भारतीय मानक

Indian Standard

IS/IEC 61400-26-1 : 2019

पवन ऊर्जा उत्पादन प्रणाली

भाग 26 पवन ऊर्जा उत्पादन प्रणाली

अनुभाग 1 उपलब्धता

Wind Energy Generation Systems

Part 26 Wind Energy Generation Systems

Section 1 Availability

ICS 47.020.60

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Wind Turbines Sectional Committee, ETD 42

NATIONAL FOREWORD

This India Standard (Part 26/Sec 1) which is identical to IEC 61400-26-1 : 2019 'Wind energy generation systems — Part 26: Wind energy generation systems — Section 1: Availability' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Wind Turbines Sectional Committee and approval of the Electrotechnical Division Council.

The text of the IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

The Committee has reviewed the provisions of the following International Standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60050-415	International Electrotechnical Vocabulary (IEV) — Part 415: Wind turbine generator systems
IEC 61400-1	Wind energy generation systems — Part 1: Design requirements

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the International Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (second *revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

INTRODUCTION

The intention of this International Standard is to define a common basis for exchange of information on availability metrics between stakeholders in the wind power generation business such as owners, utilities, lenders, operators, manufacturers, maintenance providers, consultants, regulatory bodies, certification bodies and insurance companies. From this diverse group of stakeholders, a number of external and internal interfaces arise in the operation and delivery of power. Some of these are energy related and many are informational. Since the intention is for a common basis of informational exchange, many of these interfaces are illustrated in Figure 1, which identifies external and internal elements related to energy production and asset management and which also benefit from a defined set of terms. This is achieved by providing an information model specifying how time designations shall be split into information categories.

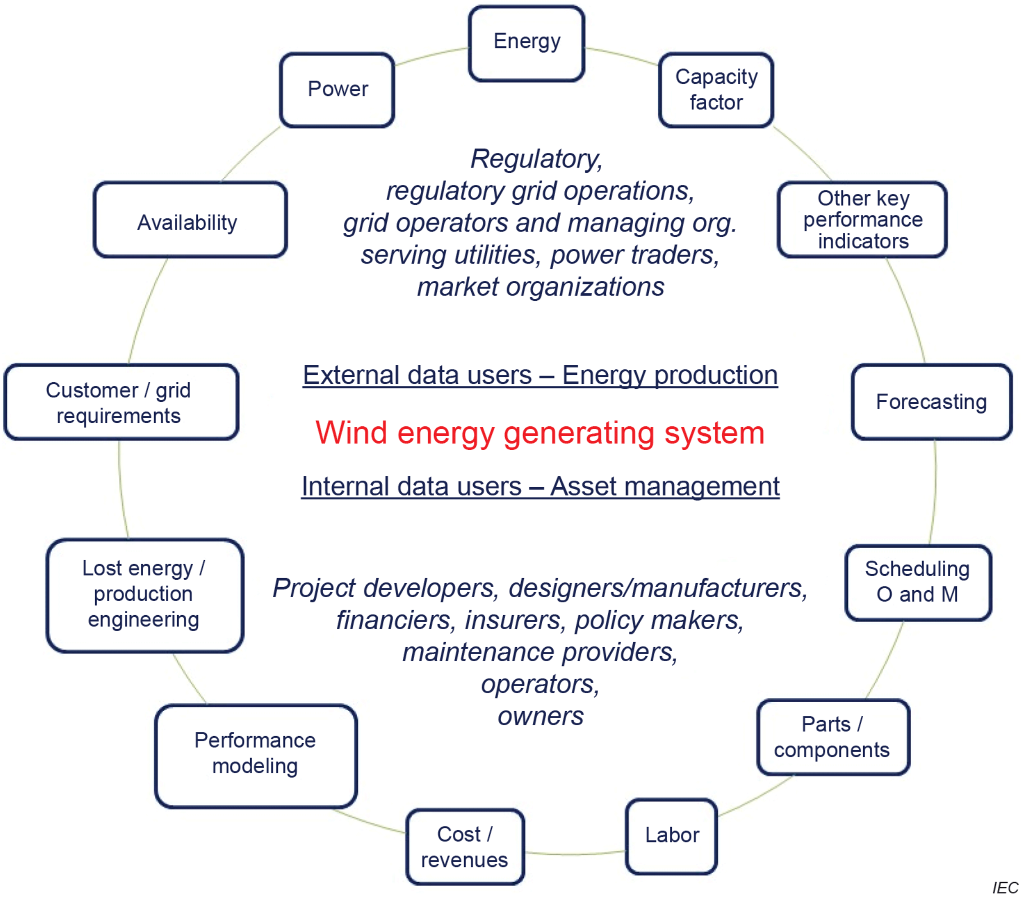

Figure 1 – Data stakeholders for a wind energy generation system

Throughout the document, reference is made to wind energy generation systems (WEGS); however, the document may be used for a single wind turbine (WTGS), as well as for any number of WTGSs combined with additional components to represent a complete wind power station (WPS). The designation WEGS used throughout the document thus shall be understood as the specifications being applicable to individual wind turbines as well as for wind power stations.

The information model specifies the terminology for reporting availability indicators. Availability indicators include time-based and production-based availability. A WEGS includes all equipment up to the point of interconnection[1], or in case of a single WTGS in a WPS, the interconnection point defined by the user. Availability indicators are based upon fractions of time and the amount a service is providing or capable of providing within the time fractions, taking internal and external aspects into account. Internal aspects will include the WEGS' components and their condition. External aspects are wind and other weather conditions, as well as grid and substation conditions.

[1] Defined in IEC 60050-415:1999, Definition 415-04-01.

Indian Standard

WIND ENERGY GENERATION SYSTEMS

PART 26 WIND ENERGY GENERATION SYSTEMS

SECTION 1 AVAILABILITY

1 Scope

This part of IEC 61400 defines an information model from which time-based, and production-based availability indicators for services can be derived and reported.

The purpose is to provide standardised metrics that can be used to create and organise methods for availability calculation and reporting according to the user's needs.

The document provides information categories, which unambiguously describe how data is used to characterise and categorise the operation. The information model specifies category priority for discrimination between possible concurrent categories. Further, the model defines entry and exit criteria to allocate fractions of time and production values to the proper information category. A full overview of all information categories, exit and entry criteria is given in Annex A, see Figure A.1.

The document can be applied to any number of WTGSs, whether represented by an individual turbine, a fleet of wind turbines, a wind power station or a portfolio of wind power stations. A wind power station is typically made up of all WTGSs, functional services and balance of plant elements as seen from the point of common coupling.

Examples are provided in informative annexes which provide guidelines for calculation of availability indicators:

- examples of optional information categories, Annex B;
- examples of application of the information categories for determination of availability, Annex C;
- examples of application scenarios, Annex D;
- examples on methods for determination of potential production, Annex E;
- examples of how to expand the model to balance of plant elements, Annex F.

This document does not prescribe how availability indicators shall be calculated. The standard does not specify the method of information acquisition, how to estimate the production terms or to form the basis for power curve performance measurements – which is the objective of IEC 61400-12.

A degree of uncertainty is inherent in both the measurement of a power curve and the calculation of potential energy production. The stakeholders should agree upon acceptable uncertainty parameters.

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 60050-415, *International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems*

IEC 61400-1, *Wind energy generation systems – Part 1: Design requirements*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-415 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

3.1.1
actual service delivery
quantified level of a service provided by the WEGS as measured

Note 1 to entry: Actual service delivery can only be assigned to measurable services.

3.1.2
balance of plant
BOP
infrastructural components of the WPS except for the WTGS(s) and its internal components and subsystems

Note 1 to entry: The infrastructure normally consists of site electrical facilities, monitoring and control (often called SCADA) as well as civil plant (such as foundations and roads) supporting the operation and maintenance of the WTGS(s).

3.1.3
constrained potential service delivery
calculated level of a service that could have been provided by the WEGS based on operating specifications such as external set-points or contractually imposed constraints combined with design criteria, technical specifications and site conditions

3.1.4
design specifications
the collection of precise and explicit information about requirements for a product design

Note 1 to entry: It provides in-depth details about the functional and non-functional design requirements including assumptions, constraints, performance, dimensions, weights, reliability and standards. For example, specifications and design considerations given in the IEC 61400-1 standard define the process for producing design specifications for WEGS.

3.1.5
external conditions
conditions outside of the WEGS that affect the operation, such as (i) operating specifications, (ii) environmental conditions and (iii) grid conditions

3.1.6
grid
electrical network to which the WEGS is electrically connected

Note 1 to entry: The WEGS delivers its services into the grid. The interface between the grid and the WEGS internal electrical system is the network connection point often referred to as the point of common coupling (PCC).

3.1.7
intended function
ability of an apparatus, machine or system to consistently perform its required function within its design specification

3.1.8
lost service
service not supplied, e.g. lost production or lost energy

Note 1 to entry: See 4.5.5.

3.1.9
physical potential service delivery
calculated level of a service that could have been provided by the WEGS based on design criteria, technical specifications and site conditions

Note 1 to entry: The potential service is the physically possible level of service.

3.1.10
potential service delivery
calculated value of physical potential service delivery or constrained potential service delivery as is appropriate

3.1.11
retrofit
the incorporation of new technology or new design parts resulting from an approved engineering change to an already supplied item

3.1.12
supervisory control and data acquisition
SCADA
system operating with signals over communication channels so as to provide control of equipment and for gathering and analysing real-time data

3.1.13
service
provision delivered by the WEGS

Note 1 to entry: Services typically include, but are not limited to, supply of active power, reactive power and support of electrical stability of the grid. Aviation warning is another example of a service.

3.1.14
site conditions
conditions affecting the service of the WEGS, e.g. topographic, climatic and meteorological conditions, sector management, electrical environment and contractual constraints

3.1.15
grid operator
operator that transmits electrical generation over the grid to regional or local electricity distribution operators

3.1.16
wind power station
WPS
station consisting of the WTGS(s) and the BOP which supports transfer of energy between the WTGS(s) and the grid

3.1.17
maintenance provider
provider typically providing the maintenance of the WEGS or parts therein

Note 1 to entry: Maintenance can be performed by multiple providers with specific scope defined.

3.1.18
operator
operator typically responsible for providing the services of the WEGS to off-takers

3.2 Abbreviated terms

IA	INFORMATION AVAILABLE category
IAO	Information available OPERATIVE category
IAOS	Information available operative IN SERVICE category
IAOSFP	Information available operative in service with FULL PERFORMANCE category
IAOSPP	Information available operative in service with PARTIAL PERFORMANCE category
IAOSRS	Information available operative in service with READY STANDBY category
IAOOS	Information available operative OUT OF SERVICE category
IAOOSTS	Information available operative out of service TECHNICAL STANDBY category
IAOOSEN	Information available operative out of service OUT OF ENVIRONMENTAL SPECIFICATION category
IAOOSRS	Information available operative out of service REQUESTED SHUTDOWN category
IAOOSEL	Information available operative out of service OUT OF ELECTRICAL SPECIFICATION category
IANO	Information available NON-OPERATIVE category
IANOSM	Information available non-operative SCHEDULED MAINTENANCE category
IANOPCA	Information available non-operative PLANNED CORRECTIVE ACTION category
IANOFO	Information available non-operative FORCED OUTAGE category
IANOS	Information available non-operative SUSPENDED category
IAFM	Information available FORCE MAJEURE category
IAS_P	INFORMATION AVAILABLE category – potential service delivery
IAS_A	INFORMATION AVAILABLE category – actual service delivery
$IAOS_P$	Information available OPERATIVE category – potential service delivery
$IAOS_A$	Information available OPERATIVE category – actual service delivery
$IAOSS_P$	Information available operative IN SERVICE category – potential service delivery
$IAOSS_A$	Information available operative IN SERVICE category – actual service delivery
$IAOSFPS_P$	Information available operative in service with FULL PERFORMANCE category – potential service delivery
$IAOSFPS_A$	Information available operative in service with FULL PERFORMANCE category – actual service delivery
$IAOSPPS_P$	Information available operative in service with PARTIAL PERFORMANCE category – potential service delivery
$IAOSPPS_A$	Information available operative in service with PARTIAL PERFORMANCE category – actual service delivery
$IAOSPP_{DR}S_P$	Information available operative in service with partial performance category, optional **derated** – potential service delivery

$IAOSPP_{DR}S_A$	Information available operative in service with partial performance category, optional **derated** – actual service delivery
$IAOSPP_{DG}S_P$	Information available operative in service with partial performance category, optional **degraded** – potential service delivery
$IAOSPP_{DG}S_A$	Information available operative in service with partial performance category, optional **degraded** – actual service delivery
$IAOSRSS_P$	Information available operative in service with READY STANDBY category – potential service delivery
$IAOSRSS_A$	Information available operative in service with READY STANDBY category – actual service delivery
$IAOOSS_P$	Information available operative OUT OF SERVICE category – potential service delivery
$IAOOSS_A$	Information available operative OUT OF SERVICE category – actual service delivery
$IAOOSTSS_P$	Information available operative out of service TECHNICAL STANDBY category – potential service delivery
$IAOOSTSS_A$	Information available operative out of service TECHNICAL STANDBY category – actual service delivery
$IAOOSENS_P$	Information available operative out of service OUT OF ENVIRONMENTAL SPECIFICATION category – potential service delivery
$IAOOSENS_A$	Information available operative out of service OUT OF ENVIRONMENTAL SPECIFICATION category – actual service delivery
$IAOOSEN_CS_P$	Information available operative out of service out of environmental specification optional category **calm winds** – potential service delivery
$IAOOSEN_CS_A$	Information available operative out of service out of environmental specification optional category **calm winds** – actual service delivery
$IAOOSEN_OS_P$	Information available operative out of service out of environmental specification optional category **other environmental** – potential service delivery
$IAOOSEN_OS_A$	Information available operative out of service out of environmental specification optional category **other environmental** – actual service delivery
$IAOOSELS_P$	Information available operative out of service OUT OF ELECTRICAL SPECIFICATION category – potential service delivery
$IAOOSELS_A$	Information available operative out of service OUT OF ELECTRICAL SPECIFICATION category – actual service delivery
$IAOOSRSS_P$	Information available operative out of service REQUESTED SHUTDOWN category – potential service delivery
$IAOOSRSS_A$	Information available operative out of service REQUESTED SHUTDOWN category – actual service delivery
$IANOS_P$	Information available NON-OPERATIVE category – potential service delivery
$IANOS_A$	Information available NON-OPERATIVE category – actual service delivery
$IANOSMS_P$	Information available non-operative SCHEDULED MAINTENANCE category – potential service delivery
$IANOSMS_A$	Information available non-operative SCHEDULED MAINTENANCE category – actual service delivery
$IANOPCAS_P$	Information available non-operative PLANNED CORRECTIVE ACTION category – potential service delivery

$IANOPCAS_A$	Information available non-operative PLANNED CORRECTIVE ACTION category – actual service delivery
$IANOPCA_RS_P$	Information available non-operative planned corrective action optional category **retrofit** – potential service delivery
$IANOPCA_RS_A$	Information available non-operative planned corrective action optional category **retrofit** – actual service delivery
$IANOPCA_US_P$	Information available non-operative planned corrective action optional category **upgrade** – potential service delivery
$IANOPCA_US_A$	Information available non-operative planned corrective action optional category **upgrade** – actual service delivery
$IANOPCA_OS_P$	Information available non-operative planned corrective action optional category **other corrective action** – potential service delivery
$IANOPCA_OS_A$	Information available non-operative planned corrective action optional category **other corrective action** – actual service delivery
$IANOFOS_P$	Information available non-operative FORCED OUTAGE category – potential service delivery
$IANOFOS_A$	Information available non-operative FORCED OUTAGE category – actual service delivery
$IANOFO_RS_P$	Information available non-operative forced outage optional category **response** – potential service delivery
$IANOFO_RS_A$	Information available non-operative forced outage optional category **response** – actual service delivery
$IANOFO_DS_P$	Information available non-operative forced outage optional category **diagnostic** – potential service delivery
$IANOFO_DS_A$	Information available non-operative forced outage optional category **diagnostic** – actual service delivery
$IANOFO_LS_P$	Information available non-operative forced outage optional category **logistic** – potential service delivery
$IANOFO_LS_A$	Information available non-operative forced outage optional category **logistic** – actual service delivery
$IANOFO_FS_P$	Information available non-operative forced outage optional category **failure repair** – potential service delivery
$IANOFO_FS_A$	Information available non-operative forced outage optional category **failure repair** – actual service delivery
$IANOSS_P$	Information available non-operative SUSPENDED category – potential service delivery
$IANOSS_A$	Information available non-operative SUSPENDED category – actual service delivery
$IANOS_SS_P$	Information available non-operative suspended optional category **suspended scheduled maintenance** – potential service delivery
$IANOS_SS_A$	Information available non-operative suspended optional category **suspended scheduled maintenance** – actual service delivery
$IANOS_PS_P$	Information available non-operative suspended optional category **suspended planned corrective action** – potential service delivery
$IANOS_PS_A$	Information available non-operative suspended optional category **suspended planned corrective action** – actual service delivery
$IANOS_FS_P$	Information available non-operative suspended optional category **suspended forced outage** – potential service delivery
$IANOS_FS_A$	Information available non-operative suspended optional category **suspended forced outage** – actual service delivery

$IAFMS_P$	Information available FORCE MAJEURE category – potential service delivery
$IAFMS_A$	Information available FORCE MAJEURE category – actual service delivery
IU	INFORMATION UNAVAILABLE category

4 Information model

4.1 Basic model

The information model comprises a number of information categories organised in layers. All calendar time shall be accounted for by distribution of time fractions into the information categories in the first layer of the model. The information category that characterises the operational state shall hold the time fractions that can be allocated to that category. A shift to another category shall be made when the operational state is no longer valid for that category. Any fraction of time can only be assigned to one category. The information model provides a hierarchical structure of four levels of defined information categories, which are mandatory and required for data collection. Further subdivision of information categories beyond the four mandatory levels is optional. Attributes of higher information categories are inherited by underlying lower information categories as illustrated in Figure 2. Time designations shall be allocated at the lowest mandatory level, level 4, or at a lower optional level with a greater granularity (level 5 or lower). The higher hierarchical information levels shall contain the aggregation of the related information categories on the lower levels. The individual information categories are introduced in 4.2.

Each information category has an associated entry point and exit point. The entry point describes the criteria that shall be fulfilled to allocate time into this specific information category. The exit point describes the criteria to be fulfilled to end time allocation to the specific information category, see Clause 5.

Priorities are assigned to the information categories. In case entry conditions are fulfilled concurrently for two or more information categories, time shall be assigned into the information category with the highest priority only. Information category priorities are described in 4.3.

4.2 Information categories

Figure 2 gives an overview of the information categories. Abbreviations for the information categories are indicated in brackets with bold letters. The abbreviations are defined in Clause 3. The properties of the information categories are described in detail in Clause 5.

The optional information categories defined in level 5 are included to allow users to customize reporting details to meet specific requirements. When applied, the optional fifth level shall be used as specified in this document. Further levels may be developed and applied at the user's own initiative. This document imposes no limits on the number of optional information categories or levels added by the user. Examples illustrating use of the optional information categories shown in Figure 2 are described in Annex B.

Mandatory information categories defined in this document are written in capital letters; optional information categories are written in bold letters.

Information categories				
Mandatory level 1	**Mandatory level 2**	**Mandatory level 3**	**Mandatory level 4**	**Optional level 5 – description see Annex B**
INFORMATION AVAILABLE (5.1) (**IA**)	OPERATIVE (5.2) (**IAO**)	IN SERVICE (5.3) (**IAOS**)	FULL PERFORMANCE (5.3.2) (**IAOSFP**)	
			PARTIAL PERFORMANCE (5.3.3) (**IAOSPP**)	**derated**
				degraded
			READY STANDBY (5.3.4) (**IAOSRS**)	
		OUT OF SERVICE (5.4) (**IAOOS**)	TECHNICAL STANDBY (5.4.2) (**IAOOSTS**)	
			OUT OF ENVIRONMENTAL SPECIFICATION (5.4.3) (**IAOOSEN**)	**calm winds**
				other environmental
			REQUESTED SHUTDOWN (**IAOOSRS**) (5.4.4)	
			OUT OF ELECTRICAL SPECIFICATION (5.4.5) (**IAOOSEL**)	
	NON-OPERATIVE (5.5) (**IANO**)	SCHEDULED MAINTENANCE (5.5.2) (**IANOSM**)		
		PLANNED CORRECTIVE ACTION (5.5.3) (**IANOPCA**)		**retrofit**
				upgrade
				other corrective action
		FORCED OUTAGE (5.5.4) (**IANOFO**)		**response**
				diagnostic
				logistic
				failure repair
		SUSPENDED (5.5.5) (**IANOS**)		**suspended scheduled maintenance**
				suspended planned corrective action
				suspended forced outage
	FORCE MAJEURE (5.6) (**IAFM**)			
INFORMATION UNAVAILABLE (5.7) (**IU**)				

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Figure 2 – Information category overview

4.3 Information category priority

Time present in the information categories shall be exclusive and continuous. In case the conditions, for allocating a time period to more than one information category, are fulfilled at the same time, the information category priorities determine which category takes precedence for the allocation of the time period being considered. Assignment of priorities to the information categories provides a uniform and transparent method for designation of time. Figure 3 illustrates the information category priorities.

The order of priorities is mandatory for compliance with this document. The priorities are ranked from one to thirteen with one as the lowest and thirteen as the highest priority. Priorities for optional information categories can be introduced for specific purposes. In such cases, the mandatory priorities can be extended with a priority for the optional information category.

Information categories				
Mandatory level 1	**Mandatory level 2**	**Mandatory level 3**	**Mandatory level 4**	**Mandatory priority**
INFORMATION AVAILABLE (**IA**)	OPERATIVE (**IAO**)	IN SERVICE (**IAOS**)	FULL PERFORMANCE (**IAOSFP**)	**1**
			PARTIAL PERFORMANCE (**IAOSPP**)	**2**
			READY STANDBY **(IAOSRS)**	**3**
		OUT OF SERVICE (**IAOOS**)	TECHNICAL STANDBY (**IAOOSTS**)	**4**
			OUT OF ENVIRONMENTAL SPECIFICATION (**IAOOSEN**)	**5**
			REQUESTED SHUTDOWN (**IAOOSRS**)	**6**
			OUT OF ELECTRICAL SPECIFICATION (**IAOOSEL**)	**7**
	NON-OPERATIVE (**IANO**)	SCHEDULED MAINTENANCE (**IANOSM**)		**8**
		PLANNED CORRECTIVE ACTION (**IANOPCA**)		**9**
		FORCED OUTAGE (**IANOFO**)		**10**
		SUSPENDED (**IANOS**)		**11**
	FORCE MAJEURE (**IAFM**)			**12**
INFORMATION UNAVAILABLE (**IU**)				**13**

IEC

Figure 3 – Information category priority

There might be conflicts within the optional categories as the **derated** category and the **degraded** category might appear simultaneously. The situation is discussed in the informative Annex B.

4.4 Services

The information categories shall be applied individually to all relevant services, provided by the WEGS, to obtain availability indicators. Services may be, but are not limited to, supply of active power, supply of reactive power and support of electrical stability of the grid. Categories shall be assigned independently to each service and are in many cases not identical within the same time period.

4.5 Service delivery layers

4.5.1 General

To allow for service delivery based availability in the information model, three layers are defined:

- time layer;
- actual service delivery layer;
- potential service delivery layer.

The three layers are specified for the mandatory levels 1 to 4. Figure 4 illustrates the complete information model with three layers and forms the basis for determination of lost service (typically energy) in the following subclause.

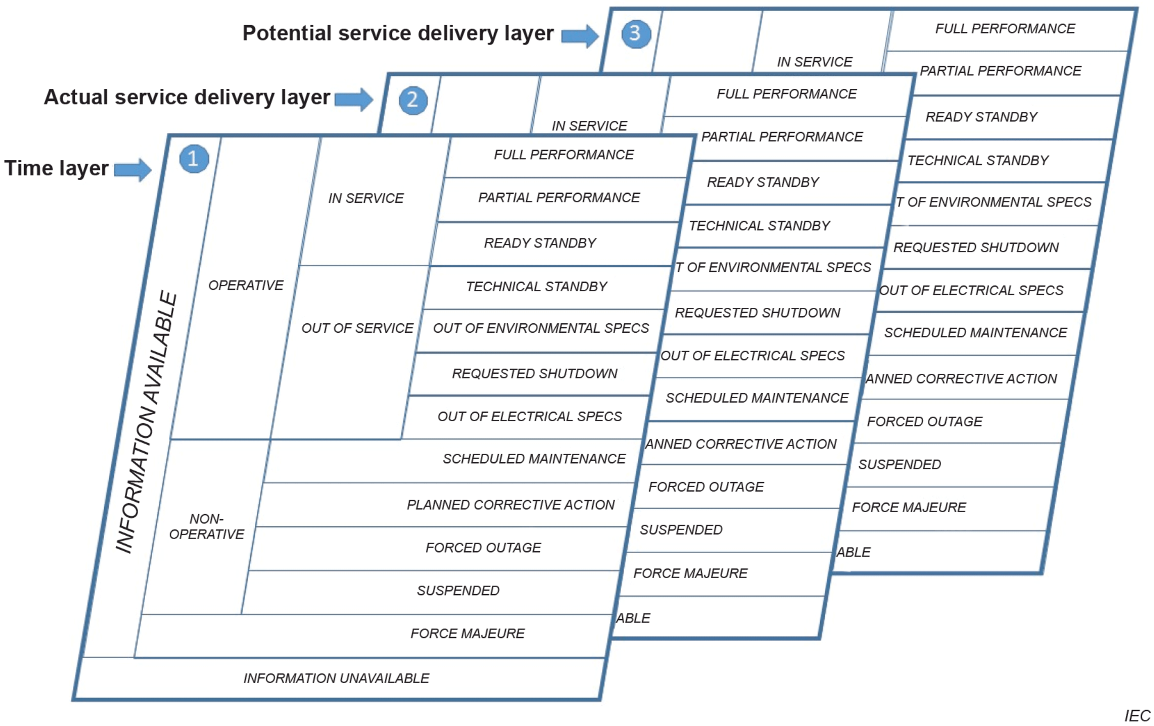

Figure 4 – Three-layer information model

4.5.2 Time layer

The time layer is identical to the Basic model described in 4.1, 4.2 and 4.3.

4.5.3 Actual service delivery layer

In layer 2, a value for the actual service rather than time is recorded. The value recorded is the actual service delivered during the same period as in the corresponding category in layer 1.

4.5.4 Potential service delivery layer

Layer 3 contains information on the potential amount of service delivery during the same periods as in the corresponding category in layers 1 and 2.

Methods for determination of the potential service is discussed in Annex E. However, the method for establishing the potential service is outside the scope of this document. Data populating this layer shall represent the service delivery that could have been realised if the

WEGS had been operating as per the FULL PERFORMANCE, taking into account the external conditions.

The potential service delivery shall be either the physical potential service delivery or constrained potential service delivery depending on what is relevant for the service. Typically, for active production, it may be appropriate to select the physical potential production and for reactive production, the constrained potential production. See Annex E for methods to determine potential production.

4.5.5 Lost service

When values for actual service delivery and potential service delivery are determined, lost service values shall be derived as follows, see Figure 5.

- No lost service shall be associated with the respective information category, when the service is operating in FULL PERFORMANCE.
- Lost service shall be determined by the difference between the potential service value and the actual service value during the time the service is operating in PARTIAL PERFORMANCE.
- Lost service shall equal the potential service during the time when the service is in INFORMATION AVAILABLE and not in IN SERVICE (see footnote in Figure 5).

It is recognized that while operating in FULL PERFORMANCE, actual service might not equal full potential service due to various factors that might affect the performance of the WEGS, such as blade fouling or misalignment, or the calculation of potential service. The characterization of the WEGS services is beyond the scope of this document. Examples of turbine performance while in the FULL PERFORMANCE information category are included in Annex D.

It is not possible or meaningful to measure a level or degree of some services, especially when the service is of a binary nature. Only time based indicators are applicable to those services. Aviation lights are an example, which can be either 'in operation' or 'out of operation' but do not have an actual or potential service attached.

4.6 Modelling multiple services

The information model supports tracking of multiple services. In order to do so, the three-layer information model is applied to each of the services. Figure 6 illustrates an example with four services.

Information categories – Layer 1				Layer 2	Layer 3	Layer 2 subtracted from layer 3
Mandatory level 1	Mandatory level 2	Mandatory level 3	Mandatory level 4	Actual service delivery	Potential service delivery	Lost service
INFORMATION AVAILABLE (**IA**)	OPERATIVE (**IAO**)	IN SERVICE (**IAOS**)	FULL PERFORMANCE (**IAOSFP**)	$\mathbf{IAOSFPS_A}$	$\mathbf{IAOSFPS_P}$	**0**
			PARTIAL PERFORMANCE (**IAOSPP**)	$\mathbf{IAOSPPS_A}$	$\mathbf{IAOSPPS_P}$	$\mathbf{IAOSPPS_P - IAOSPPS_A}$
			READY STANDBY (**IAOSRS**)	$\mathbf{IAOSRSS_A}$	$\mathbf{IAOSRSS_P}$	$\mathbf{IAOSRSS_P - IAOSRSS_A}$
		OUT OF SERVICE (**IAOOS**)	TECHNICAL STANDBY (**IAOOSTS**)	0	$\mathbf{IAOOSTSS_P}$	$\mathbf{IAOOSTSS_P}$
			OUT OF ENVIRONMENTAL SPECIFICATION (**IAOOSEN**)	0	$\mathbf{IAOOSENS_P}$	$\mathbf{IAOOSENS_P}$
			REQUESTED SHUTDOWN (**IAOOSRS**)	0	$\mathbf{IAOOSRSS_P}$	$\mathbf{IAOOSRSS_P}$
			OUT OF ELECTRICAL SPECIFICATION (**IAOOSEL**)	0	$\mathbf{IAOOSELS_P}$	$\mathbf{IAOOSELS_P}$
	NON-OPERATIVE (**IANO**)	SCHEDULED MAINTENANCE (**IANOSM**)		0	$\mathbf{IANOSMS_P}$	$\mathbf{IANOSMS_P}$
		PLANNED CORRECTIVE ACTION (**IANOPCA**)		0	$\mathbf{IANOPCAS_P}$	$\mathbf{IANOPCAS_P}$
		FORCED OUTAGE (**IANOFO**)		0	$\mathbf{IANOFOS_P}$	$\mathbf{IANOFOS_P}$
		SUSPENDED (**IANOS**)		0	$\mathbf{IANOSS_P}$	$\mathbf{IANOSS_P}$
	FORCE MAJEURE (**IAFM**)			0	$\mathbf{IAFMS_P}$	$\mathbf{IAFMS_P}$
INFORMATION UNAVAILABLE (**IU**)				*	*	*

* In the category INFORMATION UNAVAILABLE, data is missing or cannot be quantified; a value cannot be determined.

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Figure 5 – Information categories, definitions for layer 2 and layer 3, mandatory categories

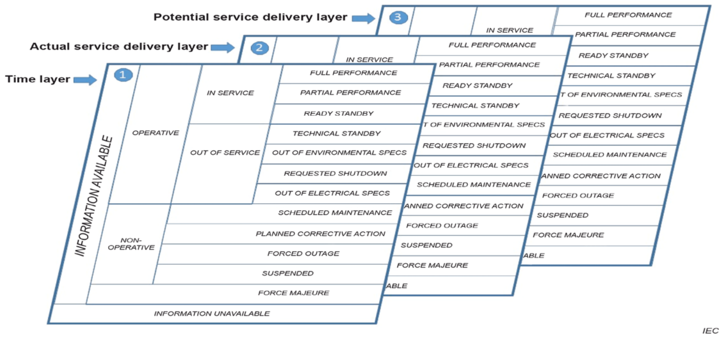
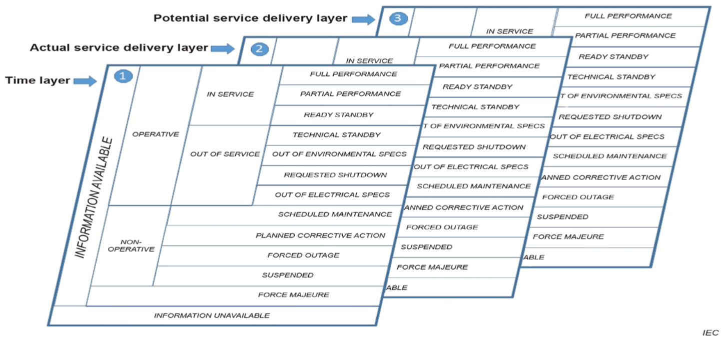
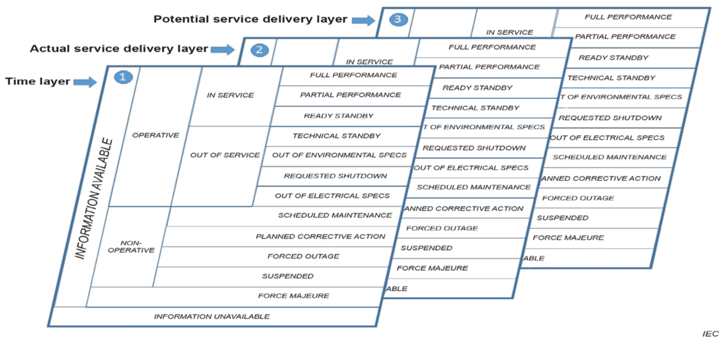
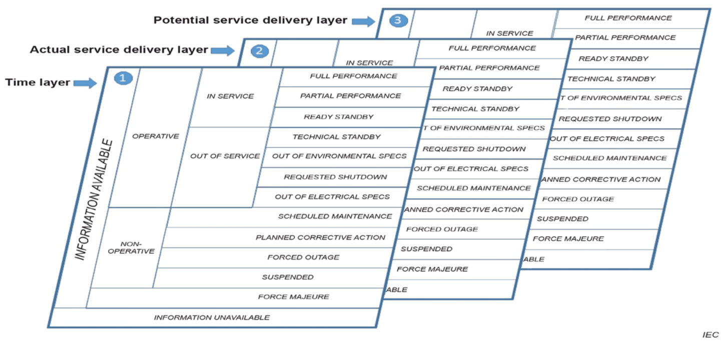
Service	WEGS
Active energy service	
Reactive energy service	
High frequency response service	
Low frequency response service	

Figure 6 – Examples of an information model representing active energy, reactive energy, high and low frequency response services

4.7 Determination of information categories for the WPS

Determination of the proper information category for the WPS level is not simply made up of the minimum, maximum, sum or average of the elements making up the WPS. The key to determining the proper information category is by evaluating compliance with exit and entry criteria defined in Clause 5. Methods for determining the information categories are discussed in Annex C.

Basic principles and assumptions for the WPS information model are:

- mandatory categories are identical in the WTGS model and the WPS model;
- optional categories are not necessarily identical in the WTGS model and the WPS model;
- measurements of WPS actual service delivery values are made as they will appear at the PCC.

While evaluating the priority, the issue is not to confuse the priorities of the individual WTGS with the priority of the WPS, e.g. a WTGS can be in FORCED OUTAGE information category and the WPS can at the same time be in PARTIAL PERFORMANCE. The specification permits the user, with caution, to prioritize data based on alternate views of the model, WPS or WTGS. When the model view is applied consistently there is no inconsistency in the expression of availability.

4.8 Application of the information model to components of the WEGS

An information model for a component level and BOP may also be developed based on the principles for the WEGS model. An example of how to apply the principles for BOP is discussed and illustrated in Annex F. The model illustrated in Annex F is optional.

5 Information categories

5.1 INFORMATION AVAILABLE

Definition – The category INFORMATION AVAILABLE is applied to all time periods, during which operational information and information on external conditions is retrieved, logged and stored manually or automatically to the extent that the characteristics of information categories can be discriminated. INFORMATION AVAILABLE is the top level for all mandatory information sub-categories as depicted at level 1 in Figure 2. Qualification for INFORMATION AVAILABLE requires sufficient information to determine that criteria for one of the mandatory level 4 categories with priority levels 1 to 12 are fulfilled.

It is recognised that there might be circumstances when information is not or only partially available. In case of insufficient information, the category INFORMATION UNAVAILABLE is likely to apply, see 5.7.

Information to determine the mandatory information category can be derived from multiple sources. Sources can be

- controller data from individual WTGSs;
- SCADA;
- BOP operation;
- metering information;
- manual entries.

For example, the information category can be determined as INFORMATION AVAILABLE if data transmission from every single WTGS of a WPS is interrupted, if data from a measurement system still gives adequate information to determine the category of the WPS.

Entry point – The operating status data are available to the extent that a category at level 4 can be determined, logged and stored.

Exit point – It is not possible to determine, log or store the level 4 category.

5.2 OPERATIVE

Definition – The WEGS is in the category OPERATIVE when capable of performing the intended functions, regardless of whether it is actually active and regardless of the capacity level that can be provided.

The OPERATIVE category is underlying the INFORMATION AVAILABLE category and has two underlying information categories as listed below and depicted in Figure 2.

- IN SERVICE – as defined in 5.3;
- OUT OF SERVICE – as defined in 5.4.

The OPERATIVE category is mandatory.

Entry point – The WEGS is able to perform the intended functions, regardless of whether it is actually active and regardless of the capacity level that can be provided.

Exit point – The WEGS is not able to maintain the intended functions.

5.3 IN SERVICE

5.3.1 General

Definition – The WEGS is performing the service.

The IN SERVICE category is an underlying category of the OPERATIVE category and has three underlying mandatory information categories as listed below and depicted in Figure 2.

- FULL PERFORMANCE – as defined in 5.3.2;
- PARTIAL PERFORMANCE – as defined in 5.3.3;
- READY STANDBY – as defined in 5.3.4.

The IN SERVICE information category is mandatory.

Entry point – The WEGS starts performing the intended functions.

Exit point – The WEGS stops performing the intended functions.

5.3.2 FULL PERFORMANCE

Definition – The WEGS is operative and functioning per design specifications with no technical restrictions or limitations beyond the ones specified in the design specifications.

No lost service shall be associated with the respective information category, when the WEGS is operating in FULL PERFORMANCE.

FULL PERFORMANCE is characterised by, but is not necessarily including all or limited to the following examples:

- all WTGSs performing according to design specifications;
- all WTGSs delivering active power according to design power curves;
- all BOP equipment performing its designed function at rated capacity;
- all WTGS delivering full rotor inertial energy for low frequency compensation.

The FULL PERFORMANCE category is an underlying category of IN SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The FULL PERFORMANCE category is mandatory.

Entry point – The WEGS is performing the intended function with the full capacity at the given conditions.

Exit point – The WEGS is not delivering the intended function with the full capacity at the given conditions.

5.3.3 PARTIAL PERFORMANCE

Definition – The WEGS is operating at reduced performance due to internal or external conditions.

PARTIAL PERFORMANCE may include, but is not limited to, the following examples:

- for a WPS, a technical fault or safety related events shutting down individual WTGSs;
- shortage in capacity of BOP components;
- grid management (partial curtailment);
- reduced load capability (individual WTGSs);
- financial considerations;
- asset management;
- WTGS(s) constrained but still operating within design specification.

The PARTIAL PERFORMANCE category is an underlying category of IN SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The PARTIAL PERFORMANCE category is mandatory.

Entry point – The WEGS is not providing the intended function with the full specified capacity.

Exit point – The conditions for being in PARTIAL PERFORMANCE no longer exist.

5.3.4 READY STANDBY

Definition – The WEGS is in the category READY STANDBY when ready to respond to a predefined event. READY STANDBY is not applicable to the active energy service.

READY STANDBY may include, but is not limited to, the following examples:

- a low frequency compensation service activated and awaiting a frequency drop;
- aviation warning light service awaiting an indication of approaching aircrafts;
- radar for bird migration awaiting a reading;
- VAr compensation system having elements disconnected but ready to engage.

The READY STANDBY category is an underlying category of IN SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The READY STANDBY category is mandatory.

Entry point – The WEGS is ready and able to respond to a pre-defined event.

Exit point – The WEGS is no longer able to respond to a pre-defined event or is now responding.

5.4 OUT OF SERVICE

5.4.1 General

Definition – The category OUT OF SERVICE is obtained when the WEGS is OPERATIVE but not IN SERVICE.

The OUT OF SERVICE category is an underlying category of OPERATIVE and has four predefined underlying mandatory information categories as listed below and depicted in Figure 2.

- TECHNICAL STANDBY – as defined in 5.4.2;
- OUT OF ENVIRONMENTAL SPECIFICATION – as defined in 5.4.3;
- REQUESTED SHUTDOWN – as defined in 5.4.4;
- OUT OF ELECTRICAL SPECIFICATION – as defined in 5.4.5.

The OUT OF SERVICE category is mandatory.

Entry point – The WEGS is OUT OF SERVICE due to one of the restrictive conditions described in the underlying information categories.

Exit point – All restrictive conditions in all underlying categories are cleared.

5.4.2 TECHNICAL STANDBY

Definition – The category TECHNICAL STANDBY is defined as periods when the WEGS is temporarily not functioning due to performance of autonomous tasks required for maintaining the intended functions.

TECHNICAL STANDBY is characterised by, but is not necessarily including all or limited to the following examples:

- component and system self-testing;
- transferring service of components, lines or interconnections;
- heating up, drying out or cooling down after a period of “out of environmental specification”;
- verification of recovery from de-icing after a period of “out of environmental specification” due to ice build-up.

The TECHNICAL STANDBY category is an underlying category of the OUT OF SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The TECHNICAL STANDBY category is mandatory.

Entry point – The WEGS determines or receives information that technical standby tasks have to be executed.

Exit point – The condition for being in TECHNICAL STANDBY no longer exists.

5.4.3 OUT OF ENVIRONMENTAL SPECIFICATION

Definition – The category OUT OF ENVIRONMENTAL SPECIFICATION is active when the WEGS is operative but not functioning as the environmental conditions are beyond the design specifications.

OUT OF ENVIRONMENTAL SPECIFICATION may include, but is not limited to, the following examples:

- ambient temperature above or below specifications;
- wind speed below specified cut in or above specified cut out;
- ice build-up.

The OUT OF ENVIRONMENTAL SPECIFICATION category is an underlying category of OUT OF SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The OUT OF ENVIRONMENTAL SPECIFICATION category is mandatory.

Entry point – One or more of the environmental conditions are out of design specification, prohibiting the WEGS from functioning.

Exit point – All natural environmental conditions change to be within the design specification.

5.4.4 REQUESTED SHUTDOWN

Definition – The category REQUESTED SHUTDOWN is active when the WEGS is operative but not functioning as it has been stopped by a request.

REQUESTED SHUTDOWN may include internal and external requests, but are not limited to, the following examples:

- safety related events;
- security breach related events;
- grid management (full curtailment);
- inspections;
- training;
- visits, demonstrations;
- nuisance – noise.

The REQUESTED SHUTDOWN category is an underlying category of the OUT OF SERVICE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The REQUESTED SHUTDOWN category is mandatory.

Entry point – The WEGS is ordered to shut down by a request.

Exit point – All active requests to shut down are cleared.

5.4.5 OUT OF ELECTRICAL SPECIFICATION

Definition – The category OUT OF ELECTRICAL SPECIFICATION is active when the WEGS is operative but not functioning as the electrical parameters of the WEGS are out of design specifications. This might be caused by grid parameters exceeding operational specifications.

OUT OF ELECTRICAL SPECIFICATION may include, but is not limited to, the following examples:

- over voltage;
- low frequency;
- phase imbalance;
- voltage drop.

The OUT OF ELECTRICAL SPECIFICATION category is an underlying category of the OUT OF SERVICE and has no predefined underlying mandatory information category as depicted in Figure 2.

The OUT OF ELECTRICAL SPECIFICATION category is mandatory.

Entry point – One or more of the electrical parameters of the WEGS go out of the operational and/or design specifications, prohibiting the WEGS from functioning.

Exit point – All electrical parameters of the WEGS change to be within the operational and/or design specifications.

5.5 NON-OPERATIVE

5.5.1 General

Definition – The NON-OPERATIVE category is applied to all situations when a WEGS is not capable of performing the intended function.

The NON-OPERATIVE category is an underlying category of the INFORMATION AVAILABLE and has four underlying mandatory information categories as listed below and depicted in Figure 2.

- SCHEDULED MAINTENANCE – as defined in 5.5.2;
- PLANNED CORRECTIVE ACTION – as defined in 5.5.3;
- FORCED OUTAGE – as defined in 5.5.4;
- SUSPENDED – as defined in 5.5.5.

The NON-OPERATIVE category is mandatory.

Entry point – The WEGS is not operating or it stops operating due to one of the restricting conditions described in the underlying information categories.

Exit point – All restricting conditions in all underlying categories are cleared.

5.5.2 SCHEDULED MAINTENANCE

Definition – The category SCHEDULED MAINTENANCE is entered during scheduled maintenance of elements of the WEGS preventing the entire WEGS from performing the intended functions.

The SCHEDULED MAINTENANCE category is an underlying category of the NON-OPERATIVE and has no predefined underlying mandatory information categories as depicted in Figure 2.

The SCHEDULED MAINTENANCE category is mandatory.

Entry point – The WEGS is stopped or prohibited with the intention of performing scheduled maintenance.

Exit point – The WEGS exits this category by manual intervention confirming that the scheduled maintenance has been interrupted or completed.

5.5.3 PLANNED CORRECTIVE ACTION

Definition – The category PLANNED CORRECTIVE ACTION is entered during actions required to retain, restore, or improve the intended functions of the WEGS when these actions are not part of normal scheduled maintenance. For the WPS, PLANNED CORRECTIVE ACTION is active when such work is on-going simultaneously on all WTGSs or on elements of the WPS (e.g. BOP) preventing the entire WPS from performing the intended functions.

PLANNED CORRECTIVE ACTION may include retrofits and upgrades, or required corrective actions identified through condition-based maintenance, inspections, investigations, etc. and is intended to account for corrective actions where the need is identified prior to any actual failure and early enough to be planned and completed before resulting in a possible forced outage.

The PLANNED CORRECTIVE ACTION category is an underlying category of the NON-OPERATIVE category and has no predefined underlying mandatory information categories as depicted in Figure 2.

The PLANNED CORRECTIVE ACTION category is mandatory.

Entry point – The function of the WEGS is stopped or prohibited with the intention of performing planned corrective actions.

Exit point – The WEGS exits this category by manual intervention confirming the planned corrective actions are interrupted or completed.

5.5.4 FORCED OUTAGE

Definition – The category FORCED OUTAGE is obtained when damage, fault, failure or alarm has disabled the WEGS. This can be detected manually or automatically. For a WPS, FORCED OUTAGE is active when such events occur simultaneously on all WTGSs or on elements of the WPS (e.g. BOP) preventing the entire WPS from performing the service.

The FORCED OUTAGE category is an underlying category of the NON-OPERATIVE and has no underlying mandatory information categories as depicted in Figure 2.

The FORCED OUTAGE category is mandatory.

Entry point – The WEGS is disabled because of damage, faults, or failures or an alarm.

Exit point – The WEGS exits this category when causes for the outage are cleared.

5.5.5 SUSPENDED

Definition – The category SUSPENDED is applied to all situations when activities in SCHEDULED MAINTENANCE, PLANNED CORRECTIVE ACTION and FORCED OUTAGE have to be interrupted or cannot be initiated due to conditions which compromise personal safety or equipment integrity.

The SUSPENDED category includes, but is not limited to:

- access limitations because of e.g. high waves, ice, snow, storm;
- severe weather conditions like lightning, tornados, hail;
- mitigation of risks such as a brush fire;
- suspension of work due to personnel safety and permit requirements;
- site working conditions are not met.

The SUSPENDED category is an underlying category of the NON-OPERATIVE and has no underlying mandatory information category as depicted in Figure 2.

The SUSPENDED category is mandatory.

Entry point – This category is entered by manual intervention when work is suspended according to predefined conditions.

Exit point – The category is terminated by manual intervention when the conditions suspending the work have been cleared.

5.6 FORCE MAJEURE

Definition – The category FORCE MAJEURE is applied to all situations where an extraordinary event or circumstance beyond the control of the parties involved, prevents the parties from fulfilling their obligations.

FORCE MAJEURE is a common clause in contracts which essentially frees concerned parties from their liability or obligation when an extraordinary event or circumstance beyond the control of the parties occurs.

FORCE MAJEURE is not intended to excuse negligence or other malfeasance of a party, as where non-performance is caused by the usual and natural consequences of external forces or where the intervening circumstances are specifically contemplated.

The FORCE MAJEURE information category is underlying the INFORMATION AVAILABLE information category on level 2 and has no underlying mandatory information categories as depicted in Figure 2.

The FORCE MAJEURE category is mandatory.

Entry point – This category is entered by manual intervention when a force majeure situation is detected according to contract.

Exit point – The category is terminated by manual intervention when a force majeure situation has been cleared according to contract.

5.7 INFORMATION UNAVAILABLE

Definition – The category INFORMATION UNAVAILABLE is applied to all time periods when the category INFORMATION AVAILABLE is not applicable.

The INFORMATION UNAVAILABLE information category is on level 1 and as such has no overlying information category. This information category exists across all mandatory levels 1 to 4. It does not have any underlying mandatory information categories as depicted in Figure 2.

The INFORMATION UNAVAILABLE category is mandatory.

Entry point – It is not possible to determine, log or store the level 4 category.

Exit point – The data on operating status is available to the extent that a category at level 4 can be determined, logged and stored.

Annex A
(informative)

Entry and exit conditions overview for WEGS

Information categories													
INFORMATION AVAILABLE												INFORMATION NOT AVAILABLE	Level 1
OPERATIVE							NON-OPERATIVE				FORCE MAJEURE		Level 2
IN SERVICE			OUT OF SERVICE										Level 3
FULL PERFORMANCE	PARTIAL PERFOMANCE	READY STAND-BY	TECH. STANDBY	OUT OF ENV. SPEC.	REQUESTED SHUTDOWN	DUT OF ELECT. SPEC.	SCHEDULED MAINTENANCE	PLANNED CORRECTIVE ACTIONS	FORCED OUTAGE	SUSPENDED			Level 4
1	2	3	4	5	6	7	8	9	10	11	12	13	Priority

Entry conditions													
The WEGS operating status data are available to the extent that an information category at level 4 can be determined, logged and stored												An information category of the WEGS at level 2, 3 or 4 cannot be determined, logged and stored	Level 1
The WEGS is able to perform the intended functions, regardless of whether it is actually active and regardless of the capacity level that can be provided.							The WEGS is not operating or it stops operating due to one of the restricting conditions described in the underlying information categories				This category is entered by manual intervention when a force majeure situation is detected according to contractual terms		Level 2
The WEGS is performing the intended functions			The WEGS is not performing the intended functions due to one of the circumstances described in the underlying information categories										Level 3
The WEGS is performing the service with full capacity at the given conditions	The WEGS is performing the service but not at full capacity	The WEGS is ready and able to activate the service	The WEGS determines or receives information that technical standby tasks have to be executed	One or more of the environmental conditions change to be out of the WEGS design specifications	The WEGS is shut down by an external request	One or more of the electrical parameters at the WEGS change to be out of the design specifications of the WEGS	The WEGS is stopped or prohibited with the intention of performing scheduled maintenance	The WEGS is stopped or prohibited with the intention of performing planned corrective actions	The WEGS is disabled because of damage, faults or failures or an alarm	The WEGS is stopped or prohibited due to manual intervention when work is suspended according to predefined conditions			Level 4
1	2	3	4	5	6	7	8	9	10	11	12	13	Priority

Exit conditions													
An information category of the WEGS at level 2, 3 or 4 cannot be determined, logged and stored												The WEGS operating status data are available to the extent that an information category at level 4 can be determined, logged and stored	Level 1
The WEGS is not able to perform the intended functions							All restricting conditions in all underlying categories are cleared				This category is terminated by manual intervention when a force majeure situation is no longer present		Level 2
The WEGS stops performing the service			All restrictive conditions in all underlying categories are cleared										Level 3
The WEGS is not performing the service with full capacity at the given conditions	The conditions for performing the service at reduced capacity are cleared	The WEGS is not in a 'ready' situation, is not able to activate the service or has activated the service	The WEGS is no longer awaiting or performing technical standby tasks	All environmental conditions change to be within the WEGS design specifications	All active external requests to shut down are cleared	All electrical parameters at the WEGS change to be within of the design specifications of the WEGS	The WEGS exits this category by manual intervention confirming that the scheduled maintenance has been interrupted or completed	The WEGS exits this category by manual intervention confirming that the planned corrective action has been interrupted or completed	The WEGS exits this category when causes for outage are cleared	This category is terminated by manual intervention when the conditions suspending the work have been cleared			Level 4
1	2	3	4	5	6	7	8	9	10	11	12	13	Priority

IEC

Figure A.1 – Overview of the entry and exit conditions of all mandatory information categories described in this document

Annex B
(informative)

Optional information categories for WEGS information model – illustrative explanation and examples

B.1 General

This annex describes examples of optional information categories proposed to be applied when more detailed information is required to address specific information needs. An overview of some possible information categories is depicted in Figure B.1.

If further detail is required more optional information categories can be added as underlying categories to the mandatory level 4 and/or to the proposed level 5 categories. All optional information categories shall be located on level 5 or higher to be compliant with this document. Priority of optional categories shall be assigned as depicted in the example in Clause B.2.

B.2 PARTIAL PERFORMANCE – optional categories

B.2.1 Introduction of optional categories

The optional information categories are introduced to further detail the mandatory information category PARTIAL PERFORMANCE as listed below and depicted in Figure B.1.

- **derated** – as defined in B.2.2;
- **degraded** – as defined in B.2.3.

B.2.2 Derated

The information category **derated** can be used to accumulate time periods when a WEGS is operative and generating at reduced power because of external commands or external constraints.

External constraints would typically include, but are not limited to, partial power curtailment, grid stability support modes, ancillary services, environmental conditions (temperature, dust, turbulence, etc.) or other external factors (noise, shadow, flicker, wake, turbulence, etc.).

The **derated** category is an underlying category of PARTIAL PERFORMANCE and has no predefined underlying optional information categories.

Entry point – An external event or manual intervention prohibits the intended function of the WEGS from operating at full specified capability.

Exit point – All external constraints which prohibit a WEGS from operating at full specified capability no longer exist.

Information categories						
Mandatory level 1	Mandatory level 2	Mandatory level 3	Mandatory level 4	Mandatory priority	Optional level 5	level 5 priority
INFORMATION 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**		

IEC

Figure B.1 – Information category overview – mandatory and optional

B.2.3 Degraded

The information category **degraded** can be used to accumulate time periods when a WEGS is operative and generating power with a reduced performance because of internal constraints.

Internal constraints could result from component damage or the need to prevent component damage, e.g. component overheating, vibration levels, bearing issues, converter cooling system reductions, etc.

The **degraded** information category is an underlying category of PARTIAL PERFORMANCE.

Entry point – An internal event or manual intervention prohibits a WEGS from operating the intended functions at full specified capability.

Exit point – All internal constraints which prohibit a WEGS from operating at a specified capability no longer exist.

B.3 OUT OF ENVIRONMENTAL SPECIFICATION – optional categories

B.3.1 Introduction of optional categories

The optional information categories are introduced to further detail the mandatory information category OUT OF ENVIRONMENTAL SPECIFICATION as listed below and depicted in Figure B.1.

- **calm winds** – as defined in B.3.2;
- **other environmental** – as defined in B.3.3.

B.3.2 Calm winds

The information category **calm winds** can be used to accumulate time periods when a WEGS is operative but not generating because the wind speed is under the design specification for the minimum wind speed of the turbine.

The **calm winds** category is an underlying category of OUT OF ENVIRONMENTAL SPECIFICATION and has no predefined underlying information categories.

Entry point – The wind speed in the natural environment changes to be below the WEGS design specification for minimum wind speed, prohibiting the WEGS from generating.

Exit point – The wind speed in the natural environment rises above the WEGS design specification for minimum wind speed.

B.3.3 Other environmental

The information category **other environmental** is obtained when the WEGS is operative but not generating as one or more conditions of the natural environment are outside the design specifications, other than wind speed being below the design specification for minimum wind speed.

The **other environmental** optional information category is an underlying category of OUT OF ENVIRONMENTAL SPECIFICATION and has no predefined underlying information categories.

Entry point – One or more conditions in the natural environment changes to be outside the WEGS design specification, other than the wind speed falling below the design specification for minimum wind speed, prohibiting the WEGS from generating.

Exit point – All conditions in the natural environment are within the design specification of the WEGS, other than the wind speed in the natural environment being above the WEGS design specification for minimum wind speed.

B.4 PLANNED CORRECTIVE ACTION – optional categories

B.4.1 Introduction of optional categories

The optional information categories are introduced to further detail the mandatory information category NON-OPERATIVE as listed below and depicted in Figure B.1. The main purpose of these optional information categories is to provide generic terms for assigning responsibility in case planned corrective actions are performed.

Optional information categories applicable for PLANNED CORRECTIVE ACTION are:

- **retrofit** – as defined in B.4.2;
- **upgrade** – as defined in B.4.3;
- **other corrective action** – as defined in B.4.4.

B.4.2 Retrofit

The information category **retrofit** will identify the planned corrective actions to incorporate any modification recommended by the manufacturer to achieve the WEGS specification.

Entry point – The retrofit activity begins. The operator has already prepared support needed such as parts, repair team, equipment, etc. A retrofit category can only be entered by manual intervention.

Exit point – This information category is terminated by manual intervention when the retrofit activity is completed.

B.4.3 Upgrade

The information category **upgrade** will identify the planned corrective actions to incorporate any modification recommended by the manufacturer to improve the WEGS performances beyond the specification. These upgrades are user’s choice to implement.

Entry point – The upgrade activity begins. The operator has already prepared support needed such as parts, repair team, equipment, etc. The upgrade category can only be entered by manual intervention.

Exit point – This information category is terminated by manual intervention when the upgrade activity is completed.

B.4.4 Other planned corrective action

The information category **other planned corrective action** will identify planned corrective actions that are not retrofits or upgrades. An example would be to replace a generator bearing that was found damaged in an earlier inspection but could continue operating while parts and logistics were prepared for the repair.

Entry point – The other planned corrective action activity begins. The operator has already prepared support needed such as parts, repair team, equipment, etc. This information category can only be entered by manual intervention.

Exit point – This information category is terminated by manual intervention when the other planned corrective action activity is completed.

B.5 FORCED OUTAGE – optional category

B.5.1 Introduction of optional categories

The following optional information categories can be applied to increase the detail of the mandatory information category FORCED OUTAGE. The main purpose for these optional information categories is to provide generic terms for assigning responsibility for various stages of an outage workflow.

When an outage category is encountered a breakdown of the outage workflow can be interesting for monitoring the performance of the various parties involved.

The time terms to be observed can be as specified in B.5.2 to B.5.5. The overall workflow can be separated into optional information categories as depicted in Figure B.2.

As seen from the schematic workflow, the time period from when a fault in a WEGS is detected to when the failure is repaired and all alarms/events are cleared can be divided into four underlying optional information categories as listed below.

- **response** (R) – as defined in B.5.2;
- **diagnostic** (D) – as defined in B.5.3;
- **logistic** (L) – as defined in B.5.4;
- **repair** (F) – as defined in B.5.5.

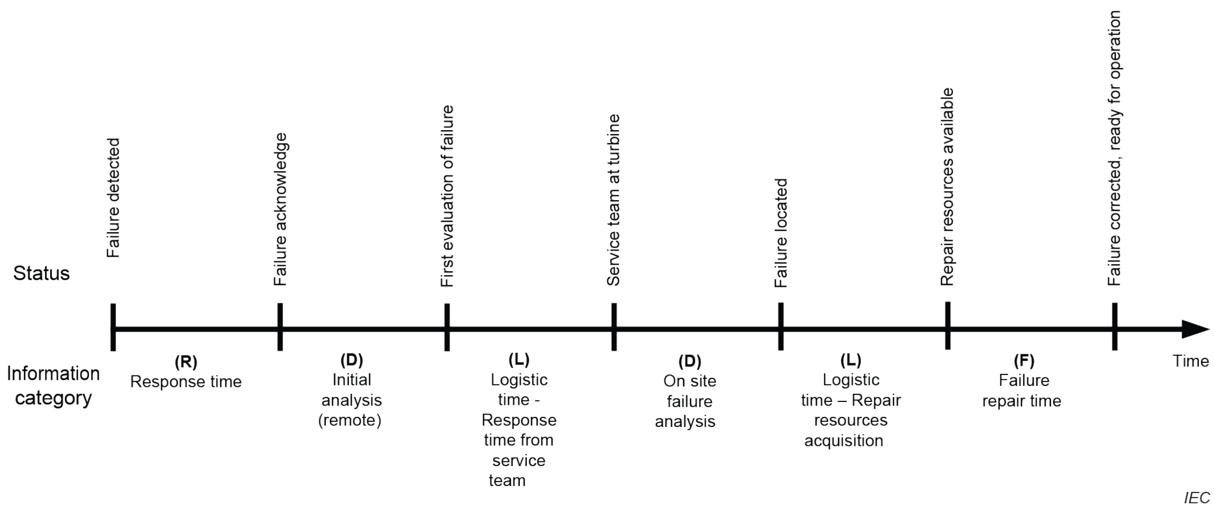


Figure B.2 – Workflow breakdown structure

B.5.2 Response

The information category **response** can be used to accumulate time periods from notification of any event until an action on the event has been initiated.

In the workflow breakdown this category could cover, but is not limited to:

- failure acknowledge;
- service partner response time for a repair request;
- service team setup;
- waiting time for acceptance to initiate a corrective action.

Entry point – An internal fault or external command is received and the WEGS generator system does not automatically return to the operative category.

Exit point – The operator detects and logs fault or status. A WEGS generator system can only exit this category by manual intervention.

B.5.3 Diagnostic

The information category **diagnostic** can be used to accumulate time periods spend to analyse a fault symptom, related measurements and findings indicating a failure and planning corrective action. In the workflow breakdown it covers, but is not limited to:

- initial analysis;
- remote detailed analysis;
- additional analysis;
- additional clarifications required;
- planning corrective actions;
- approval of corrective actions.

Entry point – The operator detects and logs fault or status. The WEGS can only enter this mode by manual intervention.

Exit point – The operator has completed analysis and determined required action. A WEGS generator system can only exit this category by manual intervention.

B.5.4 Logistic

The information category **logistic** can be used to accumulate time periods used for logistic activities such as, but is not limited to:

- transportation of tools;
- crane lead time;
- service team set-up;
- ordering support tools;
- ordering spare parts;
- waiting time for resource allocation;
- lead time for tools required;
- lead time for spare parts required.

Entry point – The operator has completed analysis and determined required action and has initiated actions such as: orders parts, calls out repair team, etc. A WEGS can only enter this category by manual intervention.

Exit point – All the required actors and equipment are in place for the activities called for by the current diagnostics. A WEGS can only exit this category by manual intervention.

B.5.5 Repair

The information category **repair** can be used to accumulate time periods used for implementation of repair activities such as, but not limited to:

- change of a defective sensor;
- change of control software version;
- verification of replaced damage parts;
- inspection or audit related to repairing activity;
- run-in test after finalizing repair activity.

Entry point – The repair activity begins either local or remote. A Repair time information category can only be entered by manual intervention.

Exit point – This information category is terminated by manual intervention when the repair activity is completed.

B.6 SUSPENDED – optional categories

B.6.1 Introduction of optional categories

The following optional information categories can be applied to increase details in the mandatory information category SUSPENDED. The main purpose for the optional information categories focusing on the suspended situation is to provide generic terms for exchange of information on availability for suspended periods.

Optional information categories applicable for SUSPENDED are:

- **scheduled maintenance** – as defined in B.6.2;
- **planned corrective action** – as defined in B.6.3;
- **forced outage** – as defined in B.6.4.

B.6.2 Suspended scheduled maintenance

The information category **suspended scheduled maintenance** covers all situations where a suspension is initiated during a scheduled maintenance activity.

Entry point – This information category is entered by manual intervention when a scheduled maintenance task is suspended according to predefined conditions.

Exit point – This information category is terminated by manual intervention when the conditions suspending the work have been cleared.

B.6.3 Suspended planned corrective action

The information category **suspended planned corrective action** covers all situations where a suspension is initiated during a planned corrective activation period.

Entry point – This information category is entered by manual intervention when a planned corrective action is suspended according to predefined conditions.

Exit point – This information category is terminated by manual intervention when the conditions for suspending the work have been cleared.

B.6.4 Suspended forced outage

The information category **suspended forced outage** covers all situations were a suspension is initiated during a forced outage.

Entry point – This information category is entered by manual intervention when a forced outage corrective action is suspended according to predefined conditions.

Exit point – This information category is terminated by manual intervention when the conditions for suspending the work have been cleared.

B.7 Considerations of competing assignment of lost service

Situations might arise where data gathered do not adequately reflect the assignment of downtime and lost production, because of enforcing mutual exclusivity of the categories in the information model.

This will occur when the entry conditions for two or more optional categories are fulfilled at the same time, thus invariably resulting in the selection of one category over another according to the principles of priority. When it comes to assigning the consequent losses, this would potentially result in undetermined/inaccurate weighting of the losses assigned to various categories as demonstrated in the example below. See Figure B.3.

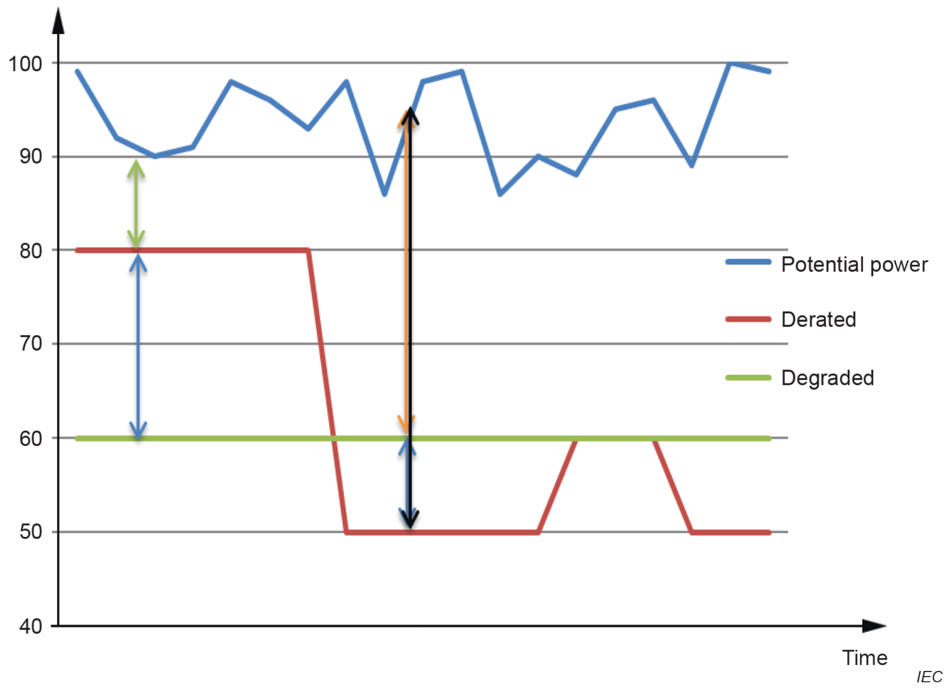


Figure B.3 – Example of simultaneous degrading and derating

Scenario:

The WEGS is degraded to 60 % of its nominal power due to deterioration. At the same time, the grid operator requests to derate the WEGS to 80 % of its nominal production and later to a value lower than the degraded value. The wind is at all times sufficient to achieve both potential service delivery values (**derated** and **degraded**). Clarification might be needed concerning which potential service delivery shall have priority: 80 % as **derated** and 60 % as **degraded**, with potential service delivery in accordance with the actual wind conditions. This limitation is inherent in the information model. Therefore, it is prudent to consider which conflicts might arise in advance, and how these should be resolved.

Annex C
(informative)

Examples of availability indicators

C.1 General

C.1.1 Introduction to the scope of this annex

Annex C is divided into three clauses. Clause C.2 deals with time-based availability, Clause C.3 describes production-based availability and Clause C.4 introduces additional availability indicators, users might apply. Examples are given for calculating time-based and production-based availability. The examples are only for illustrative purposes and appropriate application of the model can be extended to optional information categories as well as various levels of the WPS. The equations used and the assignment of categories to 'available' and 'unavailable' is entirely up to the user(s) to decide on.

C.1.2 Time-based availability

The clause on time-based availability illustrates examples of how to calculate availability of a WEGS. Each example is based on an assignment of the information categories into:

a) information categories considered as available time (green colouring);

b) information categories considered as unavailable time (red colouring);

c) information categories not to be considered in the availability calculation (grey colouring).

Users may find other arrangements of the categories more suited for their needs.

When calculating time-based availability, the following equation is widely accepted:

$$\text{Availability}_{\text{time}} = 1 - \frac{\text{Unavailable time}}{\text{Available time} + \text{Unavailable time}} \qquad \text{(C.1)}$$

C.1.3 Production-based availability

The clause on production-based availability illustrates examples of how to calculate production-based availability of a WEGS. For the time period to which production-based availability is to be calculated, the operation of the turbine shall first be categorized according to the information categories.

The examples of production-based availability calculations are defined in terms of:

a) actual service delivery (green colouring);

b) lost service (red colouring);

c) information categories not to be considered in the availability calculation (grey colouring).

When calculating the production-based availability in the examples, the following equation is applied:

$$\text{Availability}_{\text{prod}} = 1 - \frac{\text{Lost service}}{\text{Actual service delivery} + \text{lost service}} \qquad \text{(C.2)}$$

where ‘lost service’ is the sum of the individual losses in each category considered unavailable, see 4.5.5.

C.1.4 Mapping of availability and unavailability

When calculating availability, each information category shall first be assigned to being either ‘available’ or ‘unavailable’ or excluded. This assignment shall be decided and fixed by the parties involved. In this subclause, two scenarios for category assignments are presented, see Table C.1.

Table C.1 – Example of mapping of available and unavailable information categories

	Mandatory – Information categories														**Availability = 1 – unavailability/ (availability + unavailability)**	
MEANING OF COLOURS: GREEN = included in period as available; RED = included in period as unavailable; GREY = excluded	**FULL PERFORMANCE (IAOSFP)**	**PARTIAL PERFORMANCE (IAOSPP)**	**READY STANDBY (IAOSRS)**	**TECHNICAL STANDBY (IAOOSTS)**	**OUT OF ENVIRON SPEC (IAOOSEN)**	**REQUESTED SHUTDOWN (IAOOSRS)**	**OUT OF ELECTRICAL SPEC (IAOOSEL)**	**MAINTENANCE (IANOSM)**	**PLAN CORRECTIVE ACTION (IANOPCA)**	**FORCED OUTAGE (IANOFO)**	**SUSPENDED (IANOS)**	**FORCE MAJEURE (IAFM)**	**INFORMATION UNAVAILABLE (IU)**		**Operational availability (C.2)**	**Technical availability (C.3)**
Operational availability	GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY		X	
Technical availability	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY			X

‘Operational availability’ is here understood as the fraction of a given period of time in which a WEGS is actually producing. Lost operating hours due to any reason are included as unavailability. ‘Operational availability’ may be seen as the users or ‘operator’s view’.

‘Technical availability’ is here understood as the fraction of a given period of time in which a WEGS is operating according to its design specifications. ‘Technical availability’ may be considered as ‘the maintenance provider’s view’.

C.2 Time-based availability

C.2.1 General

The time-based approach is based on counting the number of hours assigned to available and unavailable information categories.

C.2.2 Time-based availability – "operational availability"

This subclause illustrates application of the Formula (C.1) for a time-based operational availability calculation. Examples are made for mandatory categories and for situations also considering the optional categories defined for level 5.

a) Basic operational availability algorithm based on mandatory categories only

In this example, time considered as available is

- FULL PERFORMANCE, IAOSFP
- PARTIAL PERFORMANCE, IAOSPP
- READY STANDBY, IAOSRS

Time considered unavailable is

- TECHNICAL STANDBY, IAOOSTS
- OUT OF ENVIRONMENTAL SPECIFICATION, IAOOSEN
- REQUESTED SHUTDOWN, IAOOSRS
- OUT OF ELECTRICAL SPECIFICATION, IAOOSEL
- SCHEDULED MAINTENANCE, IANOSM
- PLANNED CORRECTIVE ACTION, IANOPCA
- FORCED OUTAGE, IANOFO
- SUSPENDED, IANOS
- FORCE MAJEURE, IAFM

The assignment of 'availability' and 'unavailability' is illustrated in Table C.1. Applying the above definitions to Formula (C.1) gives

$$\text{Operational availability}_{\text{time}} = 1 - \frac{\text{IAOOSTS} + \text{IAOOSEN} + \text{IAOOSRS} + \text{IAOOSEL} + \text{IANOSM} + \text{IANOPCA} + \text{IANOFO} + \text{IANOS} + \text{IAFM}}{(\text{IAOSFP} + \text{IAOSPP} + \text{IAOSRS}) + (\text{IAOOSTS} + \text{IAOOSEN} + \text{IAOOSRS} + \text{IAOOSEL} + \text{IANOSM} + \text{IANOPCA} + \text{IANOFO} + \text{IANOS} + \text{IAFM})} \quad \text{(C.3)}$$

Time not considered is

- INFORMATION UNAVAILABLE, IU.

Since no information about the WEGS is known in the INFORMATION UNAVAILABLE category, these periods are not included as available or unavailable, and are excluded entirely from the calculation.

b) <u>Basic operational availability algorithm – including optional categories</u>

In this example, time considered as available is

- FULL PERFORMANCE, IAOSFP
- PARTIAL PERFORMANCE, IAOSPP
- READY STANDBY, IAOSRS
- OUT OF ENVIRONMENTAL SPECIFICATION – **calm winds**, IAOOSEN_C

Time considered unavailable is

- TECHNICAL STANDBY, IAOOSTS
- OUT OF ENVIRONMENTAL SPECIFICATION – **other environmental**, IAOOSEN_O
- REQUESTED SHUTDOWN, IAOOSRS
- OUT OF ELECTRICAL SPECIFICATION, IAOOSEL
- SCHEDULED MAINTENANCE, IANOSM
- PLANNED CORRECTIVE ACTION, IANOPCA
- FORCED OUTAGE, IANOFO

- SUSPENDED, IANOS
- FORCE MAJEURE, IAFM

Time not considered is

- INFORMATION UNAVAILABLE, IU

Applying the above definitions to Formula (C.1) gives

$$\text{Operational availability}_{time} \text{ (incl. level 5)} = 1 - \frac{IAOOSTS + IAOOSEN_O + IAOOSRS + IAOOSEL + IANOSM + IANOPCA + IANOFO + IANOS + IAFM}{(IAOSFP + IAOSPP + IAOSRS + IAOOSEN_C) + (IAOOSTS + IAOOSEN_O + IAOOSRS + IAOOSEL + IANOSM + IANOPCA + IANOFO + IANOS + IAFM)} \quad (C.4)$$

The use of the optional categories **calm winds** and **other environmental** allows for a distinction between lost operating hours due to unavailable wind resource, and those hours lost due to other operating conditions being beyond the design specifications of the WEGS. Thus, some low wind situations can be assigned as 'not penalized' (e.g. **calm winds**).

C.2.3 Time based availability – "technical availability"

This subclause illustrates application of the Formula (C.1) for a time-based technical availability calculation. An example considering mandatory categories only is presented.

In this example, time considered as available is

- FULL PERFORMANCE, IAOSFP
- PARTIAL PERFORMANCE, IAOSPP
- READY STANDBY, IAOSRS
- TECHNICAL STANDBY, IAOOSTS
- OUT OF ENVIRONMENTAL SPECIFICATION, IAOOSEN
- REQUESTED SHUTDOWN, IAOOSRS
- OUT OF ELECTRICAL SPECIFICATION, IAOOSEL

Time considered unavailable is

- PLANNED CORRECTIVE ACTION, IANOPCA
- FORCED OUTAGE, IANOFO

Time not considered is

- SCHEDULED MAINTENANCE, IANOSM
- SUSPENDED, IANOS
- FORCE MAJEURE, IAFM.
- INFORMATION UNAVAILABLE, IU

Applying the above definitions to Formula (C.1) gives

$$\text{Technical availability}_{time} = 1 - \frac{IANOPCA + IANOFO}{(IAOSFP + IAOSPP + IAOSRS + IAOOSTS + IAOOSEN + IAOOSRS + IAOOSEL) + (IANOPCA + IANOFO)} \quad (C.5)$$

C.3 Production-based availability

C.3.1 General

The production-based approach is based on summing-up the actual and potential production assigned to available and unavailable information categories.

C.3.2 Production-based availability – "operational availability"

This subclause illustrates application of the Formula (C.2) for a production-based operational availability calculation. An example considering mandatory categories only is presented.

In this example, information categories with an actual energy production are:

- FULL PERFORMANCE, $IAOSFPS_A$
- PARTIAL PERFORMANCE, $IAOSPPS_A$
- READY STANDBY, $IAOSRSS_A$

Information categories with lost production are:

- PARTIAL PERFORMANCE, $IAOSPPS_P - IAOSPPS_A$
- READY STANDBY, $IAOSRSS_P - IAOSRSS_A$
- TECHNICAL STANDBY, $IAOOSTSS_P$
- OUT OF ENVIRONMENTAL SPECIFICATION, $IAOOSENS_P$
- REQUESTED SHUTDOWN, $IAOOSRSS_P$
- OUT OF ELECTRICAL SPECIFICATION, $IAOOSELS_P$
- SCHEDULED MAINTENANCE, $IANOSMS_P$
- PLANNED CORRECTIVE ACTION, $IANOPCAS_P$
- FORCED OUTAGE, $IANOFOS_P$
- SUSPENDED, $IANOSS_P$
- FORCE MAJEURE, $IAFMS_P$

Information categories not included in the calculation are:

- INFORMATION UNAVAILABLE, IU

Applying the above definitions to Formula (C.2) gives

$$\text{Operational production-based availability}_{prod} = 1 - \frac{(IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSENS_P + IAOOSRSS_P + IAOOSELS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P + IANOSS_P + IAFMS_P}{(IAOSFPS_A + IAOSPPS_A + IAOSRSS_A) + (IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSENS_P + IAOOSRSS_P + IAOOSELS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P + IANOSS_P + IAFMS_P} \quad \text{(C.6)}$$

Note that since no information about the WEGS is known in the INFORMATION UNAVAILABLE information category, these periods are not included as available or unavailable, and are excluded entirely from the calculation. This is the equivalent of assuming that production during those periods is the same as the average production during the period for which information is available.

C.3.3 Production-based availability – "technical availability"

This subclause illustrates application of the Formula (C.2) for a production-based technical availability calculation. Examples are made for mandatory categories and for situations also considering the optional categories defined for level 5.

a) Basic operational availability algorithm based on mandatory categories only

In this example, information categories with actual energy production are:

- FULL PERFORMANCE, **IAOSFPS**$_A$
- PARTIAL PERFORMANCE, **IAOSPPS**$_A$
- READY STANDBY, **IAOSRSS**$_A$

Furthermore, although the following categories are non-generating and have no actual energy production, for the purposes of this definition, the potential energy production associated with each is included as available:

- TECHNICAL STANDBY, **IAOOSTSS**$_P$
- OUT OF ENVIRONMENTAL SPECIFICATION, **IAOOSENS**$_P$
- REQUESTED SHUTDOWN, **IAOOSRSS**$_P$
- OUT OF ELECTRICAL SPECIFICATION, **IAOOSELS**$_P$

Information categories with lost production are:

- PARTIAL PERFORMANCE, **IAOSPPS**$_P$ **– IAOSPPS**$_A$
- READY STANDBY, **IAOSRSS**$_P$ **– IAOSRSS**$_A$
- PLANNED CORRECTIVE ACTION, **IANOPCAS**$_P$
- FORCED OUTAGE, **IANOFOS**$_P$

Information categories not included in the calculation include:

- SCHEDULED MAINTENANCE, **IANOSMS**$_P$
- SUSPENDED, **IANOSS**$_P$
- FORCE MAJEURE, **IAFMS**$_P$
- INFORMATION UNAVAILABLE, **IU**

Applying the above definitions to Formula (C.2) gives

$$\text{Technical production-based availability}_{\text{prod}} = 1 - \frac{(\text{IAOSPPS}_P - \text{IAOSPPS}_A) + (\text{IAOSRSS}_P - \text{IAOSRSS}_A) + \text{IANOPCAS}_P + \text{IANOFOS}_P}{(\text{IAOSFPS}_A + \text{IAOSPPS}_A + \text{IAOSRSS}_A + \text{IAOOSTSS}_P + \text{IAOOSENS}_P + \text{IAOOSRSS}_P + \text{IAOOSELS}_P) + (\text{IAOSPPS}_P - \text{IAOSPPS}_A) + (\text{IAOSRSS}_P - \text{IAOSRSS}_A) + \text{IANOPCAS}_P + \text{IANOFOS}_P} \quad \text{(C.7)}$$

b) Basic technical availability algorithm – including optional categories

In this example, information categories with actual energy production are:

- FULL PERFORMANCE, **IAOSFPS**$_A$
- PARTIAL PERFORMANCE – **derated**, **IAOSPP**$_{DR}$**S**$_A$
- PARTIAL PERFORMANCE – **degraded**, **IAOSPP**$_{DG}$**S**$_A$
- READY STANDBY, **IAOSRSS**$_A$

Furthermore, although the following categories are non-generating and have no actual energy production, for the purposes of this definition, the potential energy production associated with each is included as available:

- PARTIAL PERFORMANCE – **derated**, $IAOSPP_{DR}S_P - IAOSPP_{DR}S_A$
- TECHNICAL STANDBY, $IAOOSTSS_P$
- OUT OF ENVIRONMENTAL SPECIFICATION – **other environmental**, $IAOOSEN_OS_P$
- REQUESTED SHUTDOWN, $IAOOSRSS_P$
- OUT OF ELECTRICAL SPECIFICATION, $IAOOSELS_P$

Information categories with lost production are:

- PARTIAL PERFORMANCE – **degraded**, $IAOSPP_{DG}S_P - IAOSPP_{DG}S_A$
- READY STANDBY, $IAOSRSS_P - IAOSRSS_A$
- PLANNED CORRECTIVE ACTION, $IANOPCAS_P$
- FORCED OUTAGE, $IANOFOS_P$

Information categories not considered in the calculation include:

- OUT OF ENVIRONMENTAL SPECIFICATION – **calm winds**, $IAOOSEN_CS_P$
- SCHEDULED MAINTENANCE, $IANOSMS_P$
- SUSPENDED, $IANOSS_P$
- FORCE MAJEURE, $IAFMS_P$
- INFORMATION UNAVAILABLE, IU

Applying the above definitions to Formula (C.2) gives

$$\text{Technical production-based availability}_{prod} = 1 - \frac{(IAOSPP_{DG}S_P - IAOSPP_{DG}S_A) + (IAOSRSP_P - IAOSRSP_A) + IANOPCAS_P + IANOFOS_P}{(IAOSFPS_A + IAOSPP_{DR}S_A + IAOSPP_{DG}S_A + IAOSRSS_A + (IAOSPP_{DR}S_P - IAOSPP_{DR}S_A) + IAOOSTSS_P + IAOOSENOS_P + IAOOSRSS_P + IAOOSELS_P) + (IAOSPP_{DG}S_P - IAOSPP_{DG}S_A) + (IAOSRSP_P - IAOSRSP_A) + IANOPCAS_P + IANOFOS_P} \quad (C.8)$$

Unlike in the example of 'operational availability' in C.2.2, the use of the optional information categories OUT OF ENVIRONMENTAL SPECIFICATION – **calm winds** and OUT OF ENVIRONMENTAL SPECIFICATION – **other environmental** is different. For calm wind situations, there is no actual or potential energy production and therefore no lost production. Periods of calm winds are essentially excluded from production-based availability calculations. Production-based availability is affected when wind resources are not captured by a WEGS due to environmental conditions beyond the design specifications of the WEGS, but the performance metric is not penalized when no wind resource is available.

C.4 Capacity factor and other performance indicators

C.4.1 General

In addition to time-based or production-based availability, which primarily describe the readiness of a WEGS to capture site wind resources, other performance indicators may be defined which might be useful in describing or characterizing additional aspects of the WEGS performance. Users may find other definitions or other performance indicators to be more applicable to their needs.

The information model can be extended by the users to other parameters of interest as well. For example, an additional layer can be defined for the revenue associated with the actual, potential, or lost production of the WEGS for any specific information category, and revenue-based production can be assessed in a similar manner.

C.4.2 Capacity factor

Capacity factor is the amount of energy produced by a WEGS compared to how much energy could have been produced if the WEGS has operated at its rated power during the specified period of time, and may be defined in terms of actual energy production or potential energy production. The capacity factor is a measure of the WEGS capability to generate electricity at a specific site (sometimes expressed as the equivalent full load hours over a specified period of time).

Capacity factors may be calculated as in the examples of Formulae (C.9) and (C.10).

$$\text{Actual capacity factor} = \frac{\text{Actual energy production}}{(\text{Rated power}) \times (\text{specified period hours})} \qquad \text{(C.9)}$$

$$\text{Potential capacity factor} = \frac{\text{Potential energy production}}{(\text{Rated power}) \times (\text{specified period hours})} \qquad \text{(C.10)}$$

where maximum production is defined as the energy that would have been produced if the WEGS has operated at its rated output during that period of time.

C.4.3 Production ratio

Production ratio is the amount of energy produced by a WEGS while in FULL PEFORMANCE compared to its potential energy production.

$$\text{Production ratio} = \frac{\text{Actual energy production}}{\text{Potential energy production}} \qquad \text{(C.11)}$$

The production ratio is a measure of whether the WEGS is producing as expected. WEGS output in FULL PERFORMANCE can be different than expected due to blade fouling, improper alignment, pitch system malfunction, temperature or turbulence effects among others. This performance metric allows for the quick identification of such issues, since the production ratio on those units is expected to be less than one. It should also be noted that actual energy production can be the same as or greater than potential energy production depending on expected variations in production and how potential energy production is defined, or over what period of time the production ratio is calculated.

C.4.4 Mean-value based information

While capacity-based information is not explicitly stored in the information model, the mean capacity can be derived from the information model for some services. This can for example be done for the actual energy production and the potential energy production data stored in layers 2 and 3, by dividing the values stored in the respective layers by the information in the corresponding category in layer 1.

Annex D
(informative)

Verification scenarios – examples

D.1 General

This annex is intended to illustrate the application of indicators introduced in Annex B and Annex C.

D.2 Time-based scenarios for a WTGS

D.2.1 Introduction to verification scenarios

Each scenario consists of a time line covering one calendar week of events that typically occur at a WTGS. The scenarios are described in the subclauses D.2.2 to D.2.7.

For each scenario, time is distributed into the mandatory information categories as depicted in graphical form in Table D.1. Colours indicate how the individual mandatory information categories are included in the availability calculations, with green indicating that time is included in the period hours as available, red indicating that time is included in the period hours as unavailable and grey indicates those hours excluded from the period hours and not included in the calculation of the performance metric.

Table D.1 – Verification scenarios – time allocation to information categories

	Mandatory – information categories													**Availability = 1 – unavailability/ (availability + unavailability)**	
MEANING OF COLOURS: **GREEN** = included in period hours as available **RED** = included in period hours as unavailable **GREY** = excluded from period hours	FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	**Operational availability (C.2.2)**	**Technical availability (C.2.3)**
Operational availability	[green]	[green]	[green]	[red]	[red]	[red]	[red]	[red]	[red]	[red]	[red]	[red]	[grey]	X	
Technical availability	[green]	[green]	[green]	[green]	[green]	[green]	[green]	[grey]	[red]	[red]	[grey]	[grey]	[grey]		X

The availability for the period is then calculated by the formula (C.1) in Annex C in this document.

For each scenario, these availability performance metrics are calculated, according to the definitions in Annex C, each with a different perspective on availability performance measurement.

D.2.2 Scenario 1 – communication aspects

Table D.2 – Verification scenarios – communication aspects

MEANING OF COLOURS:

GREEN = included in period hours as available

RED = included in period hours as unavailable

GREY = excluded from period hours

			Mandatory – Information categories														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
Operational availability			GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
Technical availability			GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
1. Scenarios		**Comments**															
1.1	WTGS produces power all week	Distribution of time (weekly hours) across information states	168	0	0	0	0	0	0	0	0	0	0	0	0	100,0 %	100,0 %
1.2	WTGS has 10 h before all communication is lost	WTGS is 100 % available during the 10 known hours	10												158	100,0 %	100,0 %
1.3	WTGS runs 5 h, has 1 h fault and then runs again 4 h before all communication is lost	if the Information Unavailable state were included in the period time, availability would be 99,4 %, an assumption that the WTGS was availability all those hours	9									1			158	90,0 %	90,0 %
1.4	An earlier gearbox fire has destroyed all communication to the unit. There is no on-line information available.	A forced outage, the state is known, but manual entry needed	0									168				0,0 %	0,0 %

In scenario 1.1 in D.2.2 where the WTGS has operated at full power for a continuous week of 168 h, these metrics are each 100 %, as expected.

The communications scenarios illustrate the importance of excluding from the calculation time where information about the turbine state is unknown. In scenario 1.3, if the 158 h of unknown state were included in the period time, the operational and technical availability would increase to 99,4 %. However, it is not known whether the WTGS was available or unavailable during this time period, and these hours shall be excluded from the calculation. This essentially extrapolates the measured availability metric throughout the period when information is unavailable.

Note that the loss of electronic or on-line communication does not necessarily imply information is unavailable. As shown in scenario 1.4 in Table D.2, the information category of a WTGS will in some instances have to be manually entered, or data corrected when a state becomes known later.

WTGS with local information storage could have a higher availability than a WTGS without local information storage. In addition, local information storage in a WTGS might facilitate a more correct picture of the availability metrics.

D.2.3 Scenario 2 – partial operational aspects

Table D.3 – Verification scenarios – partial operational aspects

MEANING OF COLOURS: **GREEN** = included in period hours as available **RED** = included in period hours as unavailable **GREY** = excluded from period hours			**Mandatory – Information categories**														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
	Operational availability		GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	**X**	
	Technical availability		GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		**X**
2. Scenarios		**Comments**															
2.1	Output is curtailed to 50 % power for 40 h due to grid constraints	Time-based performance indicators not affected by partial operation	128	40												100,0 %	100,0 %
2.2	Due to a generator bearing problem, output is limited to 50 % load for 2 days	Time-based performance indicators not affected by partial operation	120	48												100,0 %	100,0 %
2.3	WTGS mechanical failure prevents active power production for 50 h, but the unit is able to produce reactive power	100 % available if reactive power alone is considered generation. 70,2 % if not.	118									50				100,0 %	100,0 %

The scenarios depicted in Table D.3 demonstrate that for time-based availability measurements, generating at partial capacity does not affect the availability calculation, and that generating reactive power only, per the defined information category, is also considered partial generation.

D.2.4 Scenario 3 – maintenance aspects

Table D.4 – Verification scenarios – maintenance aspects

MEANING OF COLOURS:

GREEN = included in period hours as available

RED = included in period hours as unavailable

GREY = excluded from period hours

			Mandatory – Information categories														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
Operational availability			GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
Technical availability			GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
3. Scenarios		**Comments**															
3.1	8 h of scheduled maintenance, within specification for expected maintenance duration	Technical availability is not affected by maintenance since it is per design, but operational availability will increase with reducing maintenance needs	160							8						95,2 %	100,0 %
3.2	8 h of scheduled maintenance shall be extended 4 h to replace a bearing found to be near failure	Manual entry needed for excess time, which is considered a planned corrective action	156							8	4					92,9 %	97,5%

In scenarios depicted in Table D.4, maintenance affects operational availability, but not technical availability, as it is planned and scheduled. WTGS designs which require less maintenance will have higher measured operational availabilities. According to the definitions and priorities established in this document, planned corrective actions have a higher priority than maintenance, and a manual data entry might be needed to allocate time to planned corrective action after the scheduled maintenance is completed in scenario 3.2.

D.2.5 Scenario 4 – operational aspects

Table D.5 – Verification scenarios – operational aspects

			Mandatory – Information categories														
MEANING OF COLOURS: **GREEN** = included in period hours as available **RED** = included in period hours as unavailable **GREY** = excluded from period hours			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
	Operational availability		GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	**X**	
	Technical availability		GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		**X**
4. Scenarios		**Comments**															
4.1	Gusty high winds exceed cut out speed for 5 h	WTGS with higher cut out speeds will report higher operational availability, same technical availability	163				5									97,0 %	100,0 %
4.2	WTGS has a failed part in a lightning storm and the unit could not be entered for 20 h, before the 4-h repair is completed. The week also includes a 40-h grid outage	Definitions handle each point of view	104						40			4	20			61,9 %	96,3 %
4.3	Unit has to untwist 6 times		167			1										99,4 %	100,0 %
4.4	A gearbox pump failure causes 10 h of down time and while the crew is there they do a planned retro on a control card in the top box for 2 h more	Repair switch and manual entry needed	156								2	10				92,9 %	92,9 %
4.5	A lightning strike over the specification causes the turbine to come off line half way through the week	Manual entry needed. The unit will see this as a fault. Reporting 100 % available seems odd. The turbine could be more tolerant of lightning	84											84		50,0 %	100,0 %

			Mandatory – Information categories														
MEANING OF COLOURS: GREEN = included in period hours as available RED = included in period hours as unavailable GREY = excluded from period hours			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
	Operational availability		GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
	Technical availability		GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
4. Scenarios		**Comments**															
4.6	A unit if down all week due to a gearbox failure. 20 h of regular scheduled maintenance is done during this time	Down time is a higher priority and you cannot enter maintenance from this state	0									168				0,0 %	0,0 %
4.7	Blade icing is detected and unit shuts down for 10 h. During this time, cable untwist and other system checks are performed for 2 h	OUT OF ENVIRONMENTAL SPECIFICATION is higher priority. Cannot go to standby from there	158				10									94,0 %	100,0 %
4.8	There is a 2 day grid outage. During this time, 4 h of maintenance are performed, winds exceed specs for 8 h, and a planned repair is done for 2 h	OUT OF ELECTRICAL SPECIFICATION is higher priority than OUT OF ENVIRONMENTAL, lower than maintenance and repair	120						42	4	2					71,4 %	98,8 %
4.9	On an offshore unit, a generator fails just 5 h into the week, but rough seas prevent access the entire rest of the week	Technical availability is reported at 100 %	5										163			3,0 %	100,0 %
4.10	Bat diurnal patterns cause the unit to be shut down for 2 h each day		154					14								91,7 %	100,0 %

MEANING OF COLOURS:

GREEN = included in period hours as available

RED = included in period hours as unavailable

GREY = excluded from period hours

			Mandatory – Information categories														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
Operational availability			GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
Technical availability			GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
4. Scenarios		**Comments**															
4.11	WTGS faults offline for an overtemp. pitch motor and restarts after a 2-h cooling period. This happens 10 times	Cooling is recovery from a design issue – FORCED OUTAGE time	148									20				88,1 %	88,1 %
4.12	2 h into a repair of a failed part, lightning and high winds stop all work for 16 h than it resumes and is completed in 2 more hours	SUSPEND is higher priority than FORCED OUTAGE. Manual entry needed. The unit will see this as a fault	148									4	16			88,1 %	97,4 %

The operational scenarios depicted in Table D.5 more fully illustrate the distinction between operational availability and technical availability to the specifications, and the usefulness of these metrics in assessing overall availability performance. In scenario 4.1, for example, the WTGS shuts down as expected for winds which exceed the maximum design limit. Although this is per design, from the operator's viewpoint of the WTGS, the unit is unavailable, causing lost operating hours. Units with lower cut-out speeds will have comparable technical availability, but lower operational availability.

Scenario 4.2 illustrates the use of priorities and definitions to handle complicated combinations of events. Note that in scenario 4.6, performing planned maintenance during a forced outage is a part of effective operations, but the forced outage is a higher priority and the unit remains unavailable.

Scenario 4.9 highlights the difficultly in accounting for safety suspension hours. From the operator's system view, the unit is clearly unavailable, and while the lost hours contribute to WTGS unavailability since the cause of the initial forced outage was a part failure, the safety suspension prevent this condition from being corrected, extending the FORCED OUTAGE. The technical availability metric is not charged with this lost operating time. However, to report the unit as 100 % technically available during this time period is an apparent contradiction to the low operational availability.

D.2.6 Scenario 5 – grid/electrical network aspects

Table D.6 – Verification scenarios – grid / electrical network aspects

MEANING OF COLOURS: GREEN = included in period hours as available RED = included in period hours as unavailable GREY = excluded from period hours			**Mandatory – Information categories**														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
	Operational availability		GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	**X**	
	Technical availability		GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		**X**
5. Scenarios		**Comments**															
5.1	A unit operates for 80 h then is in forced outage for 4 h. There is a grid outage later in the week	OUT OF ELECTRICAL SPECIFICATION hours are included as available in WTGS availability since the unit is operable	80						84			4				47,6 %	97,6 %

As shown in Table D.6, scenario 5.1, hours when the system is outside of its electrical design specifications are considered unavailable from the operator's system perspective but not from the WTGS perspective since this is clearly beyond the control of the WTGS.

A FORCED OUTAGE, however, is a higher priority, and a unit which is in the FORCED OUTAGE category at the beginning of a grid outage would remain in a FORCED OUTAGE, even though it is unlikely the unit can be returned to service before the electrical system is brought back in to specification.

D.2.7 Scenario 6 – environmental aspects

Table D.7 – Verification scenarios – environmental aspects

MEANING OF COLOURS:

GREEN = included in period hours as available

RED = included in period hours as unavailable

GREY = excluded from period hours

			Mandatory – Information categories														
			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
Operational availability			GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
Technical availability			GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
6. Scenarios		**Comments**															
6.1	Winds are below the cut in speed for 68 h in a week	100 % technically available, but lost operating hours due to low winds	100			68										59,5 %	100,0 %
6.1a	Same as 6.1, but uses optional category OUT OF ENVIRONMENT – **calm winds**	*100 % operational availability if the optional state – OUT OF ENVIRONMENTAL **calm winds** is included as available. No lost operation due to WTGS														100,0 %*	100,0 %
6.2	Winds are only above the cut in speed for 8 h in the week, the WTGS is faulted for 4 h and runs for 4 h	Lost hours due to wind speeds outside specification affect operational availability, not technical availability	4			160					4					2,4 %	97,6 %
6.2a	Same as 6.2, but uses optional state OUT OF ENVIRONMENT – **calm winds**	*97,6 % operational availability if the optional category – OUT OF ENVIRONMENTAL **calm winds** is included as available														97,6 %*	97,6 %

			Mandatory – Information categories														
MEANING OF COLOURS: GREEN = included in period hours as available RED = included in period hours as unavailable GREY = excluded from period hours			FULL PERFORMANCE (IAOSFP)	PARTIAL PERFORMANCE (IAOSPP)	READY STANDBY (IAOSRS)	TECHNICAL STANDBY (IAOOSTS)	OUT OF ENVIRON SPEC (IAOOSEN)	REQUESTED SHUTDOWN (IAOOSRS)	OUT OF ELECTRICAL SPEC (IAOOSEL)	SCHEDULED MAINTENANCE (IANOSM)	PLAN CORRECTIVE ACTION (IANOPCA)	FORCED OUTAGE (IANOFO)	SUSPENDED (IANOS)	FORCE MAJEURE (IAFM)	INFORMATION UNAVAILABLE (IU)	Operational availability (C.2.2)	Technical availability (C.2.3)
Operational availability			GREEN	GREEN	GREEN	RED	RED	RED	RED	RED	RED	RED	RED	RED	GREY	X	
Technical availability			GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREEN	GREY	RED	RED	GREY	GREY	GREY		X
6. Scenarios		**Comments**															
6.3	Good winds, but temperatures are below operating minimum for 68h	Low operational availability ties to lost production due to cold. All OUT OF ENVIRONMENTAL. SPECIFICATION hours could be excluded from availability calculation and availability would be 100 %, but this does not reflect lost potential operating hours	100			68										59,5 %	100,0 %
6.4	A unit operates for 80 h then is in forced outage for 4 h and then temperatures drop to –30 °C and all units stop operation	FORCED OUTAGE and OUT OF ENVIRON SPECIFICATION affect operational availability same, but not technical availability	80			84					4					47,6 %	97,6 %
6.5	A WTGS rated for 30 °C operation stops operation for 20 h due to temperatures rising to 35 °C	WTGS designed for higher temperatures will have higher operational availability, but technical availability is 100 % per design	148			20										88,1 %	100,0 %
6.6	A WTGS rated for 40 °C operation continues to operate for 20 h as temperatures rise to 35 °C	Operational availability of the better WTGS is higher, as expected	168			0										100,0 %	100,0 %

The scenarios depicted in Table D.7, review environmental scenarios, primarily the impact on calculated availability metrics of ambient temperatures and wind speed above or below the design specification of the turbine.

Scenario 6.1, for example, illustrates the loss of availability due to low wind speed. Although there is little potential for production, the unit cannot operate outside its design limits and is therefore unavailable to the operator but is fully available technically. This apparent contradiction is resolved using the optional category for OUT OF ENVIRONMENTAL SPECIFICATION – **calm winds**. Similarly, when the ambient temperature is above or below the design limit, the wind turbine is also operationally unavailable, but technically available.

WTGSs which through better design have broader operating ranges of wind speed and ambient temperature, will have higher operational availability, as expected since they will likely actually operate for more hours, though both might have the same technical availability according to their respective designs. This is shown in Table D.7, scenarios 6.5 and 6.6.

D.3 Production-based scenarios for a WTGS

D.3.1 Introduction to verification scenarios

This clause illustrates examples for application of the three layers of the information model set out in this document. It illustrates methods for calculation of various production based availability indicators according to Annex C for a WTGS.

The examples illustrate possible conflicts if or when actual energy production is not equal to potential energy production. The examples suggest possible assignments of loss based on possible contractual conditions. Under all scenarios hereinafter, the following conditions are applied:

- The WTGS is assumed to produce 100 kWh or 0 kWh (potential service delivery) during the depicted period, depending on the scenario.
- Each scenario represents one time bin which consists of 10 min.

A degree of uncertainty is inherent for measurement of the power curve and for the calculation of potential energy production. In these scenarios, the WTGS user and the WTGS maintenance provider agree to accept the uncertainty to avoid disputes on the difference between the actual energy production and the potential energy production. Otherwise, the power curve and/or the calculation model most likely will need to be verified to determine whether there is lost production or not.

D.3.2 Scenarios under FULL PERFORMANCE

Table D.8 – FULL PERFORMANCE: by definition, actual energy production is equal to the potential energy production

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
1	FULL PERFORMANCE	Wind energy for the rated power is available for the whole time period.	100	100	Zero by definition	

The example in Table D.8 is an ideal scenario. Both the WTGS user and the WTGS maintenance provider are satisfied by the full performance of the WTGS. There is no lost production by definition.

Table D.9 – FULL PERFORMANCE: actual energy production is less than potential energy production but within agreed uncertainty

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
2	FULL PERFORMANCE	Wind energy for the rated power is available for the whole time period. However, actual energy production for the period is 95 kWh instead of 100 kWh.	95	100	Zero by definition	WTGS user may think that the power curve is under performing by 5 %. The WTGS maintenance provider might think that the calculation model is over predicting by 5 %. Another possibility is degraded WTGS performance due to contaminated blades or ice accumulated on blades.

Lacking agreement on uncertainty parameters, the lost production at FULL PERFORMANCE needs to be taken into account, and the information category might be changed from FULL PERFORMANCE to PARTIAL PERFORMANCE.

In the scenario in Table D.9, at least the following four examples of debate are possible:

a) the WTGS user might think that power curve is underperforming by 5 %;

b) the WTGS maintenance provider might think that the calculation model is over predicting by 5 %, thus the potential energy production is 95 kWh and there is no lost production;

c) the WTGS maintenance provider might doubt the cleanliness of the blades. If the WTGS user is assigned to keeping blades clean, he or she is also assigned to the lost production;

d) the WTGS performance might be degraded due to ice accumulated on blades. If the WTGS user has accepted the risk of ice on blades, he or she is assigned to the lost production.

Table D.10 – FULL PERFORMANCE: actual energy production greater than potential energy production

Example	**Information Category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
3	FULL PERFORMANCE	Wind energy for the rated power is available for the whole time period. However, actual energy production is 103 kWh instead of 100 kWh.	103	100	Zero by definition	The WTGS user might think that the power curve is under declared by 3 %. On the other hand, The WTGS maintenance provider might think that the calculation model is over predicting by 3 %.

In the scenario in Table D.10, at least the following two examples of debate are possible:

a) The WTGS user might think that power curve is under declared by 3 %.

b) The WTGS maintenance provider might think that the calculation model is under predicting by 3 %, thus the potential energy production is 103 kWh and there is no lost production.

D.3.3 Scenarios under PARTIAL PERFORMANCE

Table D.11 – PARTIAL PERFORMANCE – derated: grid constraint

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
4	PARTIAL PERFORMANCE **– derated**	Due to grid constraint, the WTGS output is constrained to 75 kWh. Wind energy for the rated power is available for the whole time period.	75	100	25	Grid operator is assigned to the entire lost production although financially he or she might not be assigned to compensate it.

The scenario in Table D.11 illustrates a grid constraint situation. In this case, the WTGS output is constrained only by the grid operator ordering a setpoint change and all the lost production is due to grid constraint.

Table D.12 – PARTIAL PERFORMANCE – derated: grid constraint, actual energy production less than requested

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
5	PARTIAL PERFORMANCE **– derated**	Due to grid constraint, the WTGS output is constrained to 75 kWh. Wind energy for the rated power is available for the whole time period.	65	100	35	Grid operator is assigned to 25 kWh of the lost production although financially he or she might not be assigned to compensate it. The missing 10 kWh needs to be assigned after investigation, taking into account the uncertainty.

The scenario in Table D.12 illustrates a grid constraint situation with a turbine producing less than the constrained limit. Even under the grid constraint, the WTGS is supposed to produce 75 kWh but is only producing 65 kWh. Under this scenario, at least the following four examples are possible:

a) the WTGS user might think that power curve is underperforming by approximately 13 %;

b) the WTGS maintenance provider might think that the calculation model is over predicting by 13 %, thus the potential energy production is 65 kWh and there is no lost production;

c) the WTGS maintenance provider might doubt the cleanliness of the blades. If the WTGS user is assigned to keeping blades clean, he or she is also assigned to the lost production;

d) the WTGS performance might be degraded due to ice accumulated on blades. If the WTGS user has accepted the risk of ice on blades, he or she is assigned to the lost production.

Table D.13 – Partial performance – derated: output constraint due to excessive noise of the WTGS

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
6	PARTIAL PERFORMANCE **– derated**	Noise from the WTGS is beyond the warranted level but operation is acceptable if the WTGS output is capped to half. Wind energy for the rated power is available for the whole time period.	50	100	50	Noise warranty contract between the WTGS user and the WTGS maintenance provider might have defined that the WTGS maintenance provider is assigned to lost production under derated operation due to noise.

The scenario in Table D.13 illustrates a noise constraint situation. Although the WTGS output is constrained only by noise. All the lost production is due to noise constraint.

Table D.14 – PARTIAL PERFORMANCE – derated: dirt on blades constrained performance

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
7	PARTIAL PERFORMANCE **– derated**	Contaminated blades constrain power performance of the WTGS, operator is aware of this. Wind energy for the rated power is available for the whole time period.	95	100	5	The WTGS user is assigned to keeping blades clean but failed to do so thus assigned to lost production.

In the scenario in Table D.14, the WTGS user is assigned to blade cleaning but he did not do it. He or she is therefore assigned to the lost production.

Table D.15 – PARTIAL PERFORMANCE – derated: ice accumulated on blades has been detected, WTGS is allowed to operate although the power performance is 'derated'

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
8	PARTIAL PERFORMANCE **– derated**	Ice accumulated on blades is detected and the WTGS is still allowed to operate although derated. Wind energy for the rated power is available for the whole time period.	95	100	5	The WTGS user might have agreed with the WTGS maintenance provider that he could operate the WTGS even though ice has accumulated on blades and the power performance is derated for which the WTGS maintenance provider is free from assignment.

In the scenario in Table D.15, the WTGS output is derated by ice accumulated on blades. If the WTGS user has accepted the risk of ice on blades, he or she is assigned to the lost production.

Table D.16 – PARTIAL PERFORMANCE – degraded: WTGS deterioration known to the WTGS user

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
9	PARTIAL PERFORMANCE **– degraded**	The WTGS performance has declined. Wind energy for the rated power is available for the whole time period.	50	100	50	The WTGS is under warranty and a claim is filed.

In the scenario in Table D.16, data shows that the power performance is degraded. The WTGS user issues a warranty claim.

D.3.4 Scenarios under READY STANDBY

Table D.17 – READY STANDBY: avian detection system

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
10	READY STANDBY	Avian detection system is armed but not triggered.	100	100	0	If triggered, the category for the detection system will change and effect a change in categories of other services.

The WTGS is equipped with an avian detection system which is a feature that can trigger a halt or idling situation. If the system is armed but not triggered, the system is in READY STANDBY. In this category, in Table D.17, is illustrated that the WTGS is not experiencing any change in actual production or in potential production or any loss caused by the avian detection system.

Table D.18 – READY STANDBY: Automatic generation control – var support

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
11	READY STANDBY	Grid operator directions for additional Var support.	50	100	50	If triggered, the category for the detection system will change and effect a change in categories of other services.

In the scenario in Table D.18, due to grid operator directions, additional Var is needed and the WTGS enters into a situation of automatic generator control. This is entry into a READY STANDBY for the reactive energy service. While READY STANDBY is not applicable to active energy, Table D.18 illustrates, that the production is however affected and is decreased by 50 kWh. The grid operator might be assigned to the entire lost production although financially he or she might not be assigned to compensate it.

D.3.5 Scenarios under TECHNICAL STANDBY

In the scenario in Table D.19, the design of the WTGS requires cable unwinding at certain intervals. The WTGS is unable to produce active power during the unwinding process and in this example, the contract shall be consulted to define to whom lost production due to technical standby is assigned.

Table D.19 – TECHNICAL STANDBY: WTGS is cable unwinding

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
12	TECHNICAL STANDBY	The WTGS is unwinding twisted cables and not able to produce active power. Wind energy for the rated power is available for the whole time period.	0	100	100	The contract shall define who is assigned to lost production due to technical standby for cable unwinding, which is necessary by design.

D.3.6 Scenarios under OUT OF ENVIRONMENTAL SPECIFICATION

Table D.20 – OUT OF ENVIRONMENTAL SPECIFICATION – calm winds

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
13	OUT OF ENVIRONMENTAL SPECIFICATION **– calm winds**	No wind energy for power production is available for the whole time period.	0	0	0	

In the scenario in Table D.20, there is no possibility of production, thus no loss. The WTGS is operating as intended.

Table D.21 – OUT OF ENVIRONMENTAL SPECIFICATION – high winds

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
14	OUT OF ENVIRONMENTAL SPECIFICATION **– high winds**	Wind speed is beyond the cut-out speed for the whole time period.	0	0	0	

In the scenario in Table D.21, there is no possibility of production, thus no loss. The WTGS is operating as intended. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

Table D.22 – OUT OF ENVIRONMENTAL SPECIFICATION – temperature too high

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
15	OUT OF ENVIRONMENTAL SPECIFICATION – temperature	Temperature is too high and out of the operational range as set by the WTGS manufacturer.	0	0	0	In this example, no potential production is assumed; in other examples it might be considered to have a value corresponding to the actual wind speed.

In the scenario in Table D.22, there is no possibility of production, thus no loss. The WTGS is operating as intended. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

D.3.7 Scenarios under REQUESTED SHUTDOWN

Table D.23 – REQUESTED SHUTDOWN: ice on blades is detected and WTGS user requests shutdown of the WTGS

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
16	REQUESTED SHUTDOWN – ice on blades	Ice has accumulated on blades. The WTGS user is concerned about risk of ice drop and requests shutdown of the WTGS. Wind energy for the rated power is available for the whole time period.	0	0	0	The WTGS user is assigned to the lost production although he did not count any loss by his discretion. The WTGS maintenance provider might however take a different view and insist credit for potential energy production of the 100 kWh of wind resource which is lost by shutdown.

In the scenario in Table D.23, at least the following two examples are possible:

a) the WTGS user decides to shutdown the WTGS, and the WTGS maintenance provider is in agreement. There is no potential energy production and no lost production;

b) the WTGS user decides to shutdown the WTGS but the WTGS maintenance provider argues it is not necessary. The WTGS maintenance provider then insists on credit for potential energy production of 100 kWh which is lost by the shutdown.

Since the ice coating is an environmental condition, a criterion could be established to distinguish when to apply to what model category. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

Table D.24 – REQUESTED SHUTDOWN: sector management

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
17	REQUESTED SHUTDOWN – sector management	Wind direction is subject to shutdown according to the agreement between the WTGS user and the WTGS manufacturer or maintenance provider, although wind energy for the rated power is available for the whole time period.	0	0	0	

In the scenario in Table D.24, the WTGS is shut down for sector management based on the agreement between the WTGS user and the WTGS manufacturer or maintenance provider. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

Table D.25 – REQUESTED SHUTDOWN: noise nuisance – warranty claim

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
18	REQUESTED SHUTDOWN – Noise nuisance	The WTGS user decides that noise from the WTGS is beyond the warranted level thus requests shutdown. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS user make warranty claim to the WTGS manufacturer. The WTGS manufacturer may either accept the warranty claim or pick up the burden of proof.

In the scenario in Table D.25, at least the following two examples are possible:

a) the WTGS user might make warranty claim to the WTGS manufacturer for the lost production based on the view that noise from the WTGS is beyond the warranted level;

b) the WTGS manufacturer does not agree that noise from the WTGS is beyond the warranted level. The WTGS manufacturer shall prove that noise from the WTGS is within the warranted level.

Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

D.3.8 Scenarios under OUT OF ELECTRICAL SPECIFICATION

Table D.26 – OUT OF ELECTRICAL SPECIFICATION: low voltage

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
19	OUT OF ELECTRICAL SPECIFICATION – Low voltage	The WTGS is shut down due to low voltage caused by the grid system. Wind energy for the rated power is available for the whole time period.	0	100	100	Grid operator is assigned to the entire lost production although contractually he or she might not be assigned to compensate it.

In the scenario in Table D.26, lost production is due to grid system failure and no claim is made to the grid operator. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

D.3.9 Scenarios under SCHEDULED MAINTENANCE

Table D.27 – SCHEDULED MAINTENANCE: WTGS is under scheduled maintenance work by the WTGS manufacturer or maintenance provider within the time allowance agreed by the maintenance contract

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
20	SCHEDULED MAINTENANCE	The WTGS is stopped for scheduled maintenance work. Wind energy for the rated power is available for the whole time period.	0	100	100	Some of the maintenance contracts could exempt the WTGS manufacturer or maintenance provider's assignment for lost production within the time allowance for scheduled maintenance while others might not.

In the scenario in Table D.27, at least the following two outcomes are possible:

a) the WTGS manufacturer or maintenance provider is not free from assignment for lost production even if it is within the time period of scheduled maintenance. Production-based availability for the relevant warranty contract period is then calculated by the WTGS user;

b) the WTGS manufacturer or maintenance provider is free from assignment for lost production because it is within the time allowance for scheduled maintenance and maintenance is within operating parameters of performance as intended.

D.3.10 Scenarios under PLANNED CORRECTIVE ACTION

Table D.28 – PLANNED CORRECTIVE ACTION: WTGS manufacturer or maintenance provider performs corrective action to the WTGS at his discretion outside the time allowance of scheduled maintenance

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
21	PLANNED CORRECTIVE ACTION	The WTGS is stopped for planned corrective action. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer or maintenance provider is to be assigned to lost production under the period of planned corrective action.

In the scenario in Table D.28, the WTGS manufacturer or maintenance provider is to be assigned to the lost production.

D.3.11 Scenarios under FORCED OUTAGE

Table D.29 – FORCED OUTAGE: short circuit

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
22	FORCED OUTAGE – short circuit	An electric component is damaged due to short circuit. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer or manufacturer or maintenance provider is to be assigned to lost production due to this forced outage.

In the scenario in Table D.29, the WTGS manufacturer or maintenance provider is to be assigned to the lost production, provided that the WTGS manufacturer or maintenance provider is assigned to the outage. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

Table D.30 – FORCED OUTAGE: corrosion

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
23	FORCED OUTAGE – corrosion	Tower paint is deteriorated and the tower is rusty due to corrosion. The WTGS to be repainted. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer or maintenance provider is likely to be assigned to lost production due to this forced outage.

In the scenario in Table D.30, the WTGS manufacturer or maintenance provider is likely to be assigned to the lost production, provided that the WTGS manufacturer or maintenance provider is assigned to supplying the tower with adequate coating. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

Table D.31 – FORCED OUTAGE: overheating

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
24	FORCED OUTAGE – overheating	Wheat chaff has clogged and stuffed radiator for cooling fan. Temperature is raised and the WTGS is shut down due to overheating. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer or maintenance provider is likely to be assigned to lost production due to this forced outage.

In the scenario in Table D.31, the WTGS manufacturer or maintenance provider is likely to be assigned to the lost production, provided that the WTGS manufacturer or maintenance provider is accountable for proper operation and maintenance. Please note, this optional information category is not prescribed in this document but illustrates how a user-defined optional information category can be used.

D.3.12 Scenarios under SUSPENDED

Table D.32 – SUSPENDED: suspended repair work due to storm with lightning

Example	Information category (layer 1) (10 min)	Circumstance	Actual production (layer 2) (kWh) [Measured]	Potential production (layer 3) (kWh)	Lost production (kWh)	Explanatory note
25	SUSPENDED	The WTGS maintenance provider's repair work due to forced outage is suspended by a storm accompanied by lightning. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer or maintenance provider might or might not be assigned to lost production due to this suspended period.

In the scenario in Table D.32, at least the following two outcomes are possible:

a) The WTGS manufacturer or maintenance provider is not free from assignment for lost production even though his repair work for forced outage is suspended by storm with lightning. Production-based availability for the relevant warranty contract period is then calculated by the WTGS user. This interpretation is made in accordance with provision of the maintenance contract.

b) The WTGS manufacturer or maintenance provider is free from assignment for lost production because his repair work for forced outage is suspended by storm with lightning. This interpretation is made in accordance with provision of the maintenance contract and due to safety considerations.

D.3.13 Scenarios under FORCE MAJEURE

Table D.33 – FORCE MAJEURE: no access to the WTGS due to flooding impacting infrastructure

Example	**Information category (layer 1)** (10 min)	**Circumstance**	**Actual production (layer 2)** (kWh) **[Measured]**	**Potential production (layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
26	FORCE MAJEURE	The WTGS manufacturer or maintenance provider could make no access to the WTGS due to flooding beyond the statistically expected impacting infra structure. Wind energy for the rated power is available for the whole time period.	0	100	100	By contract definition, no loss and no dispute.

In the scenario Table D.33, the contract defines that no one is assigned to lost production when a force majeure event is occurring.

D.4 Production-based scenarios for a WTGS – calculation of lost production

D.4.1 Introduction to verification scenarios

Based on the principles described in Annex C, a number of scenarios for calculation of lost production are provided for illustration. Note that the colour coding introduced in Annex C for equations is applied. Grey shaded information categories in the tables are not included in the calculations per the definitions of Figure 5 and Annex C, Table C.1.

D.4.2 Production-based availability algorithm based on mandatory information categories ("operational availability")

The scenarios in Clause D.3 are expanded further in the example in Table D.34. The scenarios are this time investigated with the purpose of determining a production availability number.

Table D.34 – Production-based availability algorithm based on mandatory information categories only,"operational availability"

Scenario (table in Clause D.3)	**Information category (layer 1)** (10 min)	**Actual energy production (layer 2)** (kWh) **[Measured]**	**Potential energy production (layer 3)** (kWh) **[Calculated]**	**Lost production** (kWh) **[Calculated]**
1	FULL PERFORMANCE (IAOSFP)	100	100	0
2	FULL PERFORMANCE (IAOSFP)	95	100	0
3	FULL PERFORMANCE (IAOSFP)	103	100	0
4	PARTIAL PERFORMANCE (IAOSPP)	75	100	25
5	PARTIAL PERFORMANCE (IAOSPP)	65	100	35
6	PARTIAL PERFORMANCE (IAOSPP)	50	100	50
7	PARTIAL PERFORMANCE (IAOSPP)	95	100	5
8	PARTIAL PERFORMANCE (IAOSPP)	95	100	5
9	PARTIAL PERFORMANCE (IAOSPP)	50	100	50
10	READY STANDBY (IAOSRS)	100	100	0
11	READY STANDBY (IAOSRS)	50	100	50
12	TECHNICAL STANDBY (IAOOSTS)	0	100	100
13	OUT OF ENVIRONMENTAL SPEC (IAOOSEN)	0	0	0
14	OUT OF ENVIRONMENTAL SPEC (IAOOSEN)	0	0	0
15	OUT OF ENVIRONMENTAL SPEC (IAOOSEN)	0	0	0
16	REQUESTED SHUTDOWN (IAOOSRS)	0	0	0
17	REQUESTED SHUTDOWN (IAOOSRS)	0	0	0
18	REQUESTED SHUTDOWN (IAOOSRS)	0	100	100
19	OUT OF ELECTRICAL SPECIFICATION, (IAOOSEL)	0	100	100
20	SCHEDULED MAINTENANCE, (IANOSM)	0	100	100
21	PLANNED CORRECTIVE ACTION, (IANOPCA)	0	100	100
22	FORCED OUTAGE (IANOFO)	0	100	100
23	FORCED OUTAGE (IANOFO)	0	100	100
24	FORCED OUTAGE (IANOFO)	0	100	100
25	SUSPENDED (IANOS)	0	100	100
26	FORCE MAJEURE (IAFM)	0	100	100

Assuming that all the above scenarios are the situations that fully account for the period for calculating the production availability and by applying the definitions in Figure 5 to Formula (C.2), the operational production-based availability can be calculated:

$$\text{Operational production-based availability} = 1 - \frac{(IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSENS_P + IAOOSRSS_P + IAOOSELS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P + IANOSS_P + IAFMS_P}{(IAOSFPS_A + IAOSPPS_A + IAOSRSS_A) + (IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSENS_P + IAOOSRSS_P + IAOOSELS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P + IANOSS_P + IAFMS_P} \quad (D.1)$$

[Numerator]:

$IAOSPPS_P - IAOSPPS_A = 170$

$IAOSRSS_P - IAOSRSS_A = 50$

$IAOOSTSS_P = 100$

$IAOOSENS_P = 0$

$IAOOSRSS_P = 100$

$IAOOSELS_P = 100$

$IANOSMS_P = 100$

$IANOPCAS_P = 100$

$IANOFOS_P = 300$

$IANOSS_P = 100$

$IAFMS_P = 100$

Subtotal = 1 220

[Denominator]:

$IAOSFPS_A = 298$

$IAOSPPS_A = 430$

$IAOSRSS_A = 150$

$IAOSPPS_P - IAOSPPS_A = 170$

$IAOSRSS_P - IAOSRSS_A = 50$

$IAOOSTSS_P = 100$

$IAOOSENS_P = 0$

$IAOOSRSS_P = 100$

$IAOOSELS_P = 100$

$IANOSMS_P = 100$

$IANOPCAS_P = 100$

$IANOFOS_P = 300$

$IANOSS_P = 100$

$IAFMS_P = 100$

Subtotal = 2 098

Operational production based availability = 1 – (1 220/2 098) = 1 – 0,582 = 0,418 [41,8 %].

D.4.3 Production-based availability algorithm – including optional categories ("technical availability")

Table D.35 – Production-based availability algorithm – including optional categories, "technical availability"

Example (table in Clause D.2)	**Information category (layer 1)** (10 min)	**Actual energy production (layer 2)** (kWh) **[Measured]**	**Potential energy production (layer 3)** (kWh)	**Lost production** (kWh)
1	FULL PERFORMANCE (IAOSFP)	100	100	0
2	FULL PERFORMANCE (IAOSFP)	95	100	0
3	FULL PERFORMANCE (IAOSFP)	103	100	0
4	PARTIAL PERFORMANCE (IAOSPP)	75	100	25
5	PARTIAL PERFORMANCE (IAOSPP)	65	100	35
6	PARTIAL PERFORMANCE (IAOSPP)	50	100	50
7	PARTIAL PERFORMANCE (IAOSPP)	95	100	5
8	PARTIAL PERFORMANCE (IAOSPP)	95	100	5
9	PARTIAL PERFORMANCE (IAOSPP)	50	100	50
10	READY STANDBY (IAOSRS)	100	100	0
11	READY STANDBY (IAOSRS)	50	100	50
12	TECHNICAL STANDBY (IAOOSTS)	0	100	100
13	OUT OF ENVIRONMENTAL SPEC. – **calm winds** ($IAOOSEN_C$)	0	0	0
14	OUT OF ENVIRONMENTAL SPEC. – **other environmental** ($IAOOSEN_o$)	0	0	0
15	OUT OF ENVIRONMENTAL SPEC. – **other environmental** ($IAOOSEN_o$)	0	0	0
16	REQUESTED SHUTDOWN (IAOOSRS)	0	0	0
17	REQUESTED SHUTDOWN (IAOOSRS)	0	0	0
18	REQUESTED SHUTDOWN (IAOOSRS)	0	100	100
19	OUT OF ELECTRICAL SPECIFICATION (IAOOSEL)	0	100	100
20	SCHEDULED MAINTENANCE, (IANOSM)	0	100	100
21	PLANNED CORRECTIVE ACTION (IANOPCA)	0	100	100
22	FORCED OUTAGE (IANOFO)	0	100	100
23	FORCED OUTAGE (IANOFO)	0	100	100
24	FORCED OUTAGE (IANOFO)	0	100	100
25	SUSPENDED (IANOS)	0	100	100
26	FORCE MAJEURE (IAFM)	0	100	100

Assuming that all the above scenarios are the situations that fully account for the period for calculating the production availability and by applying the definitions in Figure 5 to Formula (C.2), the operational production-based availability can be calculated:

Technical production-based availability (optional)

$$= 1 - \frac{(IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSEN_oS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P}{(IAOSFPS_A + IAOSPPS_A + IAOSRSS_A) + (IAOSPPS_P - IAOSPPS_A) + (IAOSRSS_P - IAOSRSS_A) + IAOOSTSS_P + IAOOSEN_oS_P + IANOSMS_P + IANOPCAS_P + IANOFOS_P} \quad (D.2)$$

[Numerator]	[Denominator]
$IAOSPPS_P - IAOSPPS_A = 170$	$IAOSFPS_A = 298$
$IAOSRSS_P - IAOSRSS_A = 50$	$IAOSPPS_A = 430$
$IAOOSTSS_P = 100$	$IAOSRSS_A = 150$
$IAOOSENS_P = 0$	$IAOSPPS_P - IAOSPPS_A = 170$
$IANOSMS_P = 100$	$IAOSRSS_P - IAOSRSS_A = 50$
$IANOPCAS_P = 100$	$IAOOSTSS_P = 100$
$IANOFOS_P = 300$	$IAOOSENS_P = 0$
	$IANOSMS_P = 100$
	$IANOPCAS_P = 100$
	$IANOFOS_P = 300$
Subtotal = 820	Subtotal = 1 698

Technical production based availability = 1 – (820/1 698) = 1 – 0,483 = 0,517 [51,7 %].

D.5 Production-based scenarios for a WPS

D.5.1 Introduction to verification scenarios

This clause illustrates examples of operational scenarios for some typical services, based on the information model set out in this document. The examples illustrate resulting information categories and values for lost production.

(P): indicates physical potential service level.

(C): indicates constrained potential service level.

D.5.2 Example 1: Normal operation – all WPS

Scenario (see Table D.36)**:** For a period of time, all WTGSs in a WPS are producing active power at rated level for the whole time period.

The reactive power production is contractually agreed to be based on constrained potential service.

The production is fed through to the grid with no restrictions. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 95 GWh. The potential production is estimated to be 95 GWh.

Actual reactive energy production for the period is 9,5 GVArh. The reactive power set point is equivalent to 9,5 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.36 – Scenario, Example 1: Normal operation – all WPS

	Information category	**Actual service**	**Potential service**	**Lost service**
Service: Active energy	FULL PERFORMANCE	95 GWh	95 GWh (P)	0 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	9,5 GVArh	9,5 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The WPS is performing the intended function with the full capacity at the given conditions, hence FULL PERFORMANCE according to 5.3.2.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system according to Figure 2, Subclause 5.3.3 and B.2.2 of this document.

The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.3 Example 2: Normal operation – part of WPS

Scenario (see Table D.37)**:** For a period of time, part of the WEGSs within a WPS is producing active power at rated level, the other part is producing at lower level (some WEGSs might be stopped). The wind energy resource for rated power is available for the whole time period but the set point for the active energy is externally set to a value corresponding to 100 GWh.

The reactive power production is contractually agreed to be reported based on constrained potential service.

The production is fed through to the grid with no restrictions. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 95 GWh. The constrained potential service is 100 GWh.

Actual reactive energy production for the period is 8,5 GVArh. The reactive energy set point is equivalent to the physically possible for the period, determined to 9,5 GVArh.

Table D.37 – Scenario, Example 2: Normal operation – part of WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **degraded**	95 GWh	100 GWh (C)	5 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **degraded**	8,5 GVArh	9,5 GVArh (P)	1 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The service is not delivering the intended function with the full capacity due to individual WEGS not producing at FULL PERFORMANCE. The category of the WPS is determined to be PARTIAL PERFORMANCE – **degraded**, according to Figure 2, Subclause 5.3.3 and B.2.3 of this document. Degraded due to the production being limited by an internal constraint e.g. a WEGS defect.

Reactive energy: The service is not delivering the intended function with the full capacity due to individual WEGS not producing at FULL PERFORMANCE. The category of the WPS is determined to be PARTIAL PERFORMANCE – **degraded**, according to Figure 2, Subclause 5.3.3 and B.2.3 of this document. The calculated lost service is 1 GVArh.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.4 Example 3: Contaminated WTGSs blades – all WPS

Scenario (see Table D.38): For a period of time, all WEGSs within a WPS are producing active power and the wind energy resource for rated power is available for the whole time period, but contaminated blades limits power performance of the WEGSs.

The reactive power production is contractually agreed to be reported based on constrained potential service.

The production is fed through to the grid with no restrictions. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 92,9 GWh. The potential production is estimated to be 95 GWh.

Actual reactive energy production for the period is 9,5 GVArh. The reactive energy set point is equivalent to 9,5 GVArh for the period. The constrained potential production substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.38 – Scenario, Example 3: Contaminated WTGSs blades – all WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **derated**	92,9 GWh	95 GWh (P)	2,1 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	9,5 GVArh	9,5 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because of the information about contaminated blades according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The calculated lost service is 2.1 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system according to Figure 2, Subclause 5.3.3 and B.2.2 of this document.

The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time- based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time-based level only.

D.5.5 Example 4: Contaminated WTGSs blades – part of WPS

Scenario (see Table D.39): For a period of time, most WTGSs within a WPS are producing active power at rated level as the wind energy resource for rated power is available for the whole time period, but contaminated blades limits power performance of some of the WTGSs.

The reactive power production is contractually agreed to be reported based on constrained potential service.

The production is fed through to the grid with no restrictions. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 90,5 GWh. The potential production is estimated to be 95 GWh.

Actual reactive energy production for the period is 9,5 GVArh. The reactive energy set point is equivalent to 9,5 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.39 – Scenario, Example 4: Contaminated WTGSs blades – part of WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **derated**	90,5 GWh	95 GWh (P)	4,5 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	9,5 GVArh	9,5 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: Even though some of the individual WTGS are at FULL PERFORMANCE, the category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because of the information about contaminated blades, according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The calculated lost service is 4,5 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system according to 5.3.3. The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.6 Example 5: BOP limitations – all WPS

Scenario (see Table D.40): For a period of time, all WTGSs within a WPS are producing active power and the wind energy resource for rated power is available for the whole time period, but deteriorated transformers within the WPS limits the power capacity of the BOP and all of the WPS. All WTGSs are curtailed. The production is fed through to the grid with restrictions.

The reactive power production is contractually agreed to be reported based on constrained potential service.

All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 55 GWh. The potential production is estimated to be 105 GWh.

Actual reactive energy production for the period is 75 GVArh. The reactive energy set point is equivalent to 75 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.40 – Scenario, Example 5: BOP limitations – all WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **degraded**	55 GWh	105 GWh (P)	50 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	75 GVArh	75 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The service is not delivering the intended function with the full capacity due to issues with BOP transformers. The category of the WPS is determined to be PARTIAL PERFORMANCE – **degraded**, according to Figure 2, Subclause 5.3.3 and B.2.3 of this document, because transformers are considered an internal condition prohibiting the WPS from operating at full performance. The calculated lost service is 50 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system, according to Figure 2, Subclause 5.3.3 and B.2.2 of this document.

The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.7 Example 6: BOP limitations – part of WPS

Scenario (see Table D.41): For a period of time, all WTGSs within a WPS are producing active power and the wind energy resource for rated power is available for the whole time period, but deteriorated transformers within the WPS limits the power capacity of the BOP and of the total output of the WPS. A number of WTGSs, but not all, are shot down or curtailed. The production is fed through to the grid with restrictions.

The reactive power production is contractually agreed to be reported based on constrained potential service.

All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 45 GWh. The potential production is estimated to be 105 GWh.

Actual reactive energy production for the period is 75 GVArh. The reactive energy set point is equivalent to 75 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.41 – Scenario, Example 6: BOP limitations – part of WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **degraded**	45 GWh	105 GWh (P)	60 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	75 GVArh	75 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The service is not delivering the intended function with the full capacity due to issues with BOP transformers. The category of the WPS is determined to be PARTIAL PERFORMANCE – **degraded**, according to Figure 2, Subclause 5.3.3 and B.2.3 of this document, because transformers are considered an internal condition prohibiting the WPS from operating at full performance. The calculated lost service is 60 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system, according to Figure 2, Subclause 5.3.3 and B.2.2 of this document.

The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.8 Example 7: "Spinning reserve" – part of WPS

Scenario (see Table D.42): For a period of time, part of the WTGSs are producing at rated level, part of the WTGSs are operating at a set point for active power at 0 for grid support service. The wind energy resource for rated power is available for the whole time period. Production is fed through to the grid.

The reactive power production is contractually agreed to be reported based on physical potential service.

All communication and WPS control system is up and running. High frequency compensation is ready to respond but dormant. Low frequency compensation is ready but dormant. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 60 GWh. The potential production is estimated to be 100 GWh.

Actual reactive energy production for the period is 51 GVArh. The reactive energy set point is equivalent to 51 GVArh for the period. The physical potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.42 – Scenario, Example 8: "Spinning reserve" – part of WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **derated**	60 GWh	100 GWh (P)	40 GWh
Service: Reactive energy	FULL PERFORMANCE	51 GVArh	51 GVArh (P)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	READY STAND-BY	NA	NA	NA

Active energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system, according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The calculated lost service is 40 GWh but as the production has been set to 60 by an external request, hence the stakeholders involved might decide to exclude this loss from the availability calculation. As an alternative, the constrained potential service for active energy can be used for calculating the loss. The value of this service is closer to the value of the actual service, thus resulting in a different (lower) lost service. Depending on the purpose, either the constrained potential service, the physical potential service or both can be determined.

Reactive energy: The category of the WPS is determined to FULL PERFORMANCE, according to 5.3.2, as the production is at rated value according to the set point and the full capacity of the system, the loss of reactive production is 0 GVArh for the period according to the definition for physical potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.9 Example 8: "Spinning reserve" – all WPS

Scenario (see Table D.43): For a period of time, all WTGSs within a WPS are operating at a set point for active power at 0 for grid support service. The wind energy resource for rated power is available for the whole time period. No active production is fed through to the grid but transmission is possible.

The reactive power production is contractually agreed to be reported based on physically potential service.

All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is ready but dormant. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based-level.

Actual active energy production for the period is 0 GWh. The potential production is estimated to be 100 GWh. The constrained potential production is 0 GWh.

Actual reactive energy production for the period is 11 GVArh. The reactive energy set point is equivalent to 11 GVArh for the period. The physically potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.43 – Scenario, Example 7: "Spinning reserve" – all WPS

	Information category	**Actual service**	**Potential service**	**Lost service**
Service: Active energy	PARTIAL PERFORMANCE – **derated**	0 GWh (C)	0 GWh (C)	0 GWh
Service: Reactive energy	FULL PERFORMANCE	11 GVArh	11 GVArh (P)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	READY STAND-BY	NA	NA	NA

Active energy: Though active production is 0, the WPS is operative and in service as the WTGS's are operating. The category of the WPS is determined to be PARTIAL PERFORMANCE according to Figure 2, Subclause 5.3.3 and B.2.2 of this document, it is **derated** due to a set point coming from an external source. The calculated lost service is 0 GWh as the constrained potential production is used as basis.

Reactive energy: The category of the WPS is determined to FULL PERFORMANCE, according to 5.3.2, as the production is at rated value according to the set point and the full capacity of the system, the loss of reactive production is 0 GVArh for the period according to the definition for physical potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

D.5.10 Example 9: Noise restrictions – warranty related

Scenario (see Table D.44): For a period of time, noise from the WTGSs is above the warranted level but operation is acceptable if the WPS output is capped to half. Wind energy for the rated power is available for the whole time period. All WTGSs within the WPS are producing active power.

The reactive power production is contractually agreed to be reported based on constrained potential service.

The production is fed through to the grid with an internal restriction (lowered set point) due to the noise level. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 50 GWh. The potential production is estimated to be 95 GWh.

Actual reactive energy production for the period is 9,5 GVArh. The reactive energy set point is equivalent to 9,5 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.44 – Scenario, Example 9: Noise restrictions – all WPS

	Information category	**Actual service**	**Potential service**	**Lost service**
Service: **Active energy**	PARTIAL PERFORMANCE – **degraded**	50 GWh	95 GWh (P)	45 GWh
Service: **Reactive energy**	PARTIAL PERFORMANCE – **derated**	9,5 GVArh	9,5 GVArh (C)	0 GVArh
Service: **High frequency compensation**	READY STAND-BY	NA	NA	NA
Service: **Low frequency compensation**	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The WPS is not delivering the intended function with the full capacity at the given conditions. An internal condition exists which prohibits the WPS from operating at full performance, but the active power output from the wind power plant is greater than zero, hence PARTIAL PERFORMANCE – **degraded** according to Figure 2, Subclause 5.3.3 and B.2.3 of this document. The calculated lost service is 45 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated,** because the production is limited by a set point and not the capacity of the system according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time-based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time-based level only.

NOTE An example with only part of the WTGS being curtailed due to noise restrictions will result in the same information categories.

D.5.11 Example 10: Noise restrictions – environmentally related

Scenario (see Table D.45): For a period of time, noise from the WTGSs is within the warranted level but due to local environmental noise constraints, the operation is acceptable if the WPS output is capped to half. Wind energy for the rated power is available for the whole time period. All WTGSs within the WPS are producing active power.

The reactive power production is contractually agreed to be reported based on constrained potential service.

The production is fed through to the grid with an internal restriction (lowered set point) due to the noise level. All communication and WPS control system is up and running. High frequency compensation is ready to respond but it is dormant. Low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 50 GWh. The potential production is estimated to be 95 GWh.

Actual reactive energy production for the period is 9,5 GVArh. The reactive energy set point is equivalent to 9,5 GVArh for the period. The constrained potential service substitutes the potential service for the reactive energy service according to the reporting agreement/contracted.

Table D.45 – Scenario, Example 10: Noise restrictions – all WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	PARTIAL PERFORMANCE – **derated**	50 GWh	95 GWh (P)	45 GWh
Service: Reactive energy	PARTIAL PERFORMANCE – **derated**	9,5 GVArh	9,5 GVArh (C)	0 GVArh
Service: High frequency compensation	READY STAND-BY	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The WPS is not delivering the intended function with the full capacity at the given conditions. An external condition exists which prohibits the WPS from operating at full performance, but the active power output from the wind power plant is greater than zero, hence PARTIAL PERFORMANCE – **derated** according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The calculated lost service is 45 GWh.

Reactive energy: The category of the WPS is determined to be PARTIAL PERFORMANCE – **derated** because the production is limited by a set point and not the capacity of the system according to Figure 2, Subclause 5.3.3 and B.2.2 of this document. The loss of reactive production is 0 GVArh for the period according to the definition for constrained potential service.

High frequency compensation: The service is ready to respond, hence READY STANDBY according to 5.3.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The service is ordered to shut down and thereby disabled, hence REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

NOTE An example with only part of the WEGS being curtailed due to noise restrictions will result in the same information categories.

D.5.12 Example 11: Ice storm on grid – all WPS

Scenario (see Table D.46): For a period of time, the grid suffers transmission outage at a location beyond the point of common coupling disabling the WPS from delivering its services. The WPS is requested to shut down all services by the grid operator. Wind energy for the rated power is available for the entire time.

All communication and WPS control system is up and running. High frequency compensation and low frequency compensation is disabled. Both frequency compensation services are considered as on/off services; the reporting requirements are only on a time based level.

Actual active energy production for the period is 0 GWh. The potential production is estimated to be 125 GWh.

Actual reactive energy production for the period is 0 GVArh. The physical potential production is equivalent to 12 GVArh for the period.

Table D.46 – Scenario, Example 11: Ice storm on grid – all WPS

	Information category	Actual service	Potential service	Lost service
Service: Active energy	REQUESTED SHUTDOWN	0 GWh	125 GWh (P)	125 GWh
Service: Reactive energy	REQUESTED SHUTDOWN	0 GVArh	12 GVArh (P)	12 GVArh
Service: High frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA
Service: Low frequency compensation	REQUESTED SHUTDOWN	NA	NA	NA

Active energy: The WPS is not delivering the intended function due to an external condition prohibiting the WPS from operating. Due to the external request the active power output from the wind power plant is disrupted, hence the category REQUESTED SHUTDOWN according to 5.4.4. The calculated lost service is 125 GWh, but as the production has been set to 0 by an external request, hence the stakeholders involved may decide excluding this loss from the availability calculation.

Reactive energy: The WPS is not delivering the intended function due to an external condition prohibiting the WPS from operating. Due to the external request, the reactive power output from the wind power plant is disrupted, hence the category REQUESTED SHUTDOWN according to 5.4.4. The loss of reactive production is 12 GVArh for the period according to the definition for physical potential service, but as the production has been set to 0 by an external request, hence the stakeholders involved may decide excluding this loss from the availability calculation.

High frequency compensation: The WPS is not delivering the intended function due to an external condition prohibiting the WPS from operating. Due to the external request, the service from the wind power plant is disrupted, hence the category REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

Low frequency compensation: The WPS is not delivering the intended function due to an external condition prohibiting the WPS from operating. Due to the external request, the service from the wind power plant is disrupted, hence the category REQUESTED SHUTDOWN according to 5.4.4. No loss is estimated as the reporting requirements are on a time based level only.

NOTE In case the external request for shut down is not issued or if the electrical parameters of the grid becomes out of design specifications before or about the same time as the issue of the shutdown request, the information category will change to OUT OF ELECTRICAL SPECIFICATION for all services. It is most likely that this category will replace REQUESTED SHUTDOWN anyway shortly after REQUESTED SHUTDOWN.

Annex E
(informative)

Possible methods for determination of potential WEGS energy production

E.1 General

Annex E includes various examples of determining the potential energy production of a specific WEGS, considering the site conditions. Due to normal variations in WEGS performance as a result of site conditions and measurement uncertainty, a WEGS operating in the FULL PEFORMANCE information category might produce more or less energy compared to its potential energy production. However, the purpose of Annex E is not to characterize this over or under production, but to assess the potential energy production when a unit is not running in FULL PERFORMANCE to determine the lost production caused by this unit.

Annex E does not specify or recommend any particular method of determining potential energy production but identifies several possibilities and lists issues to be considered for each of the methods. It is up to the user to define the method to be used. This depends on the number of WEGSs at a site, data availability, data quality and other factors.

Two methodologies are defined:

- method 1 – specific power curve and velocities;
- method 2 – power based.

E.2 Specific power curve and velocities methods

E.2.1 General

This group of methods requires a site-specific power curve for each WEGS to be found by plotting velocity vs. power production data. Velocities will then be used to extract the power production data when the WEGS is unavailable. Some of the methods are proposed below.

The following possible methods are described:

- nacelle anemometer wind measurement with power curve;
- upstream wind measurement with power curve;
- met mast wind measurement with correction factors and power curve.

E.2.2 Nacelle anemometer wind measurement with power curve

This method is based on the wind measurement from the nacelle anemometer and the power determination from a power curve for the WEGS. The wind speed is typically determined from a calibrated anemometer on the top of the nacelle and corrected for temperature and pressure to a standard reference condition. The potential energy production for that wind speed can then be determined by:

a) the manufacturer’s specified site specific reference power curve for that turbine, or
b) the historical power curve developed over time for that specific WEGS when operating in FULL PERFORMANCE.

Issues to consider:

- no equipment outside the WEGS is needed;
- measurement can be synchronised with changes of information category;
- possible for any location or for a site with one WEGS;

- inaccurate due to inclined flow behind the rotor;
- high maintenance (recalibration every two years);
- sensitive to failure of the measurement device;
- measurement in one level;
- significant prior data required to establish the historical power data.

E.2.3 Upstream wind measurement with power curve

Upstream wind sensor modules are located just behind the blades on the nacelle but are capable of measuring wind speed and direction in front of the wind turbine. These wind sensor modules are based on technologies like LIDAR (light detection and ranging), RADAR (radio detection and ranging), RASS (radio acoustic sounding system), SODAR (sonic detection and ranging), etc.

The wind sensor module measures the wind speed directly in front of the WEGS, and therefore delivers a reliable value for the wind resource and the potential energy production calculation.

As with the use of the nacelle anemometer, the measurement shall be corrected for temperature and pressure to a standard reference condition. The potential energy production for that wind speed can then be determined by:

a) the manufacturer's specified site-specific reference power curve for that WEGS, or
b) the historical power curve developed over time for that specific WEGS when operating in FULL PERFORMANCE.

Issues to consider:

- measurement over complete rotor area;
- no met mast necessary;
- sensitivity to rotor wash or turbulence;
- newer, relatively expensive technology, with fewer manufacturers;
- one module required for each direction;
- high maintenance (recalibration every two years);
- significant prior data required to establish the historical power data.

E.2.4 Met mast wind measurement with correction factors and power curve

This method relies on using a model of the topography of the site and a mathematical approach to develop a correction factor correlating the wind speed at any specific WEGS location to the wind speed measured at the met mast.

Since the measured values (i.e. wind speed and power) are difficult to synchronize with the changing information categories of the WEGS, some loss of accuracy in the speed up factors can be expected.

As with the use of the nacelle anemometer, the measurement shall be corrected for temperature and pressure to a standard reference condition. The potential energy production for that wind speed can then be determined by:

a) the manufacturer's specified site specific reference power curve for that WEGS, or
b) the historical power curve developed over time for that specific WEGS when operating in FULL PERFORMANCE.

Issues to consider:

- measurement of wind speed is less affected by local WEGS conditions;
- measurement at different levels;
- speed up factors for each machine shall be calculated;
- requires one or more met masts at each site; potentially expensive;
- high maintenance (recalibration every two years);
- wind speeds measured at the met mast shall be synchronised with the information categories of each WEGS.

E.3 Power-based methods

E.3.1 General

This group of methods does not require a site-specific power curve. However, a time log (timestamp) has to be used to calculate the potential power production data at the time when the WEGS is unavailable. Some of the methods are proposed below.

The following possible methods are described:

- average production of WPS;
- average production of representative comparison WEGSs;
- data acquisition with comparison chart/database;
- average wind speed of WPS.

E.3.2 Average production of WPS

This method assumes that a nearby WEGS operating in the FULL PERFORMANCE information category would have seen the same wind speed in a given time period as the WEGS in consideration if it has also been in FULL PERFORMANCE. The potential energy production of the WEGS in consideration during a time period is taken to be the product of the nominal power of the WEGS in consideration and the average production factor of all other WEGSs in the wind park operating in FULL PERFORMANCE in the same time period. The potential energy production is then calculated as below:

Calculation of potential energy production:

Step 1: Calculation of the "averaged production factor“

$$F_{\mathrm{AVE}} = 1/n \times \sum_{1}^{n} F(i) = 1/n \times \sum_{1}^{n} \left(P_{P\_\mathrm{AVE}(i)} / P_{\mathrm{N}}(i) \right) \quad \text{(E.1)}$$

where

F_{AVE} is the averaged production factor;

$F(i)$ is the production factor of WEGS i;

$P_{\mathrm{N}}(i)$ is the nominal power of WEGS i;

$P_{P\_\mathrm{AVE}(i)}$ is the averaged produced power of WEGS i;

n is the number of units operating in FULL PERFORMANCE (disregarding the WEGS in consideration).

Step 2: Calculation of the lost power of WEGS not in FULL PERFORMANCE

$$P_L = F_{AVE} \times P_{ND} - P_A \quad \text{(E.2)}$$

where

P_L is the lost power of the WEGS not in FULL PERFORMANCE;

F_{AVE} is the averaged production factor;

P_{ND} is the nominal power of the WEGS not in FULL PERFORMANCE;

P_A is the actual power of the WEGS not in FULL PERFORMANCE.

Because the potential energy production is taken directly from other WEGSs operating under approximately the same ambient conditions, no correction for temperature, density, or other site or WEGS conditions is required. This method is not sensitive to wind speed measurement errors.

This method is suitable only for WPS with more than one WEGS.

Issues to consider:

- no wind speed measurement is required;
- no correction for site conditions is required;
- less sensitive to WEGS aging, fouling, deterioration, wake effects, etc.;
- averaging across many units reduces sensitivity to error and variation;
- does not account for local variation in wind conditions from site average;
- requires a minimum number of WEGSs operating at FULL PERFORMANCE;
- measured values shall be synchronized with changed categories of the WEGSs;
- cannot be used if all units are curtailed to PARTIAL PERFORMANCE.

E.3.3 Average production of representative comparison WTGSs

This method is similar to the prior method using the average across the entire WPS but uses as the comparison group a subset of WEGS that are judged to have conditions more similar to the WEGS under consideration. For each WEGS, a group of WTGSs shall be pre-defined that are considered to be most representative of wind and production conditions at the WEGS under consideration. The potential energy production of the WEGS in consideration during a time period is taken to be the average actual energy production of the WEGSs operating in FULL PERFORMANCE in the same time period within the comparison group.

Because the potential energy production is taken directly from other WEGSs operating under similar ambient conditions, no correction for temperature, density, or other site or WEGS conditions is required. This method is not sensitive to wind speed measurement error.

This method is suitable only for wind farm with more than one WEGS.

Issues to consider:

- a representative comparison group shall be defined for each WEGS;
- no wind speed measurement is required;
- no correction for site conditions is required;
- less sensitive to WEGS aging, fouling, deterioration, wake effects, etc.;
- averaging across many WEGSs reduces sensitivity to error and variation;

- does not account for local variation in wind conditions from representative group average;
- requires a minimum number of WEGSs operating at FULL PERFORMANCE;
- measured values shall be synchronized with changed categories of the WEGSs;
- cannot be used if all units are curtailed to PARTIAL PERFORMANCE.

E.3.4 Data acquisition with comparison chart/database

This method is based on the correlation of the wind conditions (met mast) and the power output of the WEGS. This would imply the need of a simultaneous database and the correlation between them in form of a matrix (power output function of the met mast measured wind speed and direction). If data are available, then it is possible to compute the potential energy production.

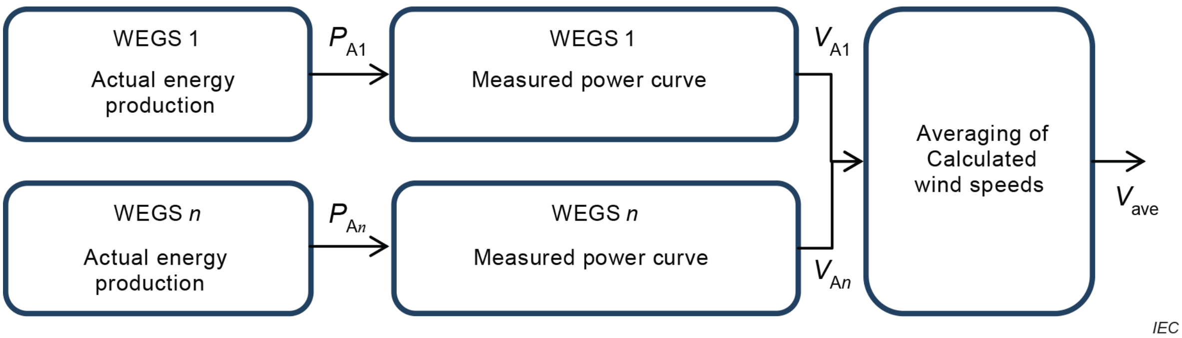
The model is site-specific and requires a learning period. It is suitable only for WPSs with more than one WEGS in the WPS. In case of modifications of the WPS or the site, the learning period has to start again.

Issues to consider:

- changes to the wake exposure of the met mast depending on what WEGSs are generating;
- recalculation of the production based availability after the learning period;
- minimum number of WEGSs required;
- learning period;
- new learning period if the instrumentation is changed or environment is changed (modifications or new WEGS, tree felling, etc.);
- high maintenance (recalibration periodically, consistency of instrumentation).

E.3.5 Average wind speed of WPS

This method is based on calculating the potential energy production of the WEGS in consideration by calculating the average wind speed of the other WEGSs of the WPS operating in FULL PERFORMANCE. The average wind speed of the other WEGSs of the WPS operating in FULL PERFORMANCE is determined by applying the manufacturer's specified site-specific reference power curve for those WEGSs to the measured power output at that time.



Key

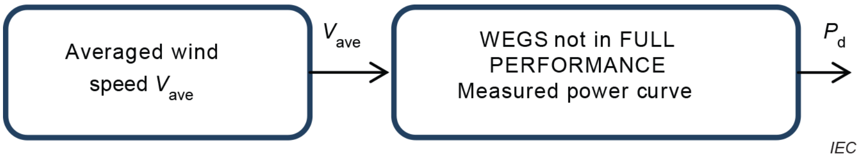
P_n measured power of working WEGS "*n*"

V_n calculated wind speed in front of WEGS "*n*"

V_{ave} averaged wind speed

Figure E.1 – Step 1: calculation of wind speed based on working WEGS 1 to *n*

The potential energy production of the WEGS in consideration is determined by applying the manufacturer's specified site specific reference power curve of the WEGS in consideration to that WEGS. The calculation method is illustrated in Figure E.1 and Figure E.2.



Key

P_d calculated lost production of the WEGS not in FULL PERFORMANCE

Figure E.2 – Step 2: estimation of lost production for WEGS not in FULL PERFORMANCE

E.4 Determination of potential production for a WPS – examples

E.4.1 Overview

Annex E does not specify or recommend any particular method of determining potential service but identifies possibilities and lists issues to be considered for the methods. It is up to the user to define the method to be used, depending on the number of elements at a WPS, data availability and quality, and other factors.

In this document, there are two terms, constrained potential production and physical potential production, together with the service terminology.

With the introduction of services, the range of products provided by the WPS is extended. In order to relate the lost production to proper terms, more definitions of potential production are needed. In some operational conditions, it's more relevant to relate to the term constrained potential production rather than physical potential production as services will seldom be performing at their potential physical level.

Examples on how to use the two variants of potential production are illustrated in Table E.1.

E.4.2 Primary service

As the active energy production normally is the primary service delivered from a WPS, this will be limited by the physical limits from the plant. In some cases, typically in curtailed situations, it might also be interesting to know the constrained potential production or maybe even both types of potential production. This can be due to different stakeholders having individual reporting requirements.

E.4.3 Secondary services

As the reactive energy production and high and low frequency compensation normally are secondary services delivered from a WPS, these will be limited by a set point. In most cases, this service operates in a curtailed situation. Thus, the constrained potential production is of interest to most stakeholders.

Table E.1 – Examples on how to determine potential production

	Physical potential production	Constrained potential production
Service: Active energy	WPS potential production is the sum of each WEGS potential production (see Annex D) compensated for losses in BOP	Set point given by external source
Service: Reactive energy	A sum of the installed reactive power capacity in the WPS compensated for losses in BOP	Set point given by external source
Service: High frequency compensation	Physical potential production of WPS Active power service plus active power consumption capacity (e.g. an energy storage unit)	Set point given by external source
Service: Low frequency compensation	WPS potential production is the sum of each WEGS potential production (see Annex D) compensated for losses in BOP (this however would require the WPS operating at no active power output)	Set point given by external source **or** The difference between actual production and physical potential production of WPS active power service

Annex F
(informative)

Balance of plant integration

F.1 WPS functions and services

As defined, the wind power station (WPS) consists of the WTGSs and the balance of plant (BOP) which supports transfer of energy services between the WTGSs and the grid. Examined as a system, the BOP provides the WEGS with the required infrastructure of the energy collection subsystem and other services needed to keep the WEGS operational and for delivery of services to the grid. In addition to the site electrical facilities, other capabilities exist such as SCADA as well as civil plant, i.e. roads, which support the operation of the WEGS. These functions may be considered to serve for external and internal purposes for service delivery and asset management which necessarily exist in the WPS.

F.2 Externally required functions and services

The intended functions and services act to integrate desired operational and associated capabilities as the WPS interconnects with the grid. Functionally, these may include reactive power, high frequency compensation, low frequency compensation, and even energy storage. Further, the off-takers, grid authorities and energy markets will need information about plant status and future performance expectations. Examples of this include forecasting, loss of plant availability, generation capacity, performance rating and scheduling. Some of these metrics, especially on prediction, are beyond the scope of this document, but might be useful for determining future performance expectations. Note that some of this is automated function of the WPS while some are the result of human processing of information.

F.3 Internally required functions and services

Asset management functions may be varied but will include the human factors needed for operations and maintenance of the WPS and the management of activities and information. Communications with grid operators, except for required automated information streams, will be performed as part of the internal asset management function and will be accomplished at the plant or a remote site. The operations and maintenance function is broad and includes management and technical staff with equipment such as fleet vehicles, other heavy equipment, and tools/parts/consumables. Reporting of key performance metrics and other required information is also part of operations. In terms of plant system and component availability, the repairs, replacements and restoration of component functionality depend on an efficient asset management function. Intervention in the anticipation of plant needs and conduct of upkeep and repairs to keep components and systems available and operating is a common part of maintenance.

It is expected that the BOP infrastructure will function at high reliability and availability. However, if there is a BOP outage, its consequence could be most severe. During common mode system failures, relatively large numbers of WEGS will be unable to operate as intended. An understanding of the consequences of BOP outages at various points in the WPS is needed to appropriately mitigate consequences. All failures or events that result in service outages are to be allocated in the information model.

F.4 Expansion of the information model for BOP functions and services

The model for BOP elements works on the same principles and model for allocating time to information categories as specified in this document. The mandatory information categories are identical to the mandatory information categories defined for the WEGS but optional categories are individual to different BOP elements. It is possible to develop a model for individual BOP elements and allocate information categories representing the service and possible categories on the principles developed in this document. For example:

Resulting BOP actual energy transfer is the sum of actually measured transferred power of each BOP element (when distributed).

Resulting BOP potential energy transfer is the minimum of the technical capability of the BOP and the potential production of the WEGSs.

The BOP will change information category only when it affects the production/services of the WEGSs and/or the WPS.

The BOP will change from FULL PERFORMANCE to PARTIAL PERFORMANCE when the resulting BOP actual energy transfer is less than the sum of individual WEGS potential productions, or the ability to deliver other electrical services is temporarily unavailable.

The optional information categories are specific to the information model for the BOP, based on the properties of the BOP and may differ from the optional categories of the WEGS. They are defined as far as they can be attributed to at least one element of the BOP. For example, TECHNICAL STANDBY is not attributable to a WEGS foundation but makes sense to attribute to a cable, a breaker or a similar electrical part of a substation. It is the intention of the model to specify generic categories, so that any part of the BOP can be allocated to an information category.

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