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INTERNATIONAL STANDARD

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Wind turbines –
Part 25-6: Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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WIND TURBINES –

Part 25-6: Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring

FOREWORD

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The text of this standard is based on the following documents:

FDIS	Report on voting
88/377A/FDIS	88/380/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61400 series, published under the general title: *Wind turbines*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 61400-25 series defines information models and information exchange models for monitoring and control of wind power plants. The modelling approach (for information models and information exchange models) of IEC 61400-25-2 and IEC 61400-25-3 uses abstract definitions of classes and services such that the specifications are independent of specific communication protocol stacks, implementations, and operating systems. The mapping of these abstract definitions to specific communication profiles is defined in IEC 61400-25-4.

Conformance to IEC 61400-25-6 requires in principle conformance to IEC 61400-25-2, IEC 61400-25-3 and IEC 61400-25-4.

The definitions in parts IEC 61400-25-1 to IEC 61400-25-5 apply also for this part 6 of the standard series.

The purpose of this part of IEC 61400 is to define an information model for condition monitoring information and to define how to use the existing definitions of IEC 61400-25-2 and to define the required extensions in order to describe and exchange information related to condition monitoring of wind turbines. The models of condition monitoring information defined in this standard may represent information provided by sensors or by calculation.

In the context of this standard, condition monitoring means a process with the purpose of observing components or structures of a wind turbine or wind power plant for a period of time in order to evaluate the state of the components or structures and any changes to it, in order to detect early indications of impending failures. With the objective to be able to monitor components and structures in approximately the same conditions, this standard introduces a concept of sorting production or power levels of a wind turbine into power bins. The power bins concept is multidimensional in order to fit the purpose of sorting complex operational conditions into comparable circumstances.

Condition monitoring is most frequently used as a predictive or condition-based maintenance technique (CBM). However, there are other predictive maintenance techniques that can also be used, including the use of the human senses (look, listen, feel, smell) or machine performance monitoring techniques. These could be considered to be part of the condition monitoring.

Condition monitoring techniques

Condition monitoring techniques that generate information to be modelled include, but are not limited to, measured or processed values such as:

- vibration measurements and analysis;
- oil debris measurement and analysis;
- temperature measurement and analysis;
- strain gauge measurement and analysis;
- acoustic measurement and analysis.

Components and structures can be monitored by using automatic measurement retrieval or via a manual process.

Condition monitoring devices

The condition monitoring functions may be located in different physical devices. Some information may be exposed by a turbine controller device (TCD) while other information may be exposed by an additional condition monitoring device (CMD). Various actors may request to exchange data values located in the TCD and/or CMD. A SCADA device may request data values from a TCD and/or CMD; a CMD may request data values from a TCD. The information exchange between an actor and a device in a wind power plant requires the use of information exchange services as defined in IEC 61400-25-3 and the additional required exchange services specified in this part 6. A summary of the above is depicted in Figure 1.

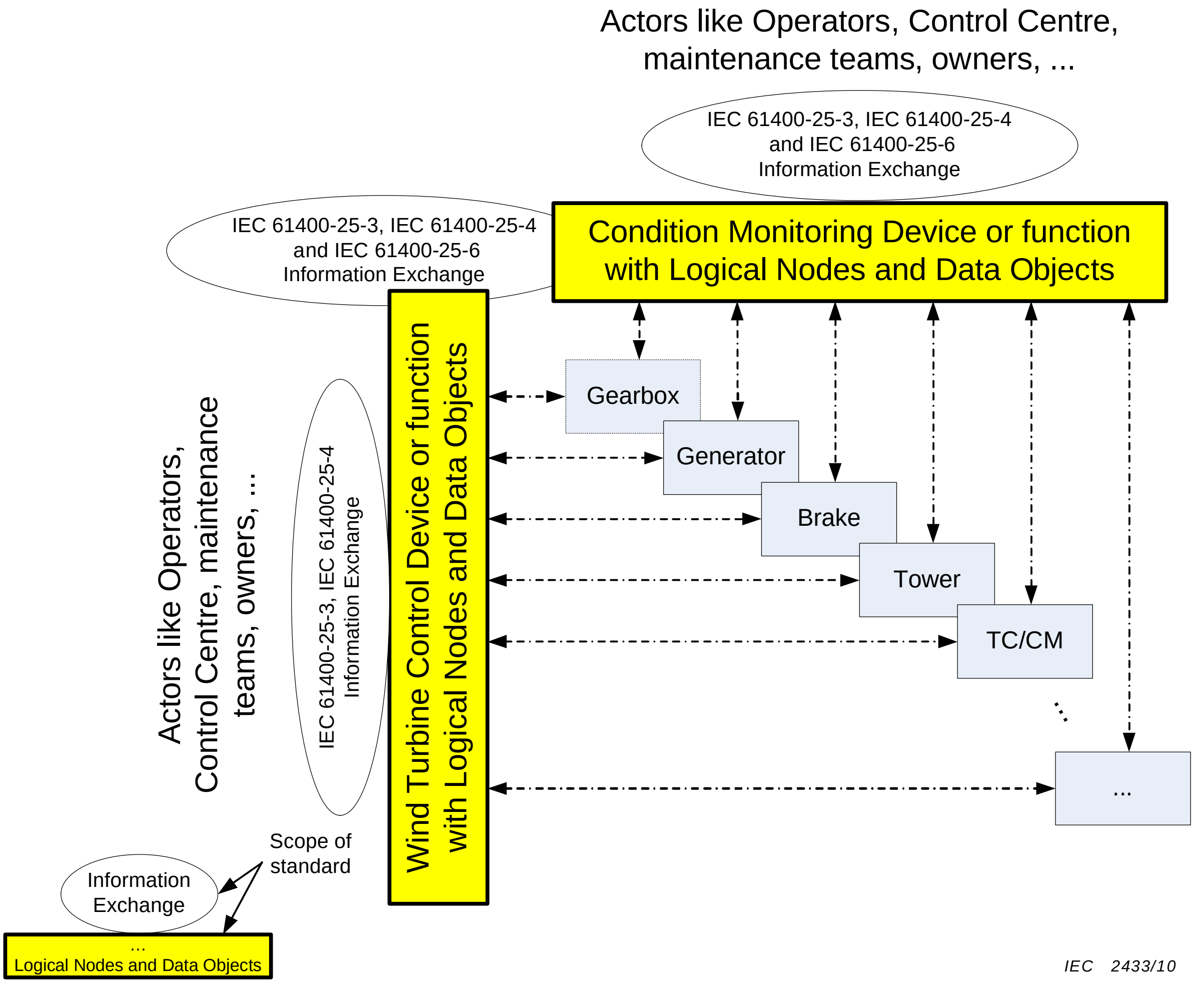


Figure 1 – Condition monitoring with separated TCD/CMD functions

The state of the art in the wind power industry is a topology with separated devices for control and condition monitoring applications. Based on this fact, the information and information exchange modelling in the present document is based on a topology with a TCD and a CMD.

IEC 61400-25-6 must be perceived as an extension of the IEC 61400-25 series of standards with the focus on condition monitoring.

WIND TURBINES –

Part 25-6: Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring

1 Scope

This part of 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.

Figure 2 illustrates the information flow of a system using condition monitoring to perform condition based maintenance. The figure illustrates how data values are refined and concentrated through the information flow, ending up with the ultimate goal of condition based maintenance – actions to be performed via issuing work orders to maintenance teams in order to prevent the wind power plant device to stop providing its intended service.

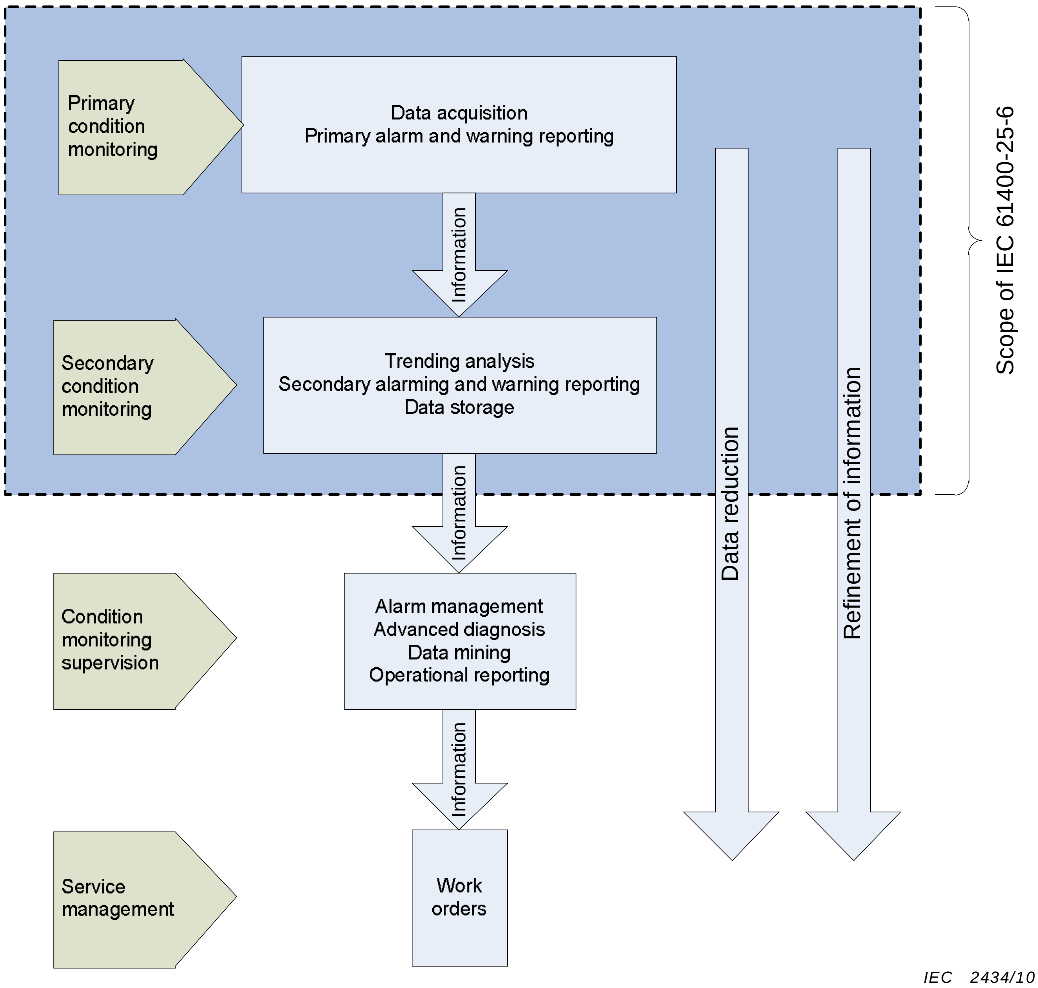


Figure 2 – Schematic flow of condition monitoring information

Condition monitoring is mainly based on the following kinds of information.

- Time waveform records (samples) of a specific time interval to be exchanged in real-time or by files for analysis (e.g. acceleration, position detection, speed, stress detection).
- Status information and measurements (synchronized with the waveform records) representing the turbine operation conditions.
- Results of time waveform record analysis of vibration data (scalar values, array values, statistical values, historical (statistical) values, counters and status information).
- Results of, for example, oil debris analysis.

It is the purpose of this standard to model condition monitoring information by using the information modelling approach as described in 6.2.2 of IEC 61400-25-1 and by extending the existing information model as specified in Clause 6 of IEC 61400-25-2, the information exchange models specified in Clause 9 of IEC 61400-25-3 and the mapping to communication profiles as specified in IEC 61400-25-4.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 61400-25-1:2006, *Wind turbines – Communications for monitoring and control of wind power plants – Overall description of principles and models*

IEC 61400-25-2:2006, *Wind turbines – Communications for monitoring and control of wind power plants – Information models*

IEC 61400-25-3:2006, *Wind turbines – Communications for monitoring and control of wind power plants – Information exchange models*

IEC 61400-25-4, *Wind turbines – Communications for monitoring and control of wind power plants – Mapping to communication profile*

IEC 61400-25-5, *Communications for monitoring and control of wind power plants – Conformance testing*

IEC 61850-7-2:2003, *Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)*

IEC 61850-7-3, *Communication networks and systems in substations – Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes*

ISO 10816 (all parts), *Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts*

ISO 13373-1:2002, *Condition monitoring and diagnostics of machines – Vibration condition monitoring – Part 1: General procedures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61400-25-1 and the following apply.

3.1
actor
any entity that receives (sends) data values from (to) another device

Examples of actors could be SCADA systems, maintenance systems, owner, etc.

3.2
mandatory
term applied where specific content must be provided in order to comply with this standard

3.3
optional
term applied where specific content might be provided in compliance to this standard

3.4
conditional
term applied where specific content defined must be provided depending on stated conditions in compliance to this standard

3.5
scalar value
data type representing a quantity which can be described by a single number, such as a temperature

3.6
data file
in a computer system, an entity of data available to system users (including the system itself and its application programs) that is capable of being manipulated as an entity (for example, a file can be moved from one file directory to another as a whole entity)

The file must have a unique name within its own directory. Some operating systems and applications describe files with given formats by giving them a particular file name suffix. (The file name suffix is also known as a file name extension.)

3.7
peak value
maximum excursion of a time wave form from its mean value within a specific time interval

3.8
peak-to-peak value
difference between the positive and negative extreme values of a time wave form within a specific time interval

3.9
crest factor
ratio of the peak value of a time waveform to the RMS value of the time waveform within a specific time interval

A crest factor is also named as a "peak-to-RMS-ratio".

3.10
root mean square value
RMS
measure of the level of a signal calculated by squaring the instantaneous value of the signal, averaging the squared values over time, and taking the square root of the average value

The RMS value is the value which is used to calculate the energy or power in a signal.

3.11
band pass
BP
filter that only passes energy between two frequencies which are named as lower and upper cut-off frequencies

Band pass filters can be fixed, where the cut-off frequencies are constant, and can be variable, where the cut-off frequencies are a percentage of the centre frequency – named as constant percentage bandwidth filters.

3.12
order
multiple of specific reference frequencies

An FFT spectrum plot displayed in orders will have multiples of running speed along the horizontal axis. Orders are commonly referred to as 1x… for first of running speed, 2x... for the second order of the running speed, and so on. When an order is an integral number of the running speed, it may be referred to as a harmonic of the running speed, e.g. 2x… could be referred to as the 2nd harmonic of the running speed.

3.13
order analysis
ability to study the amplitude changes of specific signals that are related to the rotational aspects of a device

3.14
UFF 58
de-facto standard file format for storing noise and vibration information

The definition of the de facto standard UFF 58 can be accessed from the following link:
http://www.sdrl.uc.edu/universal-file-formats-for-modal-analysis-testing-1

3.15
high frequency band pass
HFBP
overall measurement covering a high frequency range of 1 kHz to 10 kHz

Bearing faults often result in one or more resonance effects in the high frequency range. Measurements limited to this frequency range are therefore well suited for detecting bearing faults.

4 Abbreviated terms

CDC	Common data class
CM	Condition monitoring (function)
CMD	Condition monitoring device
DC	Data class
ING	Common data class for integer setting value (see IEC 61850-7-3)
LCB	Log control block

LD Logical device

LN Logical node

LPHD Logical node physical device information

RCB Report control block

RMS Root mean square

SAV Common data class for sampled analogue values (see IEC 61850-7-3)

SHS Statistical and historical statistical data (as defined in IEC 61400-25-2, Annex A)

SMV Sampled measured values; some times short: SV = sampled values

TC Turbine controller (function)

TCD Turbine controller device

TMF Tooth meshing frequency

TOC Turbine operation conditions

WPP Wind power plant

WT Wind turbine

Abbreviated terms applied in data classes shall be as listed in Table 1.

Table 1 – Abbreviated terms applied

Term	Description
1Ps	1st planetary stage
2Ps	2nd planetary stage
A	Current
AC	AC
Acc	Accelerometer
Ack	Acknowledge
Acs	Access
Act	Actual
Alm	Alarm
Alt	Altitude
An	Analogue
Ane	Anemometer
Ang	Angle
At	Active (real)
Atv	Activate
Av	Average
Avl	Availability
Ax	Axial
Az	Azimuth
bin	Active power bin
Bec	Beacon
Bl	Blade
Blk	Blocked

Term	Description
Brg	Bearing
Brk	Brake
Bn	Bin
Cab	Cable
Ccw	Counter clockwise
Ch	Characteristic
Chg	Change
Chk	Check
Chrg	Charge
Cl	Cooling
Cm	Command
Cnv	Converter
Ct	Counting
Ctl	Control
Cw	Clockwise
d	Description
Dat	Data
Db	Deadband
DC	DC (direct current)
Dcl	Dc-link
De	Drive end
Deb	Debris
Dec	Decrease

Term	Description
Dehum	De-humidifier
Del	Delta
Det	Detection
Dir	Direction
Disp	Displacement
Dly	Daily
Dmd	Demand
Dn	Down
Drv	Drive
Egy	Energy
Elev	Elevator
Emg	Emergency
En	Enable
Ent	Entrance
Ety	Empty
Evt	Event
Ex	External
Ext	Excitation
Flsh	Flash
Flt	Fault
Fr	Front
Ftr	Filter
Gbx	Gearbox
Gn	Generator
Gra	Gradient
Gri	Grid
Gs	Grease
Hi	High
Hly	Hourly
Hor	Horizontal
Hss	High speed stage
Ht	Heating
Htex	Heat-exchanger
Hum	Humidity
Hy	Hydraulic
Hz	Frequency
Ice	Ice
Id	Identifier
Idl	Idling
Inc	Increase
Inj	Injection
Inl	Inline
Inlet	Inlet
Inst	Instantaneous

Term	Description
Intl	Internal
Iss	Intermediate speed stage
Lev	Level
Lift	Lift
Lim	Limit
Lo	Low
Log	Log
Lt	Lateral
Lu	Lubrication
Lum	Luminosity
Man	Manual
Max	Maximum
Met	Meteorological
Min	Minimum
Mly	Monthly
Mn	Main
Mod	Mode
Mul	Multiplier
Mx	Measurement
Nam	Name
Nac	Nacelle
NDe	Non Drive end
Num	Number (size)
Of	Off line
Oil	Oil
Op	Operate, operating
Oper	Operator
Ov	Over
Pc	Power class
Per	Period, periodic
PF	Power factor
Ph	Phase
Pl	Plant
Plu	Pollution
Pmp	Pump
Pos	Position
Pres	Pressure
Prod	Production
Ps	Planetary stage
Pt	Pitch
Ptr	Pointer
Pwr	Power
q	Quality
Ra	Radial

Term	Description
Rdy	Ready
React	Reactive
Rep	Report
Rms	Root-mean-square
Rng	Range
Roof	Roof
Rot	Rotor (windturbine)
Rr	Rear
Rs	Reset
Rtr	Rotor (generator)
Sdv	Standard deviation
Seq	Sequence
Sev	Severity
Shf	Shaft
Sld	Structural load
Smk	Smoke
Smp	Sampled
Snd	Sound
Sp	Setpoint
Spd	Speed
St	Status
Sta	Stator
Stdby	Standby
Stg	Stage (1, 2, 3, etc.)
Stn	Strain
Stop	Stop
Str	Start
Sw	Switch
Sys	System

Term	Description
T	Timestamp
Tm	Timer
Tmp	Temperature
Torq	Torque
Tot	Total
Tow	Tower
Tra	Transient
Trd	Transducer
Trf	Transformer
Trg	Trigger
Tur	Turbine
Un	Under
Up	Upwards direction (opposite to Down (Dn))
Urg	Urgent
V	Voltage
VA	Apparent power
Val	Value
Vals	Values
Ver	Vertical
Vib	Vibration
Vis	Visibility
Wd	Wind (power)
Wly	Weekly
Wup	Windup
Xdir	X-direction
Ydir	Y-direction
Yly	Yearly
Yw	Yaw

5 General

5.1 Overview

The primary objective of condition monitoring is to detect potential failures before damage or destruction of a wind turbine.

In condition monitoring systems, predefined triggers are applied to initiate a sequence of events, for example issuing an alarm to the local SCADA system or sending a message to a monitoring centre in order to prevent further damage on components or structures. In general, such messages can be used by a condition monitoring supervision function to generate actionable information which can be used by a service organization to create work orders and initiate actions. Figure 2 illustrates the information flow of a system using condition monitoring to perform condition based maintenance.

Condition monitoring is mainly associated with the following kinds of information.

a) Time waveform records (samples) of a specific time interval to be exchanged in real-time or by files for analysis (e.g. acceleration, position detection, speed, stress detection).

b) Status information and measurements (synchronized with the waveform records) representing the turbine operation conditions.

c) Results of time waveform record analysis of vibration data (scalar values, array values, statistical values, historical (statistical) values, counters and status information).

d) Results of, for example, oil debris analysis.

The condition monitoring information can be described by specified attributes, trigger options and file structures and common data classes for the information as follows:

– monitoring bin;
– monitoring measurement description;
– scalar data;
– arrays of scalar data;
– vector data.

It is the purpose of this standard to model condition monitoring information by using the information modelling approach as described in 6.2.2 of IEC 61400-25-1 and by extending the existing information model as specified in Clause 6 of IEC 61400-25-2, the information exchange models specified in Clause 9 of IEC 61400-25-3 and the mapping to communication profiles as specified in IEC 61400-25-4.

The following extensions to the IEC 61400-25 series of standards are required to meet the needs from condition monitoring:

- The information model as defined in IEC 61400-25-2 shall be extended with the information related to condition monitoring. For example, the WTUR for status information of the condition monitoring device and WALM for inclusion of alarms generated by the condition monitoring system into the general alarm overview shall be extended. Required extensions are specified in Clause 6, 7 and 8 of the present standard.
- IEC 61400-25-3 and IEC 61400-25-4 do not include services to exchange files. File transferring is a requirement in condition monitoring systems. Until IEC 61400-25-3 includes services to exchanges files and IEC 61400-25-4 details the protocol aspects, which file transfer protocol may be chosen is outside the scope of this standard.

By extending the existing standards for the wind power information model, a high degree of reuse is targeted.

5.2 Condition monitoring information modelling

The binding of a specific condition monitoring information to a specific sensor and a specific location of a wind turbine shall be specified as follows:

a) definition of the coordinate system applied for specifying direction and angles; see 5.3;

b) attributes for identifying the environment for a condition monitoring measurement – active power bin concept; see 5.4;

c) attributes for identifying a sensor type, angular orientation, direction of motion, and physical location in a wind turbine such as shaft number, bearing position as well as identification of the primary measurement object for a sensor. For further details, see Clause 6.

The sensor and location specifications in this standard are in principle coordinated with the specifications defined in ISO 13373-1, where coordination has been applicable.

As the technological evolution for condition monitoring is evolving continuously, the specifications defined in this standard also define how extensions can be created.

5.3 Coordination system applied for identifying direction and angles

In order to be able to unambiguously identify a sensor location, a coordination system is used as a reference to specify all directions and angles. Figure 3 shows an X, Y, Z coordinate system superimposed on the wind turbine drive train. The drive train is seen in the direction of the wind. It is defined that the Z direction is always the same as the wind direction.

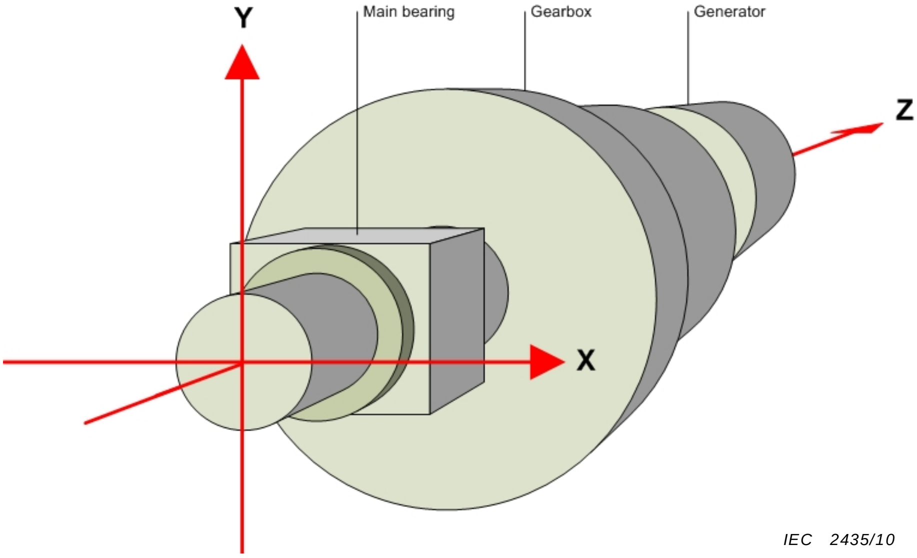


Figure 3 – Reference coordinates system for the drive train

Table 2 lists other commonly used designations as related to the reference coordinate system defined in this standard.

Table 2 – Coordinate system and wind turbine related characteristics

Used in this standard	Other designations
Z direction	Downwind (as opposed to Upwind)
	Axial (wind direction)
X direction	Lateral
	Transverse
	Horizontal
	Right (as opposed to Left)
Y direction	Vertical
	Up (as opposed to Down)

5.4 Active power bin concept

In order to describe the environment for a set of condition monitoring measurements, the power bin concept has been developed. A wind turbine operates in principle over a wide range of wind speeds causing a large variety of loads on the tower, blades and related mechanical structures. An adaptive monitoring technique is often applied to secure a higher degree of reliability and repeatability of measurements used to detect developing faults in the full operating range, thus reducing the risk of false alarms. In order to adapt to the varying operating conditions, data can be stored in several “active power bins”. The basic principle of condition monitoring is to observe the evolution of specific measured variables by comparing new measurements with old. The effect of changes in operational conditions can be limited by comparing information belonging only to the same “active power bin”.

Active power levels are used for the adaptive monitoring technique rather than the wind speed as the vibration level measured and the stress on the turbine components are found to be closely related to the active power production of the turbine. Using the active power level as measurement trigger, it is also ensured that vibration measurements are recorded only when a wind turbine is producing active power.

An example of vibration data which are individually compared to alarm limits for five different “active power bins” with individual alarm trigger levels is given in Figure 4.

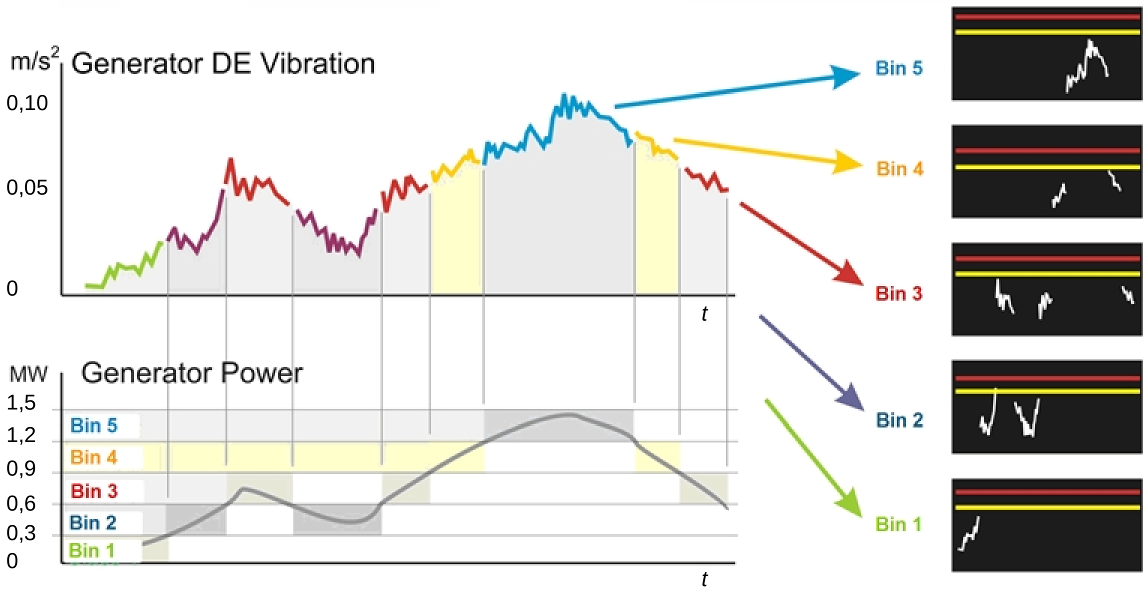


Figure 4 – Active power bin concept

6 Common data class attributes

6.1 General

Attribute types specified in Clause 7 of IEC 61400-25-2 are applicable as attributes for the common data classes specified in Clause 7 of this standard as well as the attributes defined in this clause.

The purpose of the attributes specified in 6.2.2.2 up to 6.2.4 is to describe the sensor characteristics, the position of the sensor and the primary aim for the individual sensors. In addition, it is defined how the condition monitoring attributes can be extended for individual purposes.

6.2 Attributes for condition monitoring measurement description

6.2.1 General

A condition monitoring measurement description shall provide a link between the real implementation and the modelling specified in this standard and shall be as defined as in Table 3.

Table 3 – Attributes used for measurement description

Data attribute name	Attribute type	Value/Value range
trd	VISIBLE STRING 255	Sensor
shfNum	INT8U	ShaftNumber
brgPos	INT8U	BearingPosition
mxType	ENUMERATED	ISORms | HFBP | TMF | 2TMF | 3TMF | 1MA | 2MA | LFRms | TWF | For further descriptions of the mxType values, see Table 8 in this standard.

6.2.2 Condition monitoring sensor (trd)

6.2.2.1 General

This subclause defines a convention for providing information about a sensor. The provided information is the location, the sensor type and the spatial orientation. The definitions are combined in a way that provides unambiguous sensor identification. Five definitions are used for the sensor identification; see Table 4.

The sensor shall, as a minimum, be identified by its “location”. The designations 2, 3, 4 and 5 are optional and can be used in any combination. The sequence of the designations shall be as specified in Table 4.

Table 4 – Sensor identification convention

	Definition		Length	Example	Comment	M/O/C
1	Location	Component name	No limit	GbxIss-	Gbx and Iss. See Table 1	M
		Other identification		Pos1-	Free text [a, b]	
2	Sensor type code		Two letters	AC	Accelerometer. See Table 5	O
3	Angular orientation		Three digits	280	0° to 360°	O
4	Sensor axis orientation		One letter	R	Radial. See Table 6	O
5	Direction of motion		/ + One letter	/N	Normal. See 6.2.2.5	O

[a] The location identification must be followed by a “-“.

[b] If a numbering scheme is used, it is recommended to let numbers increase in the Z direction.

EXAMPLE Application of specified convention could be as follows: GbxIss-AC090R/N - Gearbox Intermediate Speed Stage, single-axis accelerometer, positioned 90° counter clockwise from zero, mounted radial, normal motion.

6.2.2.2 Sensor type code

The sensor type shall be designated by a two letter code as specified in Table 5.

Table 5 – Sensor type code

Code	Sensor type
AC	Single-axis accelerometer
AV	Single-axis accelerometer with internal integration
AB	Biaxial accelerometer
AT	Tri-axial accelerometer
AE	Acoustic emission
BS	Blade monitoring
CR	Current probe
DP	Displacement probe
DR	Displacement probe used as phase reference
MP	Magnetic pick-up (shaft speed/phase reference)
MI	Microphone
OD	Oil debris sensor
OP	Optical sensor
PD	Dynamic pressure
PS	Static pressure
SG	Strain gauge
SW	Stress wave
TC	Temperature-thermocouple
TR	Resistance temperature detector
TT	Torque sensor
TO	Torsion sensor
VL	Velocity sensor
VT	Voltage
OT	Other

6.2.2.3 Angular orientation

The angular position of a sensor shall be measured from zero reference located at 3 o'clock when the drive train is viewed in the Z direction as shown in Figure 5.

The green arrow indicates the angular location of a sensor. The angle increases counter clockwise from 0° to 360°.

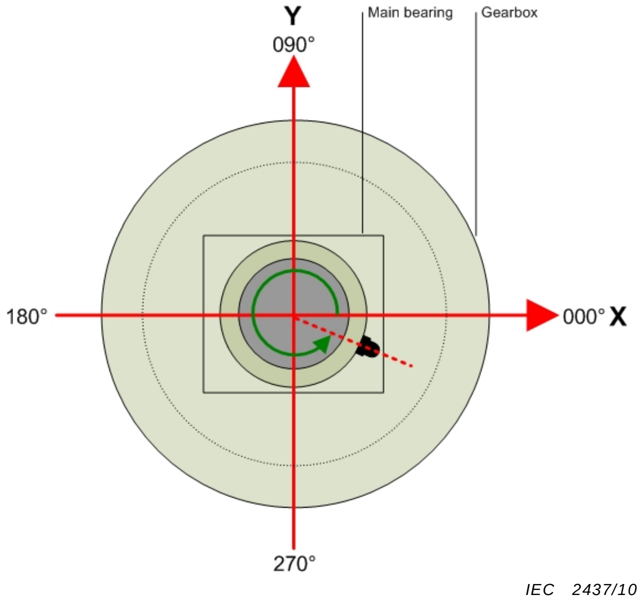


Figure 5 – Sensor angular orientation

6.2.2.4 Sensor sensitive axis orientation

The direction of the sensor sensitive axis shall be coded by a single letter as defined in Table 6.

Table 6 – Reference code for sensor sensitive axis orientation

Code	Direction	Description
R	Radial	Sensor sensitive axis perpendicular to and passes through the shaft axis
A	Axial	Sensor sensitive axis parallel to the shaft axis
T	Tangential	Sensor sensitive axis perpendicular to a radial in the plane of shaft rotation
H	Horizontal	Sensor sensitive axis located at 000° or 180° only
V	Vertical	Sensor sensitive axis located at 090° or 270° only

6.2.2.5 Direction of motion

The final two characters of the measurement location identification code for a sensor shall either be /N (normal) or /R (reverse) to identify the direction of the mounted sensors as shown in Figure 6.

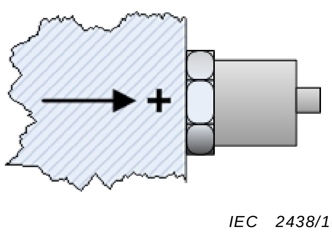


Figure 6 – Sensor motion identification

Motion into the sensor shall be defined as positive (+), motion away from the sensor is designated as negative (–) as shown in Figure 7.

Axial machine motion in the “Z” direction shall be designated as positive. When a sensor is mounted in a way that positive motion towards the sensor produces a positive signal output, the sensor shall be designated “/N” (normal). Likewise, when motion in the Z direction produces a negative signal output, the sensor shall be designated “/R” (reverse).

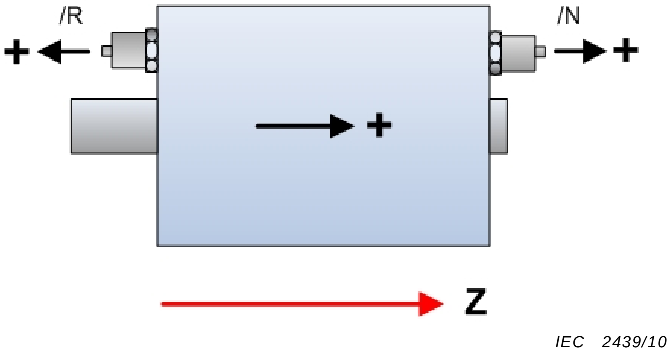


Figure 7 – Sensor normal and reverse motion

The angular orientation shall define the direction of motion for radial mounted sensors. Therefore, a default of /N (normal) should be utilized for sensors mounted radial.

6.2.3 Shaft number (shfNum) and bearing position (brgPos)

The data type of the shfNum shall be VISIBLE STRING255.
The data type for brgPos shall be VISIBLE STRING255

In order to characterize condition monitoring measurements, an attribute for description of the physical sensor allocation is required. Sensors mounted on the drive train of a wind turbine can be referred as follows:

a) a wind turbine component on the drive train,

b) a particular shaft of a wind turbine component, and

c) a particular bearing of a wind turbine component.

Figure 8 shows the principle of shaft and bearing numbering used to identify a particular location on a wind turbine gearbox with a three planetary stage gearbox. The shafts and bearings shall be identified with increasing numbers in the Z-direction from the rotor hub to the electrical generator as illustrated in Figure 8.

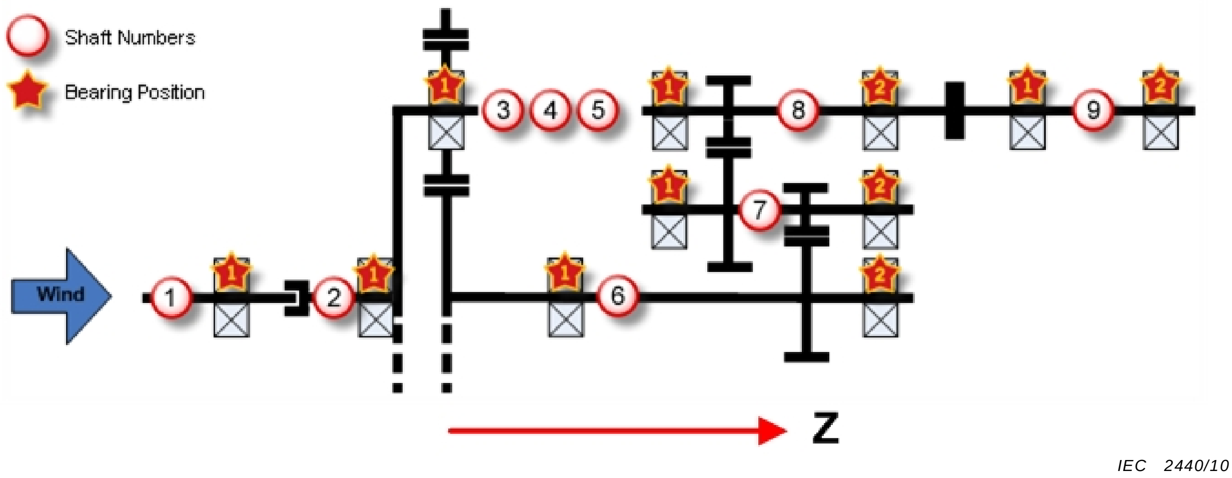


Figure 8 – Principle of shaft and bearing numbering along a drive train

Table 7 identifies in more detail the individual shafts and stages of the gearbox exemplified.

Table 7 – Gearbox shaft and bearing identification

Shaft number	Component	Bearing position	Component or subcomponent
1	Main shaft	1.1	Main bearing
2	Carrier	2.1	Carrier bearing
3, 4, 5	Planet shaft 1, 2 and 3	3.1, 4.1, 5.1	Planet bearings
6	Sun shaft	6.1, 6.2	Sun shaft bearings
7	Intermediate shaft	7.1, 7.2	Intermediate shaft bearings
8	High speed shaft	8.1, 8.2	High speed shaft bearings
9	Generator shaft	9.1, 9.2	Generator shaft bearings

The following specifications shall be applied for describing vibration measurements for a wind turbine.

a) Overall vibration measurements or band pass measurements which cannot be related to a specific shaft or bearing often cover a wide frequency range, measured by sensors located on the different parts of the turbine that cannot be related to specific shafts or bearings. Such measurements shall be identified by the location of the sensor using the convention defined in 6.2, and the name of the particular measurement.

b) Measurements which can be referred to a specific shaft, such as vibration level at shaft running speed (1st order measurement) or vibration level at a tooth meshing frequency shall be referred to by the location of the sensor using the convention defined in 6.2, the shaft number and the name of the measurement. The vibration level at tooth meshing frequencies for gears having parallel shafts such as spur gears, helical gears, and herringbone gears shall always be referred to the shaft with the highest running speed.

c) Vibration levels which can be referred to a specific bearing, such as the vibration level at the ball passing frequency of the outer ring shall be referred to by the location of the sensor using the convention defined in 6.2, the shaft number and bearing position.

6.2.4 Measurement type (mxType)

The data type of the data attribute mxType shall be ENUMERATED.

The data attribute names shall be separated into two groups as specified in Table 8. The first group of data name attribute values is specified by this standard. The coupling of semantic and value is mandatory, i.e. no value other than TMF shall be used or defined for a measurement that is a vibration level tooth meshing frequency. The other group of data name attribute values are vendor specific, i.e. the frequency spectrum 0 kHz – 10 kHz can be coupled to the value FFT1 by one vendor and to FS by another vendor.

The objective of defining a set of mandatory data name attributes is to create a uniform background for evaluating the actual status of a wind turbine.

A set of vendor specific data name attributes are examples for illustration of the extendibility of this standard due to the fact that different vendors have developed different concepts for condition monitoring on wind turbines, and a capability for customizing of the data name attributes is required in order to have an extendable and acceptable standard for condition monitoring.

Table 8 – mxType values

Value		Explanation
MANDATORY Standardized values	ISORms	Overall RMS vibration level according to ISO 10816
	HFBP	High frequency band pass vibration level (1 kHz – 10 kHz)
	TMF	Vibration level tooth meshing frequency
	2TMF	Vibration level at 2nd order tooth meshing frequency
	3TMF	Vibration level at 3rd order tooth meshing frequency
	1MA	Vibration level at shaft running speed. 1st order magnitude
	2MA	Vibration level at shaft running speed. 2nd order magnitude
	LFRms	Overall RMS, low frequency range (0,1 Hz – 10 Hz) (see Note)
	TWF	Time wave form
OPTIONAL Examples of vendor specific values	BP1	Vibration level in the frequency range 4 kHz – 6 kHz
	BP2	Vibration level in the frequency range 100 Hz – 500 Hz
	.	
	.	
	.	
	BPFO	Vibration level at the ball passing frequency outer ring
	BPFI	Vibration level at the ball passing frequency inner ring
	FFT1	Frequency spectrum 0 kHz – 10 kHz
	ES1	Envelope spectrum 0 Hz – 100 Hz (BP 1 000 Hz – 10 000 Hz)
NOTE There is no specific requirement to a 3 dB cut-off level at 0,1 Hz.		

The absolute levels of the measurements are not essential, but the measurements shall be repeatable, i.e. the measurement repeatability shall be maintained in order to compare the values.

There are no specific requirements to e.g. frequency resolution, bandwidth, etc. The essence is that the specified names shall be kept unique.

7 Common data classes for wind turbine condition monitoring

7.1 General

All common data classes that are specified in IEC 61400-25-2 can be applied for condition monitoring. Additionally, the following common data classes are specified related to condition monitoring:

a) condition monitoring bin (CMB);

b) condition monitoring measurement description (CMMD);

c) condition monitoring scalar value (CMSV);

d) common data class scalar array value (SVA);

e) condition monitoring scalar value array (CMSVA);

f) condition monitoring complex value (CMCV);

g) condition monitoring vector value (CMVV).

The CDC "condition monitoring scalar value" (CMSV) is based on the CDC "measured value" (MV). The CDC "condition monitoring vector value" (CMVV) is based on the CDC "condition monitoring complex value" (CMCV). The CDC "scalar value array" (SVA) is used as a base for the CDC "condition monitoring scalar value array" (CMSVA).

7.2 Common data classes defined in IEC 61400-25-2

The common data classes specified or referenced in Clause 7 of IEC 61400-25-2 are applicable for modelling condition monitoring information as well as the common data classes defined in the following subclauses.

7.3 Condition monitoring bin (CMB)

CMB common data class includes:

– references to the measured values that define if this bin is active or not,

– a minimum and a maximum for each measured value,

– the status of the bin. This means that the “bin” is active or not. The “bin” is active when all the measured values are inside the ranges configured for that bin.

Common data class CMB shall be defined as specified in Table 9.

Table 9 – CDC: Condition monitoring bin (CMB)

CMBC class					
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from data class (see Table 20 of IEC 61850-7-2)				
DataAttribute					
Status value					
stVal	BOOLEAN	ST	dchg	TRUE if the bin is active	M
Configuration					
ref1	ObjectReference	CF		Reference to the DataObject on which the bin classification is based (e.g. WTUR.W or WGEN.GnOpMod)	M
min1	FLOAT32	CF		Lower boundary of referenced value for this bin	M
max1	FLOAT32	CF		Upper boundary of referenced value for this bin	M
Descriptive and extension information					
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING 255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.1 of IEC 61400-25-3					

Multi dimensional active power bins shall be defined by adding as many triples of the DataAttributes ref, min and max as dimensions are required. The index shall be 1, 2, to n.

The bins shall be defined uniquely for each dimension.

The unit of the DataAttributes “min” and “max” shall be as specified in the referenced DataObject referenced by DataAttribute “ref”.

All names of DataObjects for the bin configuration shall start with “Bn”.

7.4 Condition monitoring measurement description (CMMD)

Common data class CMMD shall be defined as specified in Table 10.

Table 10 – CDC: Condition monitoring measurement description (CMMD)

CMMD class					
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from data class (see Table 20 of IEC 61850-7-2)				
DataAttribute					
Description					
trd	VISIBLE STRING 255	DC			O
shfNum	INT8U	DC			O
brgPos	INT8U	DC			O
mxType	ENUMERATED	DC		ISORms | HFBP | TMF | 2TMF | 3TMF | 1MA | 2MA | LFRms | TWF | (definitions and extensions, see Table 8)	O
d	VISIBLE STRING255	DC			O
dU	UNICODE STRING 255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.1 of IEC 61400-25-3					

7.5 Condition monitoring scalar value (CMSV)

CMSV common data class represents a measured value in the condition monitoring system and the definition of its range limits depending on the active bin at any moment. Any data configured to use this common data class should assure that only one of the configured bins is active at a time. “Range” attribute of MxVal represent the current status of this measured value. This range depends on the active bin.

Common data class CMSV for scalar values applied in condition monitoring shall be defined as specified in Table 11.

Table 11 – CDC: Condition monitoring scalar value (CMSV)

CMSV class					
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Explanation and value/range**	**M/O/C**
DataName	Inherited from data class (see Table 20 of IEC 61850-7-2)				
Data					
MxVal	MV			Condition monitoring measurement	M
DMx	CMMD			Measurement description	O
DataAttributes					
			Measurements		
actBnRef	ObjectRefer-ence	MX	dchg	Reference to the CMD DataObject, the measured value belongs to at the current time	O
			Configuration, description		
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.1 of IEC 61400-25-3					

7.6 Scalar value array (SVA)

Common data class SVA shall be defined as specified in Table 12.

Table 12 – CDC: Scalar value array (SVA)

SVA class					
Attribute Name	**Attribute Type**	**FC**	**TrgOp**	**Value/Value Range**	**M/O/C**
DataName	Inherited from Data Class (see Table 20 of IEC 61850-7-2)				
DataAttributes					
			Measurements		
instMagI	ARRAY [0..numSV] OF INT32	MX			O
instMagF	ARRAY [0..numSV] OF FLOAT	MX			O
magI	ARRAY [0..numSV] OF INT32	MX	dchg		GC_1
magF	ARRAY [0..numSV] OF FLOAT	MX	dchg		GC_1
range	ARRAY [0..numSV] OF ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
			Configuration description and extension attributes		
numSV	INT16U	CF		number of elements in the array of SV	M
units	Unit	CF		see Annex B IEC 61400-25-2	O
db	INT32U	CF		0 … 100 000	O
zeroDb	INT32U	CF		0 … 100 000	O
sVC	ScaledValueConfig	CF			AC_SCAV
smpRate	INT32U	CF			O
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M

cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.2 of IEC 61400-25-3					

7.7 Condition monitoring scalar value array (CMSVA)

Common data class CMSVA for scalar array values applied in condition monitoring shall be defined as specified in Table 13.

Table 13 – CDC: Condition monitoring scalar value array (CMSVA)

CMSV class					
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Explanation and value/range**	**M/O/C**
DataName	Inherited from data class (see Table 20 of IEC 61850-7-2)				
Data					
MxVal	SVA			Condition monitoring measurements	M
DMx	CMMD			Measurement description	O
DataAttributes					
Measurements					
actBnRef	ObjectReference	MX	-	Reference to the CMD DataObject, the measured value belongs to at the current time	O
Configuration, description					
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.1 of IEC 61400-25-3					

7.8 Condition monitoring vector value (CMVV)

Common data class CMVV for vector values applied in condition monitoring shall be defined as specified in Table 14.

Table 14 – CDC: Condition monitoring vector value (CMVV)

CMSV class					
Attribute name	**Attribute type**	**FC**	**TrgOp**	**Explanation and value/range**	**M/O/C**
DataName	Inherited from data class (see Table 20 of IEC 61850-7-2)				
Data					
MxVal	CMV			Complex measurement value	M
DMx	CMMD			Measurement description	O
DataAttributes					
			Measurements		
actBnRef	ObjectRefer-ence	MX	-	Reference to the CMD DataObject, the measured value belongs to at the current time	O
			Configuration, description		
d	VISIBLE STRING255	DC		Text	O
dU	UNICODE STRING255	DC			O
cdcNs	VISIBLE STRING255	EX			AC_DLNDA_M
cdcName	VISIBLE STRING255	EX			AC_DLNDA_M
dataNs	VISIBLE STRING255	EX			AC_DLN_M
Services					
As defined in Table B.1 of IEC 61400-25-3					

8 Logical nodes for wind turbine condition monitoring

8.1 General

Information collected with the purpose of monitoring the conditions of a wind turbine can all be related to particular parts of a wind turbine, with the objective of having a complete picture of the operational conditions in a wind turbine. The following subclauses specify the logical nodes required to fulfil this standard.

8.2 Logical nodes inherited from IEC 61400-25-2

All logical nodes specified in IEC 61400-25-2 as mandatory are required in order to be compliant with the present standard, as these LNs could include measured values of relevance to condition monitoring.

The WALM logical node class is also related to wind turbine condition monitoring as alarms from the condition monitoring system shall be referred by this class.

8.3 Wind turbine condition monitoring logical node WCON

8.3.1 General

The logical node WCON shall comprise data representing information required for condition monitoring systems which has not already been specified in IEC 61400-25-2.

WCON logical node shall be defined as specified in Table 15.

Table 15 – LN: Wind turbine condition monitoring information (WCON)

WCON class			
Attribute name	**Attr. type**	**Explanation**	**M/O**
		LN shall inherit all mandatory data from wind power plant common logical node class (see 6.1.1 of IEC 61400-25-2)	M
Data			
Measured information			
<vendor specific data name>	e.g., CMSV	e.g., for vibration of generator drive end	O
..			O
<vendor specific data name>	e.g., CMVV	e.g., for generator shaft vibration	O
Configuration			
<vendor specific bin name 1>	CMBC	e.g., Bn1Pwr or BnPwrLow	O
<vendor specific bin name 2>	CMBC	e.g., Bn2Pwr or BnPwrHigh	O
…		…	O
<vendor specific bin name n+1>	CMBC	e.g., Bn1Tmp or BnTmpLow	O
<vendor specific bin class name n+2>	CMBC	e.g., Bn2Tmp or BnTmpHigh	O

8.3.2 CDC's applicable for the logical node WCON

All common data classes that are specified or referenced in this standard or in IEC 61400-25-2 can be used for specifying the data in the logical node WCON.

9 Data file (DAF)

The data file (DAF) is used to contain time waveforms, acoustic information, video information or the like. Based on the state of the art within condition monitoring, the UFF58 file format shall be used for any kind of information exchange based on file transfer.

Annex A
(informative)

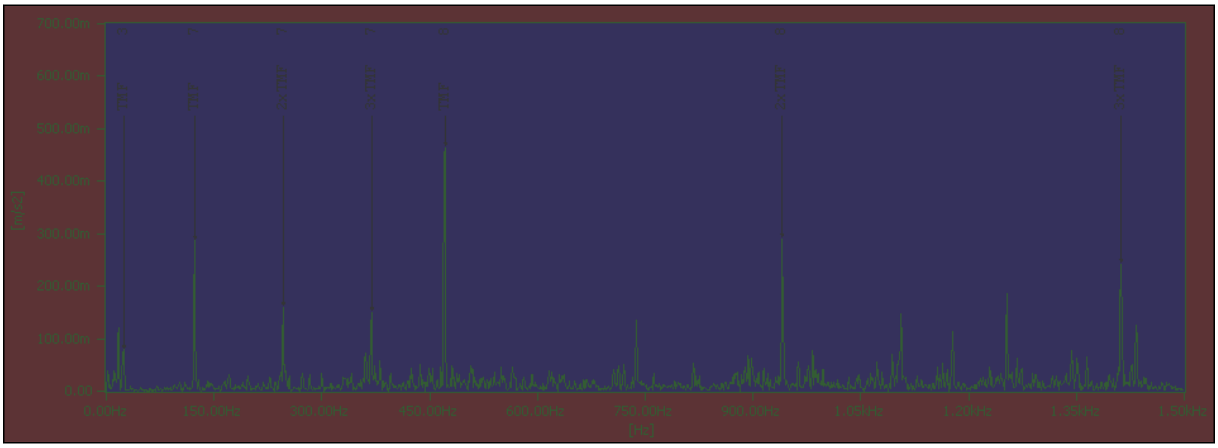
Application of shaft and bearing position numbering

A.1 General

When applying frequency spectra for analysis of vibration signal from wind turbines, the different peaks in the frequency spectrum are related to the different kinematical frequencies of, for example, a gearbox. This annex shows how the shaft and bearing numbering system introduced in 6.2.3 of this standard can be applied to annotate the peaks in the frequency spectrum, thus illustrating the relationship to the different components of the wind turbine.

A.2 Gearbox example

Figure A.1 depicts condition monitoring measurements from a real gearbox case study.



IEC 2441/10

Figure A.1 – Gearbox example – Spectral analysis from an Iss sensor

In the depicted spectrum given in Figure A.1, the tooth meshing frequencies (mxType: xTMF) from three different parts of a gearbox are annotated (see the numbers 3, 7, and 8 at the top of the figure). The shaft numbers shown along with the annotation indicate the origin of the frequency component (see Figure 8):

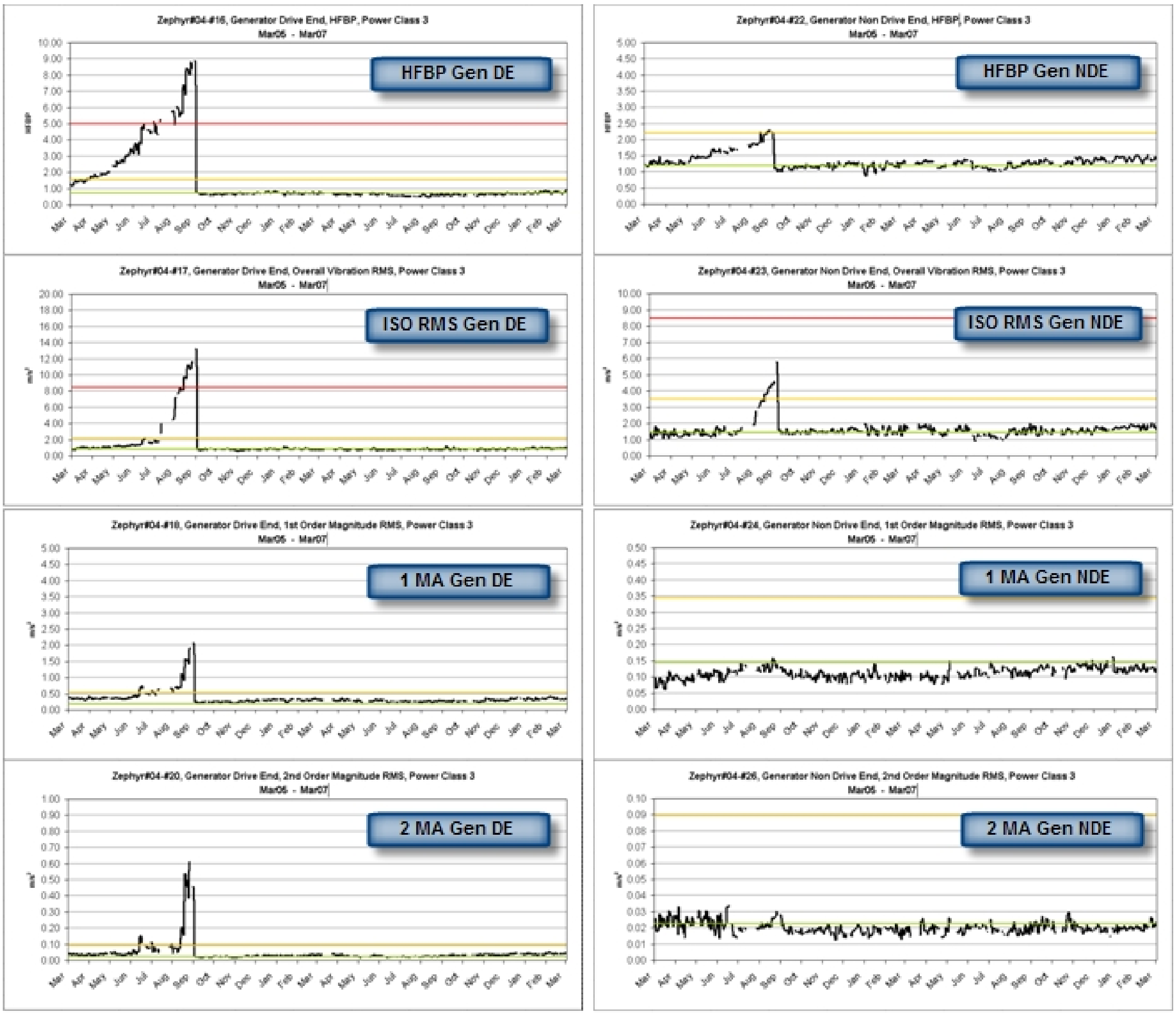
- shaft no 3 relates to planetary stages (Pl);
- shaft no 7 relates to intermediate speed stage (Iss);
- shaft no 8 relates to high speed stage (Hss).

Annex B
(informative)

Examples of trends for mandatory measurements

B.1 Trend history of generator measurements

Figure B.1 shows how a report of mandatory measurements might look. Here only data for the generator in power bin 3 are shown. Each plot spans a period of 2 years with approximately 800 to 1 000 measurements in each plot. The plots show that bearing fault has been present on the generator drive end bearing in 2005. After repair, the levels have dropped to a constant low level.



IEC 2442/10

Figure B.1 – Wind turbine condition monitoring measurements

It is seen from the plots that the HFBP which is sensitive to bearing failures provides a longer lead time than the ISO RMS measurement. At a later stage when the bearing has deteriorated, vibrations also start to rise in the frequency range covered by the ISO RMS value. The 1MA and 2MA rises at a very late stage when looseness and misalignment starts to affect the rotor vibrations.

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch