISO 13381-1:2015, 3.8, modified — the term "lead time" has been added.]

3.7
failure
termination of the ability of a *component* (3.3) or a machine to perform a required function

Note 1 to entry: Failure is an event as distinguished from *fault* (3.10), which is a state.

[SOURCE: ISO 13372:2012, 1.7, modified — “item” has been replaced with "component" and “machine”.]

3.8
functional failure
F
point in time when the machine stops performing its required function

3.9
failure mode
manner in which an equipment or machine *failure* (3.7) can occur

Note 1 to entry: A machine can have several failure modes such as rubbing, spalling, unbalance, electrical discharge damage, looseness, etc. A failure mode produces *symptoms* (3.15) indicating the presence of a *fault* (3.10).

3.10
fault
<of a component of a machine, in a machine> occurs when one of its *components* (3.3) or assembly degrades or exhibits abnormal behaviour, which can lead to *functional failure* (3.8) of the machine

Note 1 to entry: See also *potential failure* (3.12).

Note 2 to entry: Fault can be the result of a *failure* (3.7), but can exist without a failure.

[SOURCE: ISO 13372:2012, 1.8, modified — the scope of application has been added, "failure" has been replaced by "functional failure" and the Notes to entry have been changed.]

3.11
P-F interval
estimate of the period from the detection of a *fault* (3.10) [*potential failure*, P (3.12)] and *functional failure* (F) (3.8)

Note 1 to entry: *ETTF/lead time* (3.6) is equal to or less than the P-F interval.

Note 2 to entry: See also *estimated time to failure* (3.6).

Note 3 to entry: For efficient planning of a maintenance action, it is useful to know the P-F interval of a specific *failure mode* (3.9). Refer to Annex A for further explanation of P-F interval, *ETTF/lead time* (3.6) and *RUL* (3.13).

3.12
potential failure
P
point in time when a *fault* (3.10) becomes detectable

Note 1 to entry: This is sometimes also called “potential for failure”.

3.13
remaining useful life
RUL
remaining time before system health falls below a failure threshold defined by the confidence level of the *ETTF* (3.6) and the acceptable risk

Note 1 to entry: The capability to predict RUL is the goal of the prognostic process.

Note 2 to entry: Refer to Annex A for further explanation of *P-F interval* (3.11), *ETTF/lead time* (3.6) and *RUL*.

3.14
root cause
set of conditions and/or actions that occur at the beginning of a sequence of events that result in the initiation of a *failure mode* (3.9)

[SOURCE: ISO 13372:2012, 8.9, modified — the term “and” has been added.]

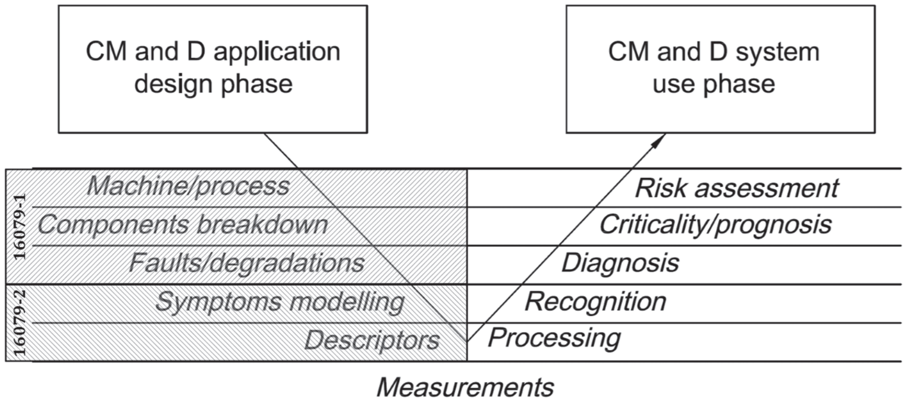
3.15
symptom
<of a fault> perception, made by means of human observations and measurements [*descriptors* (3.5)], which can indicate the presence of one or more *faults* (3.10) with a certain probability

[SOURCE: ISO 13372:2012, 9.4, modified — the scope of application has been added and the term “with a certain probability” has been added.]

4 Overview of condition monitoring procedure implementation — Set-up and diagnostics requirements

In order to implement condition monitoring and diagnostic procedures according to the faults that can occur in the wind turbine, this guideline recommends following the V-model as illustrated in ISO 13379-1.

An overview of this procedure is shown in Figure 2. The left branch corresponds to the preliminary study which prepares the necessary data for condition monitoring and diagnostics for a particular machine. The right branch of the diagram corresponds to the condition monitoring and diagnostics activities that are normally undertaken after the machine has been commissioned. Data reduction is a big issue for condition monitoring systems. Note that the data reduction process starts in the phase of the preliminary study as an outcome of the analysis process where it is prioritized which kind of failure modes it is relevant to monitor. The scopes of this document and subsequent documents such as ISO 16079-2 are indicated in Figure 2.



NOTE Source: ISO 13379-1:2012, Figure 1.

Figure 2 — Condition monitoring and diagnostics (CM and D) cycle: Design and use of the application on a machine

In accordance with ISO 13379-1, it is recommended that the preliminary study is carried out using the following, see Figure 3.

a) A FMECA (failure modes, their effects and criticality analysis) procedure. The purpose of this document is to facilitate this FMECA procedure.

b) A FMSA (failure mode and symptoms analysis) procedure, which shall be facilitated in subsequent component specific standards such as ISO 16079-2.

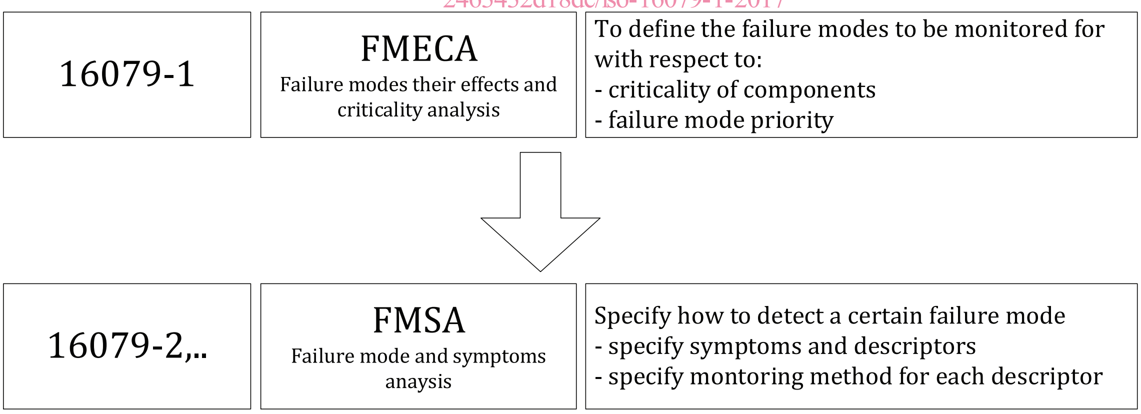


Figure 3 — Necessity of using FMECA before FMSA

