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Condition monitoring and diagnostics of wind turbines —

Part 2: **Monitoring the drive train**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 of 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 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.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 16079-2 is the second step of the procedure for carrying out the CM and D application phase according to the V-model of ISO 13379-1. In this step the monitoring strategy for the drive train is defined, based upon the prioritized failure modes which were the outcome of the FMECA procedure performed according to ISO 16079-1. Refer to Figure 1.

According to the V-Model of ISO 13379-1 and ISO 16079-1 the steps that shall be undertaken in ISO 16079-2 are as follows:

a) Decide under which operating conditions the different faults can be best observed and specify the conditions under which the symptom is most likely to be observed;

b) Identify the symptoms that can serve in assessing the condition of the machine, and that are used for diagnostics;

c) List the descriptors that are used to evaluate (recognize) the different symptoms;

d) Identify the necessary measurements and transducers from which the descriptors are derived or computed.

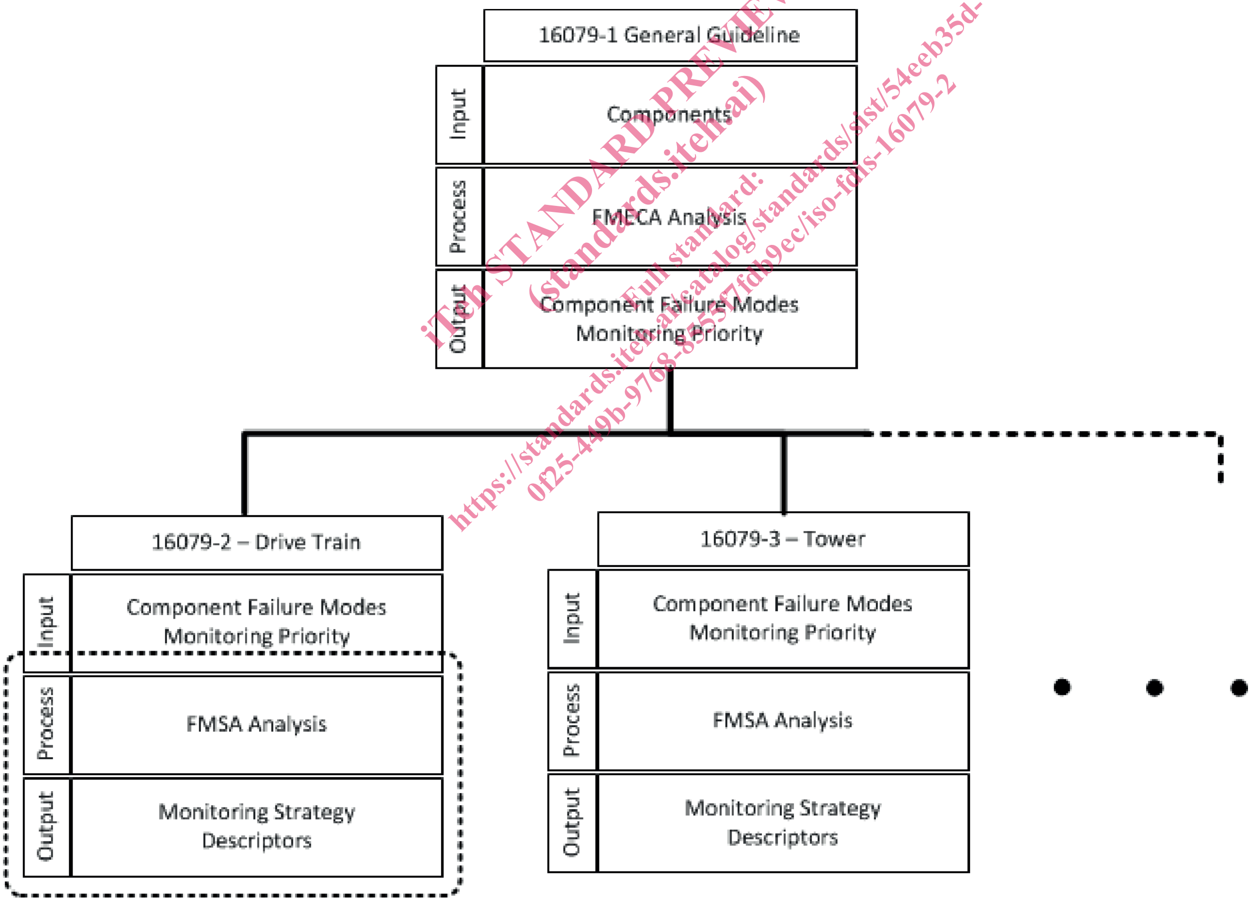


Figure 1 — The relationship of ISO 16079-2 to ISO 16079-1

NOTE The scope of this document is indicated by the dotted line.

In relation to the V-model, this International Standard describes the two last steps of the application and design phase of the Condition Monitoring System. This process shall ensure that data are available to support an efficient process in the use phase of the Condition Monitoring System. The end goal of the “Use phase process” is minimising wind turbine downtime by a risk assessment of a detected failure by means of remaining useful life (RUL) evaluation, and successive determination of maintenance timing.

The criticality and risk assessment use information from the FMECA analysis but may also feedback information into an adjustment of the initial FMECA analysis. Refer to Figure 2.

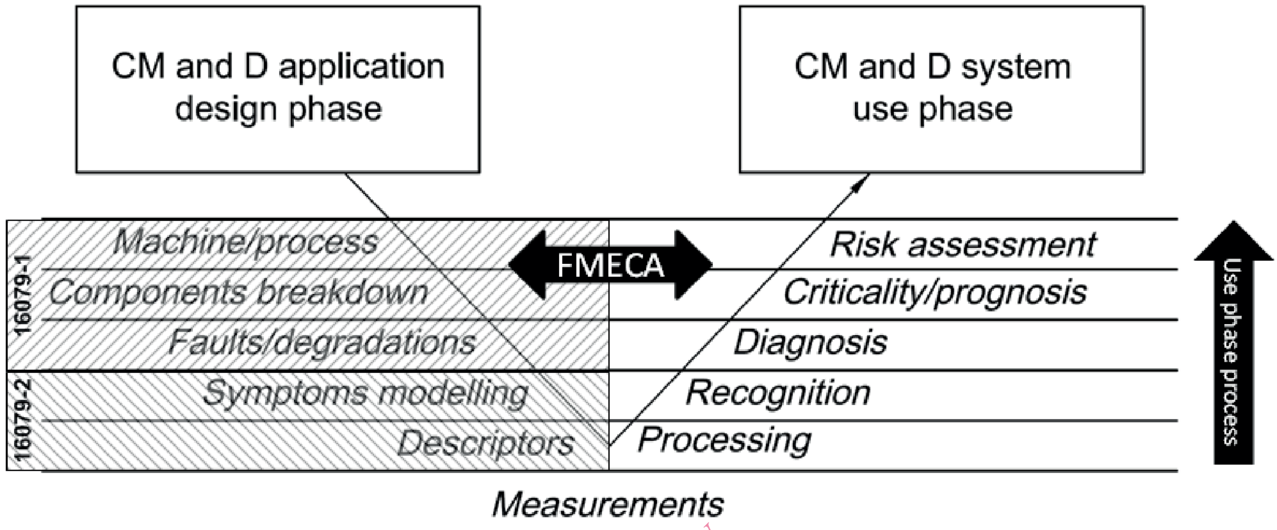


Figure 2 — Condition monitoring and diagnostics (CM and D) cycle: design and use of the application on a machine

ISO 16079-2 shows how to apply the results of an FMECA analysis made according to ISO 16079-1 by prescribing a methodology for making a Failure Mode Symptoms Analysis – FMSA with the purpose of defining symptoms and related descriptors which shall detect a particular failure mode.

In order to implement the results of the FMSA, sections with guidelines for condition monitoring of wind turbines are provided:

a. Guidelines for descriptor measurements

b. Handling of changes in operating conditions

c. Selection of transducers and transducer technology

d. Selecting transducer locations

e. Naming convention for identifying transducer locations and related descriptors

f. Evaluation criteria for descriptor measurements

g. Requirements to data for diagnosis

h. Prognosis and/or criticality assessment

i. Review of the CM & D design

   1. assessment of effectiveness of the diagnostics system

   2. cost benefit analysis

Figure 3 shows the relationship between the Monitoring strategy, Diagnostic strategy and Maintenance Strategy and how these important elements support the steps in the condition monitoring process. If the Monitoring Strategy or the Diagnostic Strategy or both, are based upon weak or missing data, it will compromise the Prognosis and the whole purpose of the condition monitoring process.

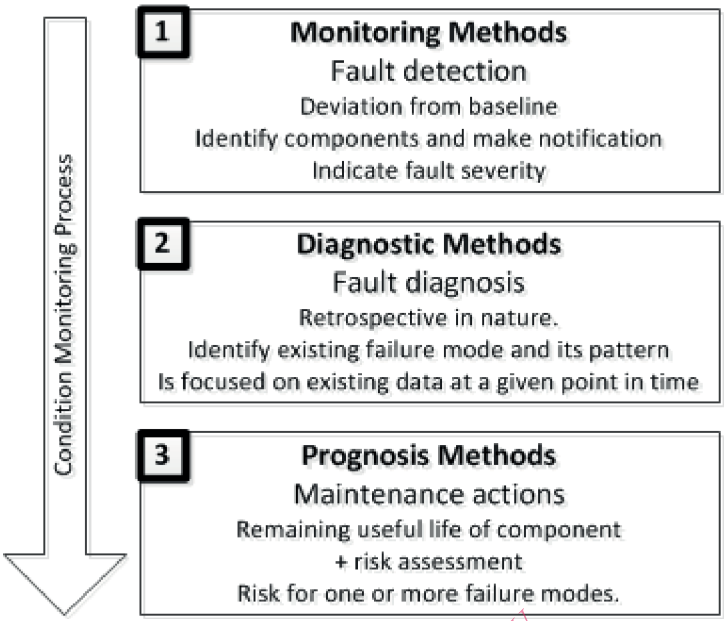


Figure 3 — Relationship between monitoring methods, diagnostic methods and maintenance actions

The selection of the monitoring method is to define:

— Where you measure, what you measure, how often you measure

In order to provide data for:

— Detecting the failure modes designated to be revealed by the condition monitoring system

— Assessing the severity of the present state of the fault

— Assessing the remaining useful lifetime of a certain component.

A weak point in the condition monitoring system setup, e.g. lack of transducers or bad transducer location, limitations in what can be measured, or too sparse data, will affect the end goal of the condition monitoring process – the prognosis.

The choice of the diagnostic method is to provide enough data for:

— Detailed analysis of a failure mode and identification of the root-cause

— Assessing the severity of the present state of the fault

— Assessing the remaining useful lifetime of a certain component.

The purpose of the prognosis is to make a prediction of remaining useful lifetime (RUL) of a component and assess the risk for related failure modes (secondary failure).

The maintenance action is based upon the data provided by the monitoring methods, the diagnostic methods and the prognosis methods, and also on knowledge of maintenance history, alarm history etc. Therefore, it is very important that not only measured data are stored, but also information about earlier alarms, maintenance actions and identification of persons, which have been involved with earlier alarm handling on the machine.

Condition monitoring and diagnostics of wind turbines —

Part 2:
Monitoring the drive train

1 Scope

This document gives guidelines for the implementation of a condition monitoring system for wind turbines. A guideline for a practical implementation of the FMSA is provided as well as a guideline for specifying best practices and minimum recommendations to the condition monitoring system used for failure mode detection, diagnostics and prognostics of the direct drive and geared wind turbine drive train:

a) Main Bearing(s)

b) Gearbox, if applicable

c) Generator (mechanical aspects)

This includes also sub components such as coupling, lubrication system etc.

The purpose of the document is to give an overview of the important subjects regarding condition monitoring of wind turbines and make references to other standards where in-depth information of the subjects is available.

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, *Condition monitoring and diagnostics of machines — Vocabulary*

ISO 16079-1, *Condition monitoring and diagnostics of wind turbines — 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 apply.

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

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

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

3.1
time waveform
sampled vibration signal recorded from the transducer

Note 1 to entry: Time waveform recordings have a certain length in time and represent the actual vibration at any instance during the recording of the time waveform.

4 List of abbreviations

Abbreviation	Explanation
TCP/IP	Transmission Control Protocol/Internet Protocol, is the suite of two protocols, TCP and IP, used to interconnect network devices on the Internet.
OPC	Open Platform Protocol. The purpose of OPC is to define an open common interface that is written once per device and then reused by any SCADA, HMI, or custom software packages. The OPC Foundation maintains the OPC standard. The OPC standard has been adopted by IEC as the IEC 62541 Standard.
MEMS	Stands for micro electro mechanical system and applies to any sensor manufactured using microelectronic fabrication techniques. These techniques create mechanical sensing structures of microscopic size, typically on silicon. When coupled with microelectronic circuits, MEMS sensors can be used to measure physical parameters such as acceleration.
IEPE	Accelerometer type using constant current supply. The abbreviation stands for: Integrated Electronics Piezoelectric. The abbreviation CCS – constant current source is also used for this type of accelerometer.
FMSA	Failure Mode Symptoms Analysis
FMECA	Failure Modes their Effect and Criticality Analysis
RUL	Remaining useful lifetime

5 Failure mode and symptoms analysis (FMSA)

5.1 General

The FMSA process is essentially an extension of the FMECA process with a focus on the symptoms produced by the identified and ranked possible failure modes that were the outcome of the FMECA analysis.

The FMSA methodology is designed to assist with the selection of monitoring techniques and strategies that will provide the greatest sensitivity to detection and rate of change of a given symptom. Thus, maximizing the confidence level in the diagnosis and prognosis of each failure modes identified for each of the components of the wind turbine drive train.

Where the confidence in a technique's sensitivity and resulting diagnosis/prognosis accuracy is questionable then the use of additional techniques for further correlation should be recommended.

Reference to ISO 16079-1 for more information on FMECA analysis.

5.2 The process of the FMSA analysis

The FMSA analysis shall be a team effort with participation of condition monitoring experts as well as participation of staff having a deep knowledge of the machine under analysis.

The essential elements of the FMSA process are:

— listing of the components involved

— listing the possible failure modes for each component

— listing the effects of each failure mode

— listing the causes of each failure mode

— listing the symptoms produced by each failure mode

— listing the most appropriate primary and feasible monitoring technique

— listing the estimated frequency of monitoring – monitoring interval

— listing the most appropriate correlation techniques. Increased diagnosis and prognosis confidence can be gained by using “Correlation Techniques” when monitored at a given frequency.

The FMSA analysis shall be performed for each component/failure mode, this can be prioritized by using the Monitoring Priority Number (MPN) of the FMECA analysis.

A practical approach is to use copies of the table below to structure the FMSA process.

Refer to the example in Annex B which shows an FMSA analysis for the most common failure modes of the wind turbine drive train.

Table 1 — Template for implementation of the FMSA analysis

Component: <RDS-PP reference>	<descriptive name from FMECA analysis>	<short name according to IEC61400-25-6>
Failure Mode	<name of failure mode from FMECA analysis>	
Cause of Failure Mode	<What is the failure mode caused by>	
Effect of failure mode	<What is the effect of the failure mode. What happens>	
Monitoring Priority Number (MPN)	<monitoring priority number from the FMECA analysis>	
P-F Timescale	<Rough assessment>	
Symptom(s)	<describe the symptom(s) indicating the failure mode>	
Descriptors	<descriptor name>	<explanation>
	<descriptor name>	<explanation>
	...	...
Primary Monitoring Technique	<describe detection method>	
Monitoring Interval	<interval between successive descriptor measurements>	
Operational State Bin Parameter	<descriptor name> if more than one correlation parameter, add more rows to the table.	

6 Descriptors for fault detection

6.1 General

The FMSA process will have provided a list of potential fault indicators – the descriptors; this clause describes how some of those descriptors may be derived. (Note! In some literature the term “characteristic value” is used instead of “descriptor”).

The format of a descriptor is a single scalar value and a timestamp. This makes descriptors very suitable for long term trending against time. Changes in the measured value of descriptors are very easily detected and correlation between different descriptor values such as vibration-based values and process values is straightforward. Any database historian can store descriptor values due to the simple format.

Regardless of the technique, the capability of a condition monitoring system relies upon the following basic elements: the number of sensors, the type of sensors, and the associated signal processing and simplification methods utilized to extract important information in the form of descriptors from the various signals and observations.

A symptom indicating a fault is expressed by the behavior of one or more descriptors with respect to:

— presence,

— absence,

— increase or decrease

— rate of change

— location(s) of the change of descriptor

— operating conditions

The more selective the descriptors are, the more selective the symptoms, and therefore, the easier the diagnosis. The descriptor selectively reduces the number of fault hypotheses when inferring from symptoms to fault.

The number of descriptors which are defined must be considered very carefully. It must be ensured that each descriptor provides value and redundancy must be avoided. The resources for performing the condition monitoring will increase with the number of descriptors, as a result of the increased number of potential alarms due to statistical outliers.

6.2 Descriptor types

The descriptors are chosen based on the FMSA, which has provided a range of characteristics of specific faults. The most common descriptor types utilized for fault detection on the wind turbine drive train can be grouped as follows and derived from:

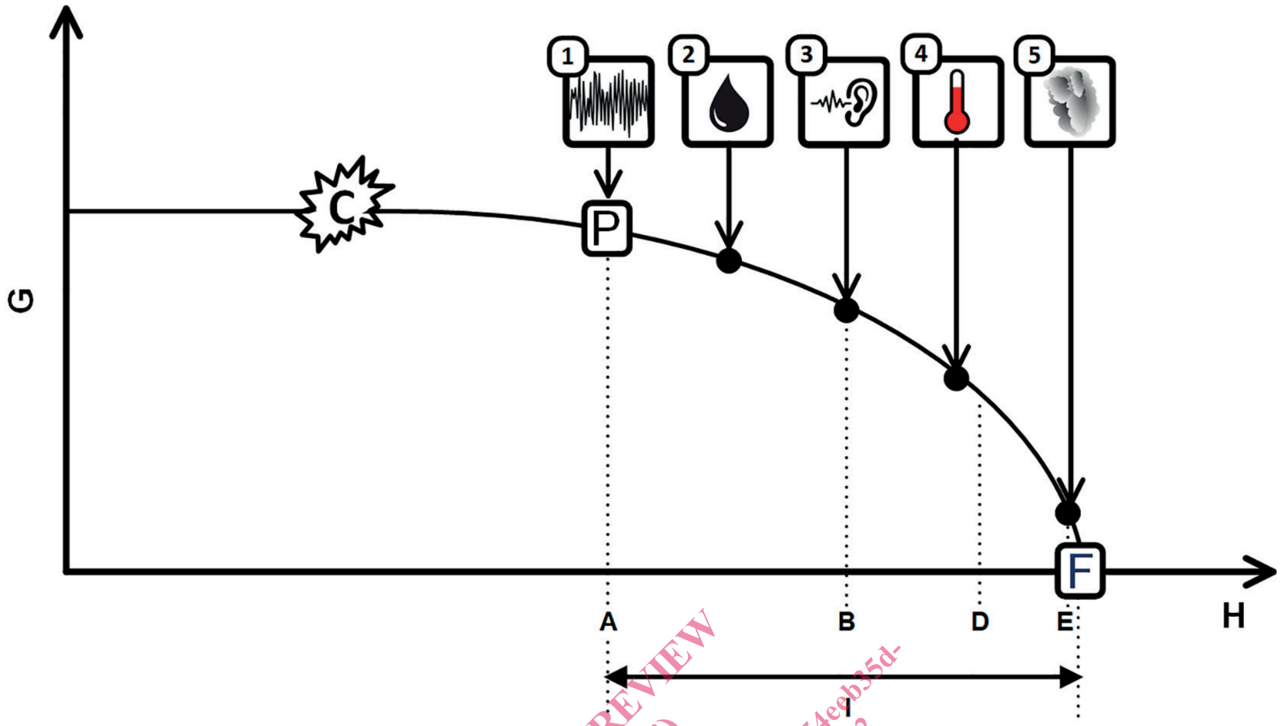
— process parameters

— rotational speed

— the vibration signal

— on-line oil analysis.

The most common types are descriptors based upon vibration. Descriptors such as rotational speed, process values like wind speed and actual power, are often used for compensating vibration-based measurements with respect to varying operating conditions. On-line oil debris measurements are used for detecting ferrous or non-ferrous particles in the oil.



Key

A Months
B Weeks
C Condition starts to change
D Days
E Minutes
F Point where functional failure occurs
G Machine condition
H Time
I $ETTF_{Tp}$ (lead time)
P Potential failure detected
1 Vibrations detected by advanced descriptors
2 Mechanical wear particles can be detected by oil analysis
3 Audible noise can be detected
4 Temperature increase detected by temperature sensors
5 Smoke detected by smell or visually

Figure 4 — Typical representation of the development of a mechanical failure

6.3 Descriptors based on process parameters– operational values

6.3.1 General

1. Process parameters or operational values are most often values acquired from the wind turbine controller or by direct measurement using a transducer. It may be values such as Temperature; Pressure; Load, Voltage; Wind Speed, Wind Direction, Pitch, Active Power, Bearing Temperatures etc.

2. Such parameters are self-contained; in that they can be trended against each other and/or against time with no further processing. For these parameters the pattern of change in value on a millisecond basis does not provide additional information over the inherent longer-term value