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TECHNICAL SPECIFICATION

colour inside

Wind energy generation systems –
Part 26-4: Reliability for wind energy generation systems

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WIND ENERGY GENERATION SYSTEMS –

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IEC TS 61400-26-4 has been prepared by IEC technical committee 88: Wind energy generation systems. It is a Technical Specification.

Throughout this document, mandatory information categories as defined in IEC 61400-26-1 are written in capital letters (e.g. FULL PERFORMANCE, OUT OF ENVIRONMENTAL SPECIFICATION).

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
88/954/DTS	88/1024/RVDTS

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

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn, or
- revised.

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WIND ENERGY GENERATION SYSTEMS –

Part 26-4: Reliability for wind energy generation systems

1 Scope

This part of IEC 61400, which is a Technical Specification, specifies terms and information categories for identification and reporting of reliability metrics. The definitions are applicable to key components, any number of wind turbines, fleets of wind turbine types, a wind power station or a portfolio of wind power stations. The wind power station is made up of all WTGSs (Wind Turbine Generator Systems), functional services and balance of plant elements as seen from the point of common coupling.

This document provides guidelines regarding reliability methodologies with informative annexes regarding use.

It expands on the information model in IEC 61400-26-1, recognizing that availability and reliability are interrelated.

It does not assign specific reliability specifications, constraints or targets but rather provides standardized means of categorizing and prioritizing data and illustrates the use of the model and metrics in informative annexes.

It does not specify the method of information acquisition or specific use. Beyond that, it is not the intention of this document to specify exactly how to calculate other undefined or performance-based reliability metrics.

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.

IEC 61400-26-1, *Wind energy generation systems – Part 26-1: Availability for wind energy generation systems*

IEC 60050-192, *International Electrotechnical Vocabulary (IEV) – Part 192: Dependability*

IEC 61703, *Mathematical expressions for reliability, availability, maintainability and maintenance support terms*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192, IEC 61400-26-1 and the following apply.

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

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
failure
loss of ability to perform to specification

Note 1 to entry: EN 13306 defines failure as "termination of the ability of an item to perform a required function".

Note 2 to entry: After failure the item has a fault, which can be complete or partial.

Note 3 to entry: "failure" is an event, as distinguished from "fault", which is a state.

[SOURCE: IEC 60050-192:2015, 192-03-01, modified – Notes to entry have been changed.]

3.1.2
MACMT
mean active corrective maintenance time
expectation of the active corrective maintenance time

[SOURCE: IEC 60050-192:2015, 192-07-22]

3.1.3
MAD
mean administrative delay
expectation of the administrative delay

[SOURCE: IEC 60050-192:2015, 192-07-26]

3.1.4
downtime
expectation of the down time

[SOURCE: IEC 60050-192:2015, 192-08-10]

3.1.5
fault detection time
FDT
time interval between failure and detection of the resulting fault

[SOURCE: IEC 60050-192:2024, 192-07-11, modified – Notes and figures have been deleted]

3.1.6
MLD
mean logistic delay
expectation of the logistic delay

[SOURCE: IEC 60050-192:2015, 192-07-27]

3.1.7
reliability
ability to perform to specification, without failure, for a given time interval, under given conditions

Note 1 to entry: The time interval duration can be expressed in units appropriate to the item concerned, e.g., calendar time, operating cycles, distance run, etc., and the units should always be clearly stated.

Note 2 to entry: Given conditions include aspects that affect reliability, such as: mode of operation, stress levels, environmental conditions, and maintenance.

Note 3 to entry: Reliability can be quantified using appropriate measures, see IEC 60050-192, 192-05-05, Reliability related concepts: measures.

Note 4 to entry: A general definition of reliability is provided in EN 13306: "ability of an item to perform a required function under given conditions for a given time interval."

[SOURCE: IEC 60050-192:2015, 192-01-24, modified – Note 3 to entry has been changed and Note 4 to entry has been added.]

3.1.8
repair
direct action taken to effect restoration

EXAMPLE 1: To restore equipment damaged, faulty or worn to a serviceable condition.

Note 1 to entry: IEC 60050-192 further defines several subsets of availability, e.g., "instantaneous availability" (192-08-01), "inherent availability" (192-08-02) and "operational availability" (192-08-03).

Note 2 to entry: Repair also includes fault localization and function checkout.

[SOURCE: IEC 60050-192:2015, 192-06-14, modified – Note 1 to entry has been changed, an example and Note 2 to entry have been added.]

3.1.9
mean repair time
MRT

expectation of the repair time

[SOURCE: IEC 60050-192:2015, 192-07-21]

3.1.10
technical delay
TD
delay incurred in performing auxiliary technical actions associated with, but not part of, the maintenance action

EXAMPLE Rendering the equipment safe (such as immobilising, cooling, isolation and grounding).

[SOURCE: IEC 60050-192:2015, 192-07-15]

3.1.11
MTBF
mean operating time between failures
expectation of the duration of the operating time between failures

Note 1 to entry: Mean operating time between failures should only be applied to repairable items. For non-repairable items, see mean operating time to failure (192-05-11).

[SOURCE: IEC 60050-192:2015, 192-05-13]

3.1.12
mean time to failure
MTTF
expectation of the operating time to failure

Note 1 to entry: In the case of non-repairable items with an exponential distribution of operating times to failure (i.e. a constant failure rate) the MTTF is numerically equal to the reciprocal of the failure rate. This is also true for repairable items if after restoration they can be considered to be "as-good-as-new".

Note 2 to entry: See also operating time to failure (192-05-01).

[SOURCE: IEC 60050-192:2015, 192-05-11]

3.1.13
mean time to restoration
MTTR
expectation of the time to restoration

Note 1 to entry: IEC 60050-191:1990 (now withdrawn; replaced by IEC 60050-192) defined the term ”mean time to recovery” as a synonym, but restoration and recovery are not synonyms.

[SOURCE: IEC 60050-192:2015, 192-07-23]

3.1.14
MUT
mean up time
expectation of the up time

[SOURCE: IEC 60050-192:2015, 192-08-09]

3.2 Abbreviated terms

ACMT	active corrective maintenance time
AD	administrative delay
DT	down time
FDT	fault detection time
IA	INFORMATION AVAILABLE
IANO	NON-OPERATIVE
IAFM	FORCE MAJEURE
IAO	OPERATIVE
IANOFO	FORCED OUTAGE
IANOPCA	PLANNED CORRECTIVE ACTION
IANOS	SUSPENDED
IANOSM	SCHEDULED MAINTENANCE
IAOOS	OUT OF SERVICE
IAOOSEN	OUT OF ENVIRONMENTAL SPECIFICATION
IAOOSTS	TECHNICAL STANDBY
IAOS	IN SERVICE
IAOSFP	FULL PERFORMANCE
IAOSPP	PARTIAL PERFORMANCE
IAOSRS	READY STANDBY
IAOOSEL	OUT OF ELECTRICAL SPECIFICATION

IAOOSRS	REQUESTED SHUTDOWN
LD	logistic delay
MACMT	mean active corrective maintenance time
MAD	mean administrative delay
MDT	mean down time
MFDT	mean fault detection time
MLD	mean logistic delay
MRT	mean repair time
MTBF	mean operating time between failures
MTD	mean technical delay
MTTF	mean operating time to failure
MTTR	mean time to restoration
MUT	mean up time
RT	repair time
TBF	time between failures
TD	technical delay
TTF	time to failure
TTR	time to restoration
UT	up time
WEGS	wind energy generation system
WTGS	wind turbine generator system

4 Preamble

The key aspect of this document is that a reliability interpretation of the information model specified in IEC 61400-26-1 is achieved by creating counters, one for each information category at each mandatory level, optionally expanded with level 5 and level 6 categories.

These accumulated figures are in the present document used as the basis for data needed for deriving reliability metrics for a WEGS.

The methodology illustrated is made only on the time-based modelling specified in IEC 61400-26-1. A production-based approach is generally not implementable as standardised reliability terms and definitions applicable to the production-based model are not developed.

5 Reliability terms derived from the information model

5.1 Information categories applied in reliability metrics

Each level of the information model defined in IEC 61400-26-1 (see Figure 1) represents mutually exclusive and collectively exhaustive states for a WEGS. The information model can be regarded as a collection of state-transition machines; for each column/level, there are several operational states as each information category represents one state.

The WEGS can be only in one state at each level. At level 1, the WEGS can be only in IA or IU. At level 2, the WEGS can be only in IAO, IANO, IAFM or IU. The same principle applies to level 3 and 4. The prioritization of the information categories defined in IEC 61400-26-1 shall apply to the state machine approach too. The logic shall also apply to implementations with optional levels (illustrated in Figure 1 with level 5 added).

EXAMPLE 1: A WEGS experiences a situation at PARTIAL PERFORMANCE and a transition to OUT OF ENVIRONMENTAL SPECIFICATION is made. At level 3, the WEGS will transition from IN SERVICE to OUT OF SERVICE, but at levels 1 and 2 no change takes place.

EXAMPLE 2: A WEGS experiences a situation at FULL PERFORMANCE where a technical fault is detected by the turbine controller. At level 4, a transition to FORCED OUTAGE is made. At level 3, the WEGS will transition from IN SERVICE to FORCED OUTAGE, and at level 2, a transition from OPERATIVE to NON-OPERATIVE is made, but at level 1 no change takes place; IA remains.

5.2 Derivation of parameters for reliability metrics

5.2.1 General

IEC 61400-26-1 requires that the actual state of all mandatory levels is determined, meaning that even though level 4 defines the more detailed information, the preceding (upper) levels shall also be determined and documented. These upper states are used for the derivation of parameters for reliability metrics.

Information categories						
Mandatory level 1	Mandatory level 2	Mandatory level 3	Mandatory level 4	Mandatory priority	Optional level 5	Level 5 priority
INFORMA-TION AVAILABLE (**IA**)	OPERATIVE (**IAO**)	IN SERVICE (**IAOS**)	FULL PERFORMANCE (**IAOSFP**)	**1**		
			PARTIAL PERFORMANCE (**IAOSPP**)	**2**	**derated**	**2.1**
					degraded	**2.2**
			READY STANDBY **(IAOSRS)**	**3**		
		OUT OF SERVICE (**IAOOS**)	TECHNICAL STANDBY (**IAOOSTS**)	**4**		
			OUT OF ENVIRONMENTAL SPECIFICATION (**IAOOSEN**)	**5**	**calm winds**	**5.1**
					other environmental	**5.2**
			REQUESTED SHUTDOWN (**IAOOSRS**)	**6**		
			OUT OF ELECTRICAL SPECIFICATION (**IAOOSEL**)	**7**		
	NON-OPERATIVE (**IANO**)	SCHEDULED MAINTENANCE (**IANOSM**)		**8**		
		PLANNED CORRECTIVE ACTION (**IANOPCA**)		**9**	**retrofit**	**9.1**
					upgrade	**9.2**
					other corrective action	**9.3**
		FORCED OUTAGE (**IANOFO**)		**10**	**response**	**10.1**
					diagnostic	**10.2**
					logistic	**10.3**
					failure repair	**10.4**
		SUSPENDED (**IANOS**)		**11**	**suspended scheduled maintenance**	**11.1**
					suspended planned corrective action	**11.2**
					suspended forced outage	**11.3**
	FORCE MAJEURE (**IAFM**)			**12**		
INFORMATION UNAVAILABLE (**IU**)				**13**		

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Figure 1 – IEC 61400-26-1 information model

5.2.2 Additional state information required

To derive reliability metrics, it is necessary to obtain a further granularity than that provided by the counters defined in IEC 61400-26-1 giving only aggregated numbers for a full given period. For each unbroken period, when the state at a given level has been constant, it is necessary to know the duration, the preceding state, and the succeeding state. To provide a basis for more complex analyses (e.g., dependency on time-of-day, day-of-week, etc,), information about the duration of a period shall be completed with timestamps for the start and end of said period.