IEC TS 61400-26-2

Edition 1.0 2014-06

TECHNICAL SPECIFICATION

colour inside

Wind turbines –
Part 26-2: Production-based availability for wind turbines

IEC TS 61400-26-2:2014-06(en)

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CONTENTS

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WIND TURBINES –

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 61400-26-2, which is a technical specification, has been prepared by IEC technical committee 88: Wind turbines.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
88/455/DTS	88/483/RVC

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

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

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

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual edition of this document may be issued at a later date.

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INTRODUCTION

The intention of this technical specification is to define a common basis for exchange of information on performance indicators between owners, utilities, lenders, operators, manufacturers, consultants, regulatory bodies, certification bodies, insurance companies and other stakeholders in the wind power generation business. This is achieved by providing an information model specifying how time designations shall be split into information categories. The information model forms the basis for how to allocate time for reporting availability and reliability indicators.

The technical specification defines generic terms of wind turbine systems and environmental constraints in describing system and component availability, lifetime expectancy, repairs and criteria for determining overhaul intervals. The specification defines terminology and generic terms for reporting energy based generating unit availability measurement. A generating unit includes all equipment up to the point of electrical connection. Availability measurements are concerned with fractions of time and energy a unit is capable of providing during service, taking environmental aspects into account. Environmental aspects will be wind and other weather conditions, as well as grid and substation conditions. The specification furthermore defines terminology and terms for reporting performance indicators based on energy production. Mandatory information categories defined in the technical specification are written in capital letters; optional information categories defined in the technical specification are written in bold letters.

The project scope is accomplished by separating the technical specification into three parts:

- IEC TS 61400-26-1, which specifies terms for time-based availability of a wind turbine generating system;
- IEC TS 61400-26-2, which specifies terms for production-based availability of a wind turbine generating system;
- IEC/TS 61400-26-3, which specifies terms for time-based and production-based availability of a wind power station.

Part 2 is an extension of Part 1 that deals with the use of production elements based on the information model defined in Part 1. The structure and interrelations in the applied information model are defined in Part 1 and apply to the production based extensions made in Part 2.

The intention of Part 2 is to define a common basis for exchange of information on production-based availability. This is achieved by using the information model specifying how time and energy designations shall be split into information categories and assigned to production terms.

NOTE The point of electrical connection is defined individually from one project to the other, but is normally understood as the electrical low voltage or high voltage terminals of the wind turbine generating system connecting to the feeder cables.

WIND TURBINES –

Part 26-2: Production-based availability for wind turbines

1 Scope

This part of IEC 61400 provides a framework from which production-based performance indicators of a WTGS (wind turbine generator system) can be derived. It unambiguously describes how data is categorised and provides examples of how the data can be used to derive performance indicators.

The approach of this part of IEC 61400 is to expand the time allocation model, introduced in IEC TS 61400-26-1, with two additional layers for recording of the actual energy production and potential energy production associated with the concurrent time allocation.

It is not the intention of this Technical Specification to define how production-based availability shall be calculated. Nor is it the intention to form the basis for power curve performance measurements, which is the objective of IEC 61400-12.

This document also includes informative annexes with:

- examples of determination of lost production,
- examples of algorithms for production-based indicators,
- examples of other performance indicators,
- examples of application scenarios.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org/)

IEC TS 61400-26-1:2011, *Wind turbines – Part 26-1: Time-based availability for wind turbine generating systems*

3 Terms, definitions and abbreviations

For the purposes of the present document, the following terms, definitions and abbreviations apply, as well as the relevant terms and definitions contained in IEC TS 61400-26-1 and IEC 60050-415.

3.1 Terms and definitions

3.1.1
site conditions
conditions affecting the energy production of the WTGS, e.g. topographic, climatic and meteorological conditions, sector management, electrical environment and contractual constraints

3.1.2
actual energy production
energy measured at the point of connection to the power collection system (according to IEV and IEC 60050-415)

Note 1 to entry: The connection point may be at low voltage level or at medium or high voltage level depending on the design of the WTGS.

3.1.3
potential energy production
calculated energy based on the WTGS design criteria and technical specifications and the site conditions

3.1.4
lost production
energy not supplied

Note 1 to entry: The lost production is the difference between potential energy production potential energy production and actual energy production.

3.2 Abbreviations

3.2.1 Information available

IA	Information available category
IAO	Information available operative category
IAOG	Information available operative generating category
IAOGFP	Information available operative generating with full performance category
IAOGPP	Information available operative generating with partial performance category
IAONG	Information available operative non generating category
IAONGTS	Information available operative non generating technical standby category
IAONGEN	Information available operative non generating out of environmental specification category
IAONGEL	Information available operative non generating out of electrical specification category
IAONGRS	Information available operative non generating requested shutdown 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
IAP_P	Information available category – potential energy production
IAP_A	Information available category – actual energy production
$IAOP_P$	Information available operative category – potential energy production
$IAOP_A$	Information available operative category – actual energy production
$IAOGP_P$	Information available operative generating category – potential energy production
$IAOGP_A$	Information available operative generating category – actual energy production
$IAOGFPP_P$	Information available operative generating with full performance category – potential energy production

$IAOGFPP_A$	Information available operative generating with full performance category – actual energy production
$IAOGPPP_P$	Information available operative generating with partial performance category – potential energy production
$IAOGPPP_A$	Information available operative generating with partial performance category – actual energy production
$IAOGPP_{DR}P_P$	Information available operative generating with partial performance category, optional derated – potential energy production
$IAOGPP_{DR}P_A$	Information available operative generating with partial performance category, optional derated – actual energy production
$IAOGPP_{DG}P_P$	Information available operative generating with partial performance category, optional degraded – potential energy production
$IAOGPP_{DG}P_A$	Information available operative generating with partial performance category, optional degraded – actual energy production
$IAONGP_P$	Information available operative non generating category – potential energy production
$IAONGP_A$	Information available operative non generating category – actual energy production
$IAONGTP_P$	Information available operative non generating technical standby category – potential energy production
$IAONGTP_A$	Information available operative non generating technical standby category – actual energy production
$IAONGENP_P$	Information available operative non generating out of environmental specification category – potential energy production
$IAONGENP_A$	Information available operative non generating out of environmental specification category – actual energy production
$IAONGEN_CP_P$	Information available operative non generating out of environmental specification optional category calm winds – potential energy production
$IAONGEN_CP_A$	Information available operative non generating out of environmental specification optional category calm winds – actual energy production
$IAONGEN_OP_P$	Information available operative non generating out of environmental specification optional category other environmental – potential energy production
$IAONGEN_OP_A$	Information available operative non generating out of environmental specification optional category other environmental – actual energy production
$IAONGELP_P$	Information available operative non generating out of electrical specification category – potential energy production
$IAONGELP_A$	Information available operative non generating out of electrical specification category – actual energy production
$IAONGRSP_P$	Information available operative non generating requested shutdown category – potential energy production
$IAONGRSP_A$	Information available operative non generating requested shutdown category – actual energy production
$IANP_P$	Information available non operative category – potential energy production
$IANP_A$	Information available non operative category – actual energy production
$IANOSMP_P$	Information available non operative scheduled maintenance category – potential energy production
$IANOSMP_A$	Information available non operative scheduled maintenance category – actual energy production

$IANOPCAP_P$	Information available non operative planned corrective action category – potential energy production
$IANOPCAP_A$	Information available non operative planned corrective action category – actual energy production
$IANOFOP_P$	Information available non operative forced outage category – potential energy production
$IANOFOP_A$	Information available non operative forced outage category – actual energy production
$IANOSP_P$	Information available non operative suspended category – potential energy production
$IANOSP_A$	Information available non operative suspended category – actual energy production
$IAFMP_P$	Information available force majeure category – potential energy production
$IAFMP_A$	Information available force majeure category – actual energy production

3.2.2 Information unavailable

IU	Information unavailable category

4 Information model

4.1 General

Figure 1 provides an information category overview.

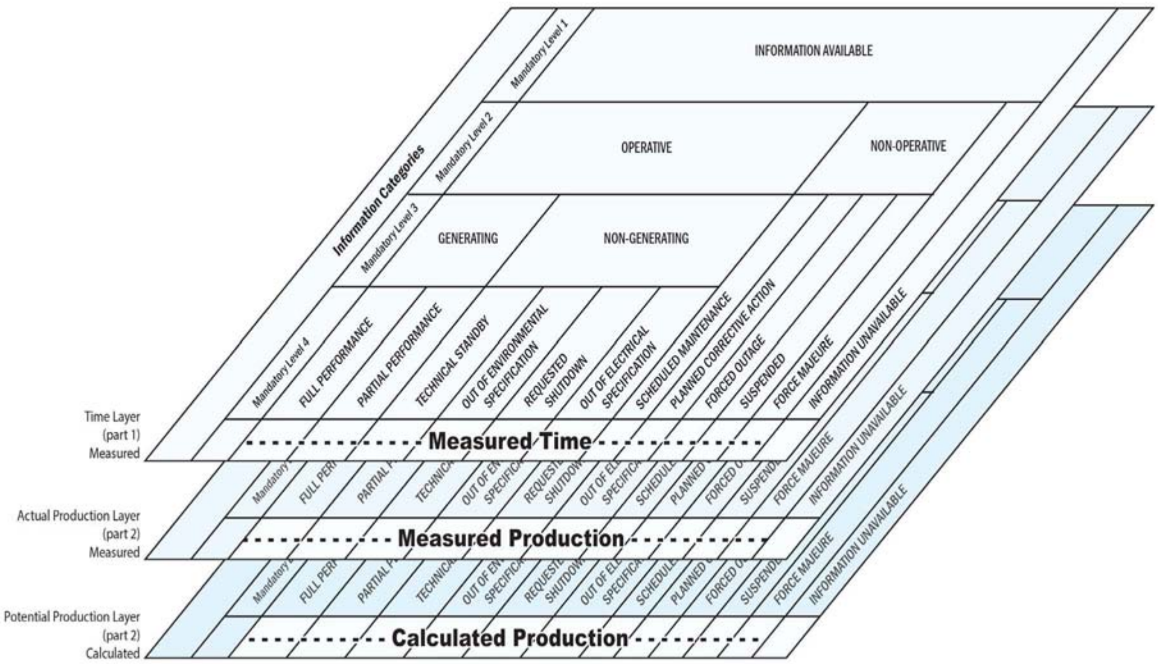
<table>
<tr><th colspan="5">Information categories</th></tr>
<tr><td>Mandatory level 1</td><td>Mandatory level 2</td><td>Mandatory level 3</td><td>Mandatory level 4</td><td>Optional – see IEC TS 61400-26-1 and Annex A</td></tr>
<tr><td rowspan="13">INFORMATION AVAILABLE (IA)</td><td rowspan="8">OPERATIVE (IAO)</td><td rowspan="3">GENERATING (IAOG)</td><td>FULL PERFORMANCE (IAOGFP)</td><td></td></tr>
<tr><td rowspan="2">PARTIAL PERFORMANCE (IAOGPP)</td><td>Derated</td></tr>
<tr><td>Degraded</td></tr>
<tr><td rowspan="5">NON-GENERATING (IAONG)</td><td>TECHNICAL STANDBY (IAONGTS)</td><td></td></tr>
<tr><td rowspan="2">OUT OF ENVIRONMENTAL SPECIFICATION (IAONGEN)</td><td>Calm winds</td></tr>
<tr><td>Other environmental</td></tr>
<tr><td>REQUESTED SHUTDOWN (IAONGRS)</td><td></td></tr>
<tr><td>OUT OF ELECTRICAL SPECIFICATION (IAONGEL)</td><td></td></tr>
<tr><td rowspan="4">NON-OPERATIVE (IANO)</td><td colspan="2">SCHEDULED MAINTENANCE (IANOSM)</td><td></td></tr>
<tr><td colspan="2">PLANNED CORRECTIVE ACTION (IANOPCA)</td><td>Retrofit
Upgrade
Other corrective action</td></tr>
<tr><td colspan="2">FORCED OUTAGE (IANOFO)</td><td>Response
Diagnostic
Logistic
Failure repair</td></tr>
<tr><td colspan="2">SUSPENDED (IANOS)</td><td>Scheduled maintenance
Planned corrective action
Forced outage</td></tr>
<tr><td colspan="3">FORCE MAJEURE (IAFM)</td><td></td></tr>
<tr><td colspan="4">INFORMATION UNAVAILABLE (IU)</td><td></td></tr>
</table>

IEC 1711/14

Figure 1 – Information category overview

The information model is strictly based on the model specified in IEC TS 61400-26-1. The model from IEC TS 61400-26-1 is reproduced in Figure 1. The main characteristics of this model are summarised below; however, for a complete description of all features, see IEC TS 61400-26-1.

The model has been extended to allow for production-based availability to be calculated. The extension is done by adding two additional layers to the model from IEC TS 61400-26-1, as shown in Figure 2. It is important to note that all characteristics of the model in IEC TS 61400-26-1 apply here.



IEC 1712/14

Figure 2 – Extended information category model

Layer 1 of this extended model is exactly the model described in IEC TS 61400-26-1. In layer 2 of the augmented model, actual energy production rather than time is recorded. The production value recorded is the actual energy production recorded during the same period as in the corresponding category in layer 1.

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

4.2 Allocation of production terms to the information categories

The production terms are defined in the definitions of this document. The terms introduced are actual energy production and potential energy production.

Layer 1 is the allocation of time as specified in the information model in IEC TS 61400-26-1. Layer 2 is the allocation of values of actual energy production to each of the information categories, as illustrated in Figure 3. The actual energy production shall be the production as measured at the point of connection.

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 energy production	Potential energy production	Lost production
INFORMATION AVAILABLE (**IA**)	OPERATIVE (**IAO**)	GENERATING (**IAOG**)	FULL PERFORMANCE (**IAOGFP**)	**$IAOGFPP_{A}$**	**$IAOGFPP_{P}$**	**0**
			PARTIAL PERFORMANCE (**IAOGPP**)	**$IAOGPPP_{A}$**	**$IAOGPPP_{P}$**	**$IAOGPPP_{P}$ – $IAOGPPP_{A}$**
		NON-GENERATING (**IAONG**)	TECHNICAL STANDBY (**IAONGT**)	0	**$IAONGTP_{P}$**	**$IAONGTP_{P}$**
			OUT OF ENVIRONMENTAL SPECIFICATION (**IAONGEN**)	0	**$IAONGENP_{P}$**	**$IAONGENP_{P}$**
			REQUESTED SHUTDOWN (**IAONGRS**)	0	**$IAONGRSP_{P}$**	**$IAONGRSP_{P}$**
			OUT OF ELECTRICAL SPECIFICATION (**IAONGEL**)	0	**$IAONGELP_{P}$**	**$IAONGELP_{P}$**
	NON-OPERATIVE (**IANO**)	SCHEDULED MAINTENANCE (**IANOSM**)		0	**$IANOSMP_{P}$**	**$IANOSMP_{P}$**
		PLANNED CORRECTIVE ACTION (**IANOPCA**)		0	**$IANOPCAP_{P}$**	**$IANOPCAP_{P}$**
		FORCED OUTAGE (**IANOFO**)		0	**$IANOFOP_{P}$**	**$IANOFOP_{P}$**
		SUSPENDED (**IANOS**)		0	**$IANOSP_{P}$**	**$IANOSP_{P}$**
	FORCE MAJEURE (**IAFM**)			0	**$IAFMP_{P}$**	**$IAFMP_{P}$**
INFORMATION UNAVAILABLE (**IU**)				*	*	*

IEC 1713/14

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

Figure 3 – Information categories, addition of layer 2 and layer 3, mandatory categories

Layer 3 is the allocation of values of potential energy production to each of the information categories as illustrated in Figure 3. Possible methods for determination of the potential energy production are included in Annex A, however the method for establishing the potential energy production is outside the scope of this specification. The intention is that the data that populate this layer should represent, as closely as is possible, the production that could have been realised if the turbine had been operating as per the FULL PERFORMANCE, taking into account the amount of wind energy available.

When actual energy production and potential energy production are determined, lost production may be derived as follows.

- No lost production shall be associated with the respective information category, when the WTGS is generating in FULL PERFORMANCE.
- Lost production shall be determined by the difference between the potential energy production and the actual energy production during the time the WTGS is generating in PARTIAL PERFORMANCE.
- Lost production shall equal the potential energy production during the time when the WTGS is not in GENERATING (except for INFORMATION UNAVAILABLE, see footnote in Figure 3).

It is recognized that while generating in FULL PERFORMANCE, actual energy production may not exactly equal potential energy production due to various factors that can affect the performance of the WTGS, such as blade fouling or misalignment or other WTSG issues, or due to how the potential energy production is calculated. However, fully characterizing the WTGS production is beyond the scope of this technical specification. Examples of turbine performance while in the FULL PERFORMANCE information category are included in Annex C.

4.3 Mean-value based information

While capacity-based information is not explicitly stored in the information model presented in 4.2, the mean capacity, or mean power, can be derived from the information model. This can 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.

The example in the informative Annex C can be applied to both actual and potential capacity factors, and resultant production-based availability.

4.4 Limitations

It is not in the scope of this technical specification to determine the method of information acquisition and how to estimate the production terms.

During periods of non-generation, the WTGS may be consuming power (parasitic losses). This is not considered for the model as this is not contributing to provision of services as defined in the scope.

Production during transition between information categories is not considered, as this is insignificant.

4.5 Entry and exit points

Entry and exit points of the information categories are as specified in IEC TS 61400-26-1.

4.6 Information category priority

Priorities of the information categories are as specified in IEC TS 61400-26-1.

There may be conflicts within the optional categories as derated production and degraded production may appear simultaneously. The situation is discussed in the informative Annex E.

Annex A
(informative)

Possible methods for the determination of potential energy production

A.1 General

Annex A includes various examples of determining the potential energy production of a specific WTGS, considering the site conditions. Due to normal variations in turbine performance as a result of site conditions and measurement uncertainty, a WTGS operating in the FULL PEFORMANCE information category may produce more or less energy compared to its potential energy production. However, the purpose of Annex A 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 in order to determine the lost production caused by this unit.

Annex A 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, depending on the number of turbines at a site, data availability and quality, and other factors.

Two methodologies are defined:

- Method 1 – Specific power curve and velocities;
- Method 2 – Power based.

A.2 Specific power curve and velocities methods

A.2.1 General

This group of methods requires a site-specific power curve for each WTGS to be found by plotting velocity vs. power production data. Velocities will then be used to extract the power production data when the WTGS 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.

A.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 turbine. 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 WTGS when operating in FULL PERFORMANCE.

Issues to consider:

- No equipment outside the WTGS is needed;

- Measurement can be synchronised with changes of information category;
- Possible for any location or for a site with one WTGS;
- 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.

A.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 wind turbine, 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 must 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 turbine, or
b) the historical power curve developed over time for that specific WTGS when operating in FULL PERFORMANCE.

Issues to consider:

- Measurement over complete rotor area;
- No met mast necessary;
- Insensitive 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.

A.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 WTGS 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 WTGS, some loss of accuracy in the speed up factors can be expected.

As with the use of the nacelle anemometer, the measurement must 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 turbine, or
b) the historical power curve developed over time for that specific WTGS when operating in FULL PERFORMANCE.

Issues to consider:

- Measurement of wind speed is less affected by local wind turbine conditions;
- Measurement at different levels;
- Speed up factors for each machine must 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 must be synchronised with the information categories of each WTGS.

A.3 Power-based methods

A.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 WTGS is unavailable. Some of the methods are proposed below.

The following possible methods are described:

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

A.3.2 Average production of wind farm

This method is based on the assumption that a nearby WTGS operating in the FULL PERFORMANCE information category would have seen the same wind speed in a given time period as the WTGS in consideration if it has also been in FULL PERFORMANCE. The potential energy production of the WTGS in consideration during a time period is taken to be the product of the nominal power of the WTGS in consideration and the average production factor of all other WTGSs 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“

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

where

F_{AVE} is the averaged production factor;

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

$P_{N(i)}$ is the nominal power of turbine i;

$P_{P\_AVE(i)}$ is the averaged produced power of turbine i;

n is the number of turbines operating in FULL PERFORMANCE (disregarding the WTGS in consideration).

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

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

where

F_{AVE} is the averaged production factor;

P_A is the actual power of the turbine not in FULL PERFORMANCE;

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

P_{ND} is the nominal power of the turbine not in FULL PERFORMANCE.

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

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

Issues to consider:

- No wind speed measurement is required;
- No correction for site conditions is required;
- Less sensitive to turbine aging, fouling, deterioration, wake effects, etc.;
- Averaging across many turbines reduces sensitivity to error and variation;
- Does not account for local variation in wind conditions from site average;
- Requires a minimum number of machines operating at FULL PERFORMANCE;
- Measured values must be synchronized with changed categories of the machines;
- Cannot be used if all units are curtailed to PARTIAL PERFORMANCE.

A.3.3 Average production of representative comparison turbines

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

Because the potential energy production is taken directly from other turbines operating under similar ambient conditions, no correction for temperature, density, or other site or turbine 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 WTGS.

Issues to consider:

- A representative comparison group must be defined for each WTGS;
- No wind speed measurement is required;
- No correction for site conditions is required;
- Less sensitive to turbine aging, fouling, deterioration, wake effects, etc.;
- Averaging across many turbines reduces sensitivity to error and variation;
- Does not account for local variation in wind conditions from representative group average;
- Requires a minimum number of machines operating at FULL PERFORMANCE;
- Measured values must be synchronized with changed categories of the machines;

- Cannot be used if all units are curtailed to PARTIAL PERFORMANCE.

A.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 WTGS. 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 wind farms with more than one WTGS in the wind farm. In case of modifications of the wind farm or the site, the learning period has to start again.

Issues to consider:

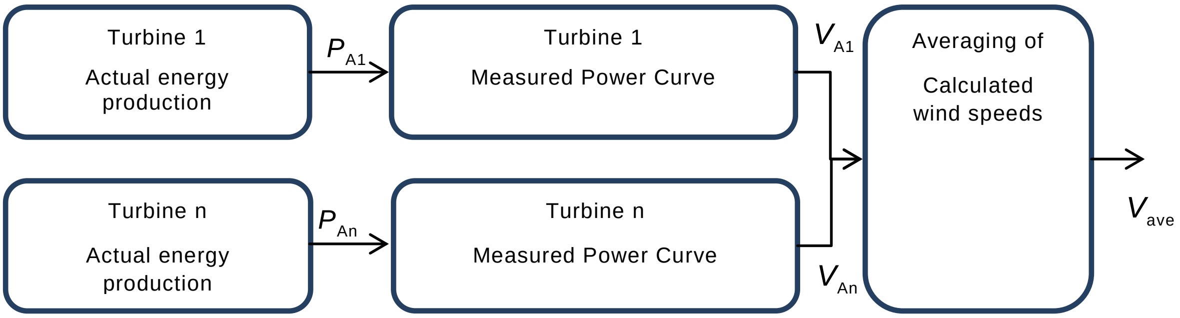
- Changes to the wake exposure of the met mast depending on what WTGSs are generating;
- Recalculation of the production-based availability after the learning period;
- Minimum number of machines required;
- Learning period;
- New learning period if the instrumentation is changed or environment is changed (modifications or new WTGS, tree felling, etc.);
- High maintenance (recalibration periodically, consistency of instrumentation).

A.3.5 Average wind speed of wind farm

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

The potential energy production of the WTGS in consideration is determined by applying the manufacturer's specified site-specific reference power curve of the WTGS in consideration to that WTGS.

The calculation method is illustrated below in Figure A.1 and Figure A.2.



IEC 1714/14

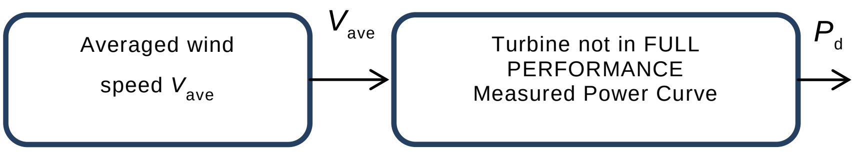
Key

P_n measured power of working wind turbine "n"

V_n calculated wind speed in front of turbine "n"

V_{ave} averaged wind speed

Figure A.1 – Step 1: Calculation of wind speed based on working wind turbine 1 to n



IEC 1715/14

Key

V_{ave} averaged wind speed

P_d calculated lost production of the wind turbine not in FULL PERFORMANCE

Figure A.2 – Step 2: Estimation of lost production for WTGS not in FULL PERFORMANCE

Annex B
(informative)

Production-based availability indicators – examples

B.1 General

Annex B describes examples of how to calculate various measures of production-based availability of a WTGS, based on the information categories defined in this document and in IEC TS 61400-26-1. Examples are given using mandatory and optional categories. Users may find other optional categories or definitions of production-based availability more specific to their needs.

In the time period for which production-based availability is to be calculated, the operation of the turbine must first be categorized according to the information categories defined in IEC TS 61400-26-1.

Each example of production-based availability is defined in terms of:

a) actual energy production;
b) lost production; and
c) information categories not to be considered in the availability calculation.

When calculating the measure of availability, the following equation is applied:

$$\text{Production-based availability} = 1 - \frac{\text{Lost production}}{\text{Actual energy production} + \text{Lost production}} \qquad \text{(B.1)}$$

Lost production = Potential energy production – Actual energy production

The actual energy production in Clause B.1 is the sum of the information in layer 2 for each of the information categories specified for each definition of availability.

The lost production in Clause B.1 is the sum of the information in layer 3 for each of the information categories specified for each definition of availability, except for GENERATING – FULL PERFORMANCE and GENERATING – PARTIAL PERFORMANCE, where the information in layer 3 less that in layer 2 equals the lost production.

B.2 System operational production-based availability (“WTGS user’s view”)

B.2.1 General

System operational production-based availability is the ratio of actual energy production in a given period of time compared to what the production would have been if the unit has been generating in full performance the entire time. All causes of lost production are included. This may be considered as representative of the WTGS user’s view of availability and production.

B.2.2 System operational production-based availability algorithm based on mandatory information categories only

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

- GENERATING – FULL PERFORMANCE, $\mathbf{IAOGFPP_A}$

- GENERATING – PARTIAL PERFORMANCE**, $\mathbf{IAOGPPP_A}$**

Information categories with lost production are:

- GENERATING – PARTIAL PERFORMANCE, $\mathbf{IAOGPPP_P - IAOGPPP_A}$
- TECHNICAL STANDBY, $\mathbf{IAONGTP_P}$
- OUT OF ENVIRONMENTAL SPECIFICATION, $\mathbf{IAONGENP_P}$
- REQUESTED SHUTDOWN, $\mathbf{IAONGRSP_P}$
- OUT OF ELECTRICAL SPECIFICATION, $\mathbf{IAONGELP_P}$
- SCHEDULED MAINTENANCE, $\mathbf{IANOSMP_P}$
- PLANNED CORRECTIVE ACTION, $\mathbf{IANOPCAP_P}$
- FORCED OUTAGE, $\mathbf{IANOFOP_P}$
- SUSPENDED, $\mathbf{IANOSP_P}$
- FORCE MAJEURE, $\mathbf{IAFMP_P}$

Examples of cases are illustrated in Annex D.

Information categories not included in the calculation are:

INFORMATION UNAVAILABLE, **IU**

$$\text{System operational production-based availability} = 1 - \frac{(IAOGPPP_P - IAOGPPP_A) + IAONGTP_P + IAONGENP_P + IAONGRSP_P + IAONGELP_P + IANOSMP_P + IANOPCAP_P + IANOFOP_P + IANOSP_P + IAFMP_P}{(IAOGFPP_A + IAOGPPP_A) + (IAOGPPP_P - IAOGPPP_A) + IAONGTP_P + IAONGENP_P + IAONGRSP_P + IAONGELP_P + IANOSMP_P + IANOPCAP_P + IANOFOP_P + IANOSP_P + IAFMP_P} \quad (B.2)$$

Note that since no information about the turbine 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.

Unlike the definition of system operational availability in IEC TS 61400-26-1:2011, B.2.3, the use of the optional information categories out of environmental specification – calm and out of environmental specification – other environmental is not needed in this example since with calm winds, there is no actual or potential energy production and therefore no lost production. system operational production-based availability is not affected. Periods of calm winds are essentially excluded from production-based availability calculations. System operational production-based availability is affected when wind resources are not captured by a WTGS due to environmental conditions beyond the design specifications of the WTGS, but the performance metric is not penalized when no wind resource is available.

B.2.3 Turbine operational production-based availability algorithm – including optional information categories

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

- GENERATING – FULL PERFORMANCE, $IAOGFPP_A$
- Generating – partial performance, derated, $IAOGPP_{DR}P_A$
- Generating – partial performance, degraded, $IAOGPP_{DG}P_A$

In this example, information categories with lost production are:

- Generating – partial performance, derated, $IAOGPP_{DR}P_P - IAOGPP_{DR}P_A$
- Generating – partial performance, degraded, $IAOGPP_{DG}P_P - IAOGPP_{DG}P_A$
- TECHNICAL STANDBY, $IAONGTP_P$
- Out of Environmental Specification – Other, $IAONGEN_OP_P$
- SCHEDULED MAINTENANCE, $IANOSMP_P$
- PLANNED CORRECTIVE ACTION, $IANOPCAP_P$
- FORCED OUTAGE, $IANOFOP_P$
- SUSPENDED, $IANOSP_P$

Information categories not included in the calculation are:

- Out of Environmental Specification – Calm winds, $IAONGEN_CP_P$
- REQUESTED SHUTDOWN, $IAONGRSP_P$
- OUT OF ELECTRICAL SPECIFICATION, $IAONGELP_P$
- FORCE MAJEURE, $IAFMP_P$
- INFORMATION UNAVAILABLE, IU

$$\text{Turbine operational production-based availability (optional)} = 1 - \frac{(IAOGPP_{DR}P_P - IAOGPP_{DR}P_A) + (IAOGPP_{DG}P_P - IAOGPP_{DG}P_A) + IAONGTP_P + IAONGEN_OP_P + IANOSMP_P + IANOPCAP_P + IANOFOP_P + IANOSP_P}{(IAOGFPP_A + IAOGPP_{DR}P_A + IAOGPP_{DG}P_A) + (IAOGPP_{DR}P_P - IAOGPP_{DR}P_A) + (IAOGPP_{DG}P_P - IAOGPP_{DG}P_A) + IAONGTP_P + IAONGEN_OP_P + IANOSMP_P + IANOPCAP_P + IANOFOP_P + IANOSP_P} \quad (B.3)$$

Turbine operational production-based availability differs from system operational production-based availability in that categories generally beyond the control of the turbine are excluded from consideration. Turbine performance is not being evaluated during periods where the operator has requested a shutdown, an electrical connection is not available, or a force majeure event has occurred.

B.3 Technical production-based availability (“WTGS manufacturer’s view”)

B.3.1 General

Technical production-based availability is the ratio of actual energy production in a given period of time compared to what production would have been if the WTGS has been operating according to its design specifications. This is more representative of the WTGS manufacturer’s view of availability and production.

B.3.2 Technical production-based availability based on mandatory information categories only

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

- GENERATING – FULL PERFORMANCE, $\mathbf{IAOGFPP_A}$
- GENERATING – PARTIAL PERFORMANCE, $\mathbf{IAOGPPP_A}$

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, $\mathbf{IAONGTP_P}$
- OUT OF ENVIRONMENTAL SPECIFICATION, $\mathbf{IAONGENP_P}$

- REQUESTED SHUTDOWN, $\mathbf{IAONGRSP_P}$
- OUT OF ELECTRICAL SPECIFICATION, $\mathbf{IAONGELP_P}$

Information categories with lost production are:

- GENERATING – PARTIAL PERFORMANCE, $\mathbf{IAOGPPP_P - IAOGPPP_A}$
- PLANNED CORRECTIVE ACTION, $\mathbf{IANOPCAP_P}$
- FORCED OUTAGE, $\mathbf{IANOFOP_P}$

Information categories not included in the calculation include:

- SCHEDULED MAINTENANCE, $\mathbf{IANOSMP_P}$
- SUSPENDED, $\mathbf{IANOSP_P}$
- FORCE MAJEURE, $\mathbf{IAFMP_P}$
- INFORMATION UNAVAILABLE, **IU**

$$\text{Technical production-based availability} = 1 - \frac{(\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P}}{(\mathbf{IAOGFPP_A} + \mathbf{IAOGPPP_A}) + (\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P}} \qquad \text{(B.4)}$$

Annex C
(informative)

Capacity factor and other performance indicators

C.1 General

In addition to time-based or production-based availability, which primarily describe the readiness of a WTGS to capture wind resources, other performance indicators may be defined which may be useful in describing or characterizing additional aspects of the WTGS performance. Annex C describes examples of one such performance indicator, capacity factor. It is based on the information categories and terms defined in this document and in IEC TS 61400-26-1. Users may find other definitions of other performance indicators to be more specific to their needs.

C.2 Capacity factor

Capacity factor is the amount of energy produced by a WTGS compared to how much energy could have been produced if the WTGS 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

$$\text{Actual capacity factor} = \frac{\text{Actual energy production}}{\text{Maximum production}} \tag{C.1}$$

$$\text{Potential capacity factor} = \frac{\text{Potential energy production}}{\text{Maximum production}} \tag{C.2}$$

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

The capacity factor is a measure of the WTGS capability to generate electricity at a specific site (sometimes expressed as the equivalent full load hours over a specified period of time). Note that the ratio of the actual and potential capacity factors is by definition production-based availability. Other performance indicators may include production ratios, production losses and revenue-based availability.

The model and information categories introduced in IEC TS 61400-26-1 and used to define time-based availability performance indicators have been extended in this technical specification to describe production-based availability indicators by adding an additional layer to the information model to account not only for the hours associated with a given information category, but also for the actual and potential energy production associated with that information category. In general, that model can be extended by the user 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 WTGS for any specific information category, and revenue-based production can be assessed in a similar manner. The availability model in Annex B can be extended for alternate definitions of revenue-based availability.

C.3 Production ratio

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

$$\text{Production ratio} = \frac{\text{Actual energy production } (\text{IAOGFPP}_A)}{\text{Potential energy production } (\text{IAOGFPP}_P)} \qquad \text{(C.3)}$$

The production ratio is a measure of whether the turbine is producing as expected. Turbine 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.

Annex D
(informative)

Verification scenarios – examples

D.1 General

Annex D illustrates examples for application of the three layers of the information model set out in this Technical Specification. It illustrates methods for calculation of various production-based availability indicators according to Annex B.

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.

D.2 Application scenarios

D.2.1 General

Under all scenarios hereinafter, the following conditions are applied.

- The WTGS is assumed to produce 100 kWh (potential energy production) during the depicted period.
- Each scenario represents one time bin which consists of 10 min.
- High degree of uncertainty is inherently attached to both measurement of power curve and calculation of potential energy production. The WTGS user and the WTGS manufacturer agree to accept the uncertainty, thus no debate is needed on the difference between the actual energy production and the potential energy production.
- Otherwise, the power curve and/or the calculation model will need to be verified to determine whether there is lost production or not.

D.2.2 Scenarios under FULL PERFORMANCE

Table D.1 – 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**
D.2.2.1	FULL PERFORMANCE	Wind energy for the rated power is available for the whole time period.	100	100	Zero by definition	Not applicable

The example in Table D.1 is the ideal scenario. Both the WTGS user and the WTGS manufacturer are satisfied by the full performance of the WTGS. There is no lost production by definition and thus no concern.

Table D.2 – FULL PERFORMANCE: Actual energy production is less 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**
D.2.2.2	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 underperforming by 5 %. The WTGS manufacturer may think that the calculation model is over predicting by 5 %. Another possibility is degraded WTGS performance due to dirty blades or ice accumulated on blades.

It has been explicitly mentioned in the introduction of the application scenarios that high degree of uncertainty is inherently attached to both measurement of power curve and calculation of potential energy production. It is therefore assumed, as the base case scenario, that the WTGS user and the WTGS manufacturer agree to accept the uncertainty, thus no debate is needed on the difference between the actual energy production and the potential energy production.

If the lost production at FULL PERFORMANCE needs to be taken into account, the information category may be changed from FULL PERFORMANCE to PARTIAL PERFORMANCE.

In the scenario in Table D.2, at least the following four examples of debate are possible:

a) The WTGS user may think that power curve is underperforming by 5 %.

b) The WTGS manufacturer may 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 manufacturer may doubt the cleanliness of the blades. If the WTGS user is assigned to keeping blades clean, he 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 is assigned to the lost production.

Table D.3 – 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**
D.2.2.3	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 may think that the power curve is under declared by 3 %. On the other hand, The WTGS manufacturer may think that the calculation model is over predicting by 3 %.

It has been explicitly mentioned in the introduction of the application scenarios that high degree of uncertainty is inherently attached to both measurement of power curve and calculation of potential energy production. It is therefore assumed, as the base case scenario, that the WTGS user and the WTGS manufacturer agree to accept the uncertainty, thus no debate is needed on the difference between the actual energy production and the potential energy production.

If the lost production at FULL PERFORMANCE needs to be taken into account, the information category may be changed from FULL PERFORMANCE to PARTIAL PERFORMANCE.

In the scenario in Table D.3, at least the following two examples of debate are possible:

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

b) The WTGS manufacturer may 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.2.3 Scenarios under PARTIAL PERFORMANCE

Table D.4 – 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**
D.2.3.1	**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 to the entire lost production although financially he might not be assigned to compensate it.

The scenario in Table D.4 illustrates a grid constraint situation. Although the WTGS output is constrained by grid, it performs fully. All the lost production is due to grid constraint.

Table D.5 – Partial performance – Derated: Grid constraint, actual energy production less 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**
D.2.3.2	**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.	70	100	30	Grid operator is assigned to 25 kWh of the lost production although financially he might not be assigned to compensate it.

The scenario in Table D.5 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 instead of 70 kWh. Under this scenario, at least the following four examples are possible:

a) The WTGS user may think that power curve is underperforming by 7 %.

b) The WTGS manufacturer may think that the calculation model is over predicting by 7 %, thus the potential energy production is 70 kWh and there is no lost production.

c) The WTGS manufacturer may doubt the cleanliness of the blades. If the WTGS user is assigned to keeping blades clean, he 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 is assigned to the lost production.

Table D.6 – Partial performance – Derated: Output constraint due to excessive noise from 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**
D.2.3.3	**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 manufacturer might have defined that the WTGS manufacturer is assigned to lost production under derated operation due to noise.

The scenario in Table D.6 illustrates a noise constraint situation. Although the WTGS output is constrained by noise, it performed fully. All the lost production is due to noise constraint.

Table D.7 – 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**
D.2.3.4	**Partial performance – Derated**	Dirty blades constrained 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.7, the WTGS user is assigned to blade cleaning but he did not do it. He is therefore assigned to the lost production.

Table D.8 – Partial performance – Derated: Ice accumulated on blades has been detected and the 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**
D.2.3.5	**Partial performance – Derated Partial performance – Derated: Ice accumulated on blades has been detected and the WTGS is allowed to operate although the power performance is 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 manufacturer that he could operate the WTGS even if ice has accumulated on blades and the power performance is derated for which the WTGS manufacturer is free from assignment.

In the scenario in Table D.8, the WTGS output is derated by ice accumulated on blades. If the WTGS user has accepted the risk of ice on blades, he is assigned to the lost production.

Table D.9 – 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
D.2.3.6	**Partial performance – Degraded**	The WTGS is deteriorated. Wind energy for the rated power is available for the whole time period.	50	100	50	The WTGS is still under warranty by 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.9, it is obvious to the WTGS user that power performance is degraded. The WTGS user issues warranty claim to the WTGS manufacturer.

D.2.4 Scenarios under TECHNICAL STANDBY

Table D.10 – 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
D.2.4.1	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.

In the scenario in Table D.10, the contract shall define who is assigned to lost production due to technical standby for cable unwinding.

D.2.5 Scenarios under OUT OF ENVIRONMENTAL SPECIFICATION

Table D.11 – 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
D.2.5.1	**Out of environmental specification – Calm winds**	No wind energy for power production is available for the whole time period.	0	0	0	Not applicable

In the scenario in Table D.11, there is no possibility of production, thus no loss.

Table D.12 – 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**
D.2.5.2	**Out of environmental specification – High winds**	Wind speed is beyond the cut-out speed for the whole time period.	0	0	0	Not applicable

In the scenario in Table D.12, there is no possibility of production, thus no loss.

Table D.13 – 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**
D.2.5.3	**Out of environmental specification – Temperature**	Temperature is too high and out of the operational range as set by the WTGS manufacturer.	0	0	0	Not applicable

In the scenario in Table D.13, there is no possibility of production, thus no loss.

D.2.6 Scenarios under REQUESTED SHUTDOWN

Table D.14 – 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**
D.2.6.1	**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 manufacturer may however take a different view and insist credit for potential energy production of the 100 kWh which is lost by shutdown.

In the scenario in Table D.14, at least the following two examples are possible:

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

Table D.15 – 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**
D.2.6.2	**Requested shutdown – Sector management**	Wind direction is subject to shutdown according to the agreement between the WTGS user and the WTGS manufacturer, although wind energy for the rated power is available for the whole time period.	0	0	0	Not applicable

In the scenario in Table D.15, the WTGS is shut down for sector management based on the agreement between the WTGS user and the WTGS manufacturer. There is no need for debate.

Table D.16 – Requested shutdown: Noise nuisance

Example	**Information category (Layer 1)** (10 min)	**Circumstance**	**Actual production (Layer 2)** (kWh) [Measured]	**Potential production (Layer 3)** (kWh)	**Lost production** (kWh)	**Explanatory note**
D.2.6.3	**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 makes 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.16, at least the following two examples are possible:

a) The WTGS user may 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.

D.2.7 Scenarios under OUT OF ELECTRICAL SPECIFICATION

Table D.17 – 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**
D.2.7.1	**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 might not be assigned to compensate it.

In the scenario in Table D.17, lost production is due to grid system failure and no claim is made to the grid operator.

D.2.8 Scenarios under SCHEDULED MAINTENANCE

Table D.18 – SCHEDULED MAINTENANCE: WTGS is under scheduled maintenance work by the WTGS manufacturer 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**
D.2.8.1	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 contract may exempt the WTGS manufacturer's assignment for lost production within the time allowance for scheduled maintenance while others may not.

In the scenario in Table D.18, at least the following two outcomes are possible:

a) The WTGS manufacturer 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 is free from assignment for lost production because it is within the time allowance for scheduled maintenance.

D.2.9 Scenarios under PLANNED CORRECTIVE ACTION

Table D.19 – PLANNED CORRECTIVE ACTION: WTGS manufacturer 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**
D.2.9.1	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 is to be assigned to lost production under the period of planned corrective action.

In the scenario in Table D.19, the WTGS manufacturer is to be assigned to the lost production.

D.2.10 Scenarios under FORCED OUTAGE

Table D.20 – 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**
D.2.10.1	**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 is to be assigned to lost production due to this forced outage.

In the scenario in Table D.20, the WTGS manufacturer is to be assigned to the lost production, provided that the WTGS manufacturer is assigned to the outage.

Table D.21 – 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**
D.2.10.2	**Forced outage – Corrosion**	Tower paint is deteriorated and the tower is rusty due to corrosion. The WTGS is to be repainted. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer is likely to be assigned to lost production due to this forced outage.

In the scenario in Table D.21, the WTGS manufacturer is likely to be assigned to the lost production, provided that the WTGS manufacturer is assigned to supplying the tower with adequate coating.

Table D.22 – 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**
D.2.10.3	**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 is likely to be assigned to lost production due to this forced outage.

In the scenario in Table D.22, the WTGS manufacturer is likely to be assigned to the lost production, provided that the WTGS manufacturer is accountable for proper operation at the site-specific environment.

D.2.11 Scenarios under SUSPENDED

Table D.23 – 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**
D.2.11.1	SUSPENDED	The WTGS manufacturer's repair work due to forced outage is suspended by a storm which is accompanied by lightning. Wind energy for the rated power is available for the whole time period.	0	100	100	The WTGS manufacturer may or may not be assigned to lost production due to this suspended period.

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

a) The WTGS manufacturer 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 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.

D.2.12 Scenarios under FORCE MAJEURE

Table D.24 – 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**
D.2.12.1	FORCE MAJEURE	The WTGS manufacturer 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 debate.

In the scenario in Table D.24, the contract defines that no one is assigned to lost production when a force majeure event is occurring.

D.3 Calculation of production-based availability indicators according to Annex B

D.3.1 General

According to the methods described in Clauses B.2 and B.3, the information models introduced for Clause D.2 are derived for illustration.

D.3.2 System operational production-based availability algorithm based on mandatory information categories only (“WTGS user’s view”)

Note that in the example in Table D.25, the shaded information categories are not included in the calculation.

Table D.25 – System operational production-based availability algorithm based on mandatory information categories only (“WTGS user’s view”)

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) [Calculated]	**Lost production** (kWh) [Calculated]
D.2.2.1	FULL PERFORMANCE, (IAOGFP)	100	100	0
D.2.2.2	FULL PERFORMANCE, (IAOGFP)	95	100	0
D.2.2.3	FULL PERFORMANCE, (IAOGFP)	103	100	0
D.2.3.1	PARTIAL PERFORMANCE, (IAOGPP)	75	100	25
D.2.3.2	PARTIAL PERFORMANCE, (IAOGPP)	70	100	30
D.2.3.3	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.3.4	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.5	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.6	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.4.1	TECHNICAL STANDBY, (IAONGT)	0	100	100
D.2.5.1	OUT OF ENVIRONMENTAL SPEC. – Calm ($IAONGEN_C$)	0	0	0
D.2.5.2	OUT OF ENVIRONMENTAL SPEC., (IAONGEN)	0	0	0
D.2.5.3	OUT OF ENVIRONMENTAL SPEC., (IAONGEN)	0	0	0
D.2.6.1	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.2	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.3	REQUESTED SHUTDOWN, (IAONGRS)	0	100	100
D.2.7.1	OUT OF ELECTRICAL SPECIFICATION, (IAONGEL)	0	100	100
D.2.8.1	SCHEDULED MAINTENANCE, (IANOSM)	0	100	100
D.2.9.1	PLANNED CORRECTIVE ACTION, (IANOPCA)	0	100	100
D.2.10.1	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.2	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.3	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.11.1	SUSPENDED, (IANOS)	0	100	100
D.2.12.1	FORCE MAJEURE, (IAFM)	0	100	100

$$\text{System operational production-based availability} = 1 - \frac{(\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IAONGTP_P} + \mathbf{IAONGENP_P} + \mathbf{IAONGRSP_P} + \mathbf{IAONGELP_P} + \mathbf{IANOSMP_P} + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P} + \mathbf{IANOSP_P} + \mathbf{IAFMP_P}}{(\mathbf{IAOGFPP_A} + \mathbf{IAOGPPP_A}) + (\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IAONGTP_P} + \mathbf{IAONGENP_P} + \mathbf{IAONGRSP_P} + \mathbf{IAONGELP_P} + \mathbf{IANOSMP_P} + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P} + \mathbf{IANOSP_P} + \mathbf{IAFMP_P}} \quad \text{(B.2)}$$

[Numerator]

$\mathbf{IAOGPPP}_P$ – $\mathbf{IAOGPPP}_A$ = 165

$\mathbf{IAONGTP}_P$ = 100

$\mathbf{IAONGENP}_P$ = 0

$\mathbf{IAONGRSP}_P$ = 100

$\mathbf{IAONGELP}_P$ = 100

$\mathbf{IANOSMP}_P$ = 100

$\mathbf{IANOPCAP}_P$ = 100

$\mathbf{IANOFOP}_P$ = 300

$\mathbf{IANOSP}_P$ = 100

$\mathbf{IAFMP}_P$ = 100

Subtotal = 1165

[Denominator]

$\mathbf{IAOGFPP}_A$ = 298

$\mathbf{IAOGPPP}_A$ = 435

$\mathbf{IAOGPPP}_P$ – $\mathbf{IAOGPPP}_A$ = 165

$\mathbf{IAONGTP}_P$ = 100

$\mathbf{IAONGENP}_P$ = 0

$\mathbf{IAONGRSP}_P$ = 100

$\mathbf{IAONGELP}_P$ = 100

$\mathbf{IANOSMP}_P$ = 100

$\mathbf{IANOPCAP}_P$ = 100

$\mathbf{IANOFOP}_P$ = 300

$\mathbf{IANOSP}_P$ = 100

$\mathbf{IAFMP}_P$ = 100

Subtotal = 1898

System operational production based availability = 1 – (1165 / 1898) = 1 – 0,61 = 0,39 [39 %].

D.3.3 Turbine operational production-based availability algorithm – including optional categories (“WTGS user’s view”)

Note that in the example in Table D.26, the shaded information categories are not included in the calculation.

Table D.26 – Turbine operational production-based availability algorithm – including optional categories ("WTGS user's view")

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)
D.2.2.1	FULL PERFORMANCE, (IAOGFP)	100	100	0
D.2.2.2	FULL PERFORMANCE, (IAOGFP)	95	100	0
D.2.2.3	FULL PERFORMANCE, (IAOGFP)	103	100	0
D.2.3.1	PARTIAL PERFORMANCE, (IAOGPP)	75	100	25
D.2.3.2	PARTIAL PERFORMANCE, (IAOGPP)	70	100	30
D.2.3.3	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.3.4	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.5	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.6	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.4.1	PARTIAL PERFORMANCE, (IAOGPP)	0	100	100
D.2.5.1	OUT OF ENVIRONMENTAL SPEC. – Calm, ($IAONGEN_C$)	0	0	0
D.2.5.2	OUT OF ENVIRONMENTAL SPEC. – Other, ($IAONGEN_o$)	0	0	0
D.2.5.3	OUT OF ENVIRONMENTAL SPEC. – Other, ($IAONGEN_o$)	0	0	0
D.2.6.1	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.2	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.3	REQUESTED SHUTDOWN, (IAONGRS)	0	100	100
D.2.7.1	OUT OF ELECTRICAL SPECIFICATION, (IAONGEL)	0	100	100
D.2.8.1	SCHEDULED MAINTENANCE, (IANOSM)	0	100	100
D.2.9.1	PLANNED CORRECTIVE ACTION, (IANOPCA)	0	100	100
D.2.10.1	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.2	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.3	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.11.1	SUSPENDED, (IANOS)	0	100	100
D.2.12.1	FORCE MAJEURE, (IAFM)	0	100	100

$$\text{Turbine operational production-based availability (optional)} = 1 - \frac{(\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IAONGEN_OP_P} + \mathbf{IANOSMP_P} + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P} + \mathbf{IANOSP_P}}{(\mathbf{IAOGFPP_A} + \mathbf{IAOGPPP_A}) + (\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IAONGEN_OP_P} + \mathbf{IANOSMP_P} + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P} + \mathbf{IANOSP_P}} \quad \text{(B.3)}$$

[Numerator]

$\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A} = 165$

$\mathbf{IAONGEN_0P_P} = 0$

$\mathbf{IANOSMP_P} = 100$

$\mathbf{IANOPCAP_P} = 100$

[Denominator]

$\mathbf{IAOGFPP_A} = 298$

$\mathbf{IAOGPPP_A} = 435$

$\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A} = 165$

$\mathbf{IAONGEN_0P_P} = 0$

$\mathbf{IANOFOP}_P = 300$

$\mathbf{IANOSP}_P = 100$

Subtotal = 765

$\mathbf{IANOSMP}_P = 100$

$\mathbf{IANOPCAP}_P = 100$

$\mathbf{IANOFOP}_P = 300$

$\mathbf{IANOSP}_P = 100$

Subtotal = 1498

Turbine operational production based availability = 1 – (765 / 1498) = 1 – 0,51 = 0,49 [49 %].

D.3.4 Technical production-based availability based on mandatory information categories only (“WTGS manufacturer's view”)

Note that in the example in Table D.27, the shaded information categories are not included in the calculation.

Table D.27 – Technical production-based availability based on mandatory information categories only (“WTGS manufacturer's view”)

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)
D.2.2.1	FULL PERFORMANCE, (IAOGFP)	100	100	0
D.2.2.2.a	FULL PERFORMANCE, (IAOGFP)	95	100	0
D.2.2.3.a	FULL PERFORMANCE, (IAOGFP)	103	100	0
D.2.3.1	PARTIAL PERFORMANCE, (IAOGPP)	75	100	25
D.2.3.2.a	PARTIAL PERFORMANCE, (IAOGPP)	70	100	30
D.2.3.3	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.3.4	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.5	PARTIAL PERFORMANCE, (IAOGPP)	95	100	5
D.2.3.6	PARTIAL PERFORMANCE, (IAOGPP)	50	100	50
D.2.4.1	TECHNICAL STANDBY, (IAONGT)	0	100	100
D.2.5.1	OUT OF ENVIRONMENTAL SPEC. – Calm ($IAONGEN_C$)	0	0	0
D.2.5.2	OUT OF ENVIRONMENTAL SPEC., (IAONGEN)	0	0	0
D.2.5.3	OUT OF ENVIRONMENTAL SPEC., (IAONGEN)	0	0	0
D.2.6.1.a	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.2	REQUESTED SHUTDOWN, (IAONGRS)	0	0	0
D.2.6.3.a	REQUESTED SHUTDOWN, (IAONGRS)	0	100	100
D.2.7.1	OUT OF ELECTRICAL SPECIFICATION, (IAONGEL)	0	100	100
D.2.8.1.a	SCHEDULED MAINTENANCE, (IANOSM)	0	100	100
D.2.9.1	PLANNED CORRECTIVE ACTION, (IANOPCA)	0	100	100
D.2.10.1	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.2	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.10.3	FORCED OUTAGE, (IANOFO)	0	100	100
D.2.11.1	SUSPENDED, (IANOS)	0	100	100
D.2.12.1	FORCE MAJEURE, (IAFM)	0	100	100

$$\text{Technical production-based availability} = 1 - \frac{(\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P}}{(\mathbf{IAOGFPP_A} + \mathbf{IAOGPPP_A}) + (\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A}) + \mathbf{IANOPCAP_P} + \mathbf{IANOFOP_P}} \quad \text{(B.4)}$$

[Numerator]

$\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A} = 165$

$\mathbf{IANOPCAP_P} = 100$

$\mathbf{IANOFOP_P} = 300$

Subtotal = 565

[Denominator]

$\mathbf{IAOGFPP_A} = 298$

$\mathbf{IAOGPPP_A} = 435$

$\mathbf{IAOGPPP_P} - \mathbf{IAOGPPP_A} = 165$

$\mathbf{IANOPCAP_P} = 100$

$\mathbf{IANOFOP_P} = 300$

Subtotal = 1298

Technical production-based availability = 1 – (565 / 1298) = 1 – 0,44 = 0,56 [56 %].

Annex E
(informative)

Considerations of competing assignment of lost production

As a consequence of enforcing mutual exclusivity of the categories in the information model, situations may arise where data gathered do not adequately reflect the assignment of downtime and lost production.

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 E.1.

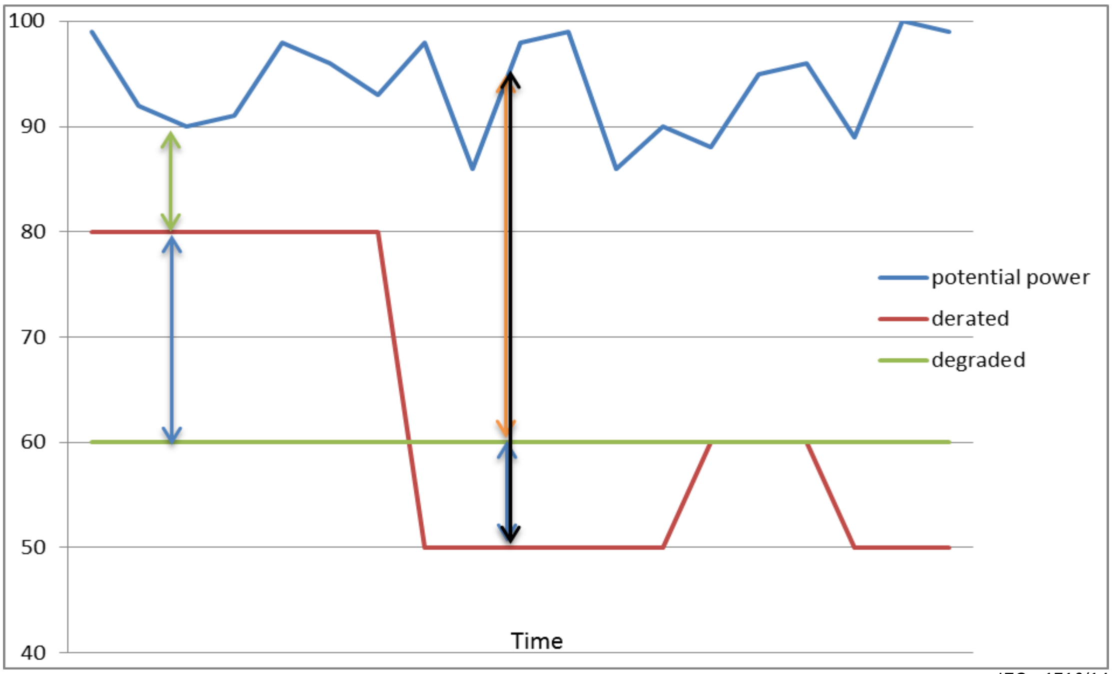


Figure E.1 – Example of simultaneous degrading and derating

Scenario:

The WTGS is degraded to 60 % of its nominal power because the service provider does not have the necessary spare part available, at the same time the grid operator requests to derate the WTGS to 80 % of its nominal production. The wind is at all times sufficient to achieve both potential energy production values (derated and degraded).

Depending on the purpose the calculation is used for (e.g. compensation under a service contract between manufacturer and owner of the wind farm, compensation between grid operator and the owner of the wind farm), clarification is needed concerning which potential energy production shall have priority for the calculation:

- 80 % as derated;
- 60 % as degraded;
- potential energy production in accordance with the actual wind conditions.

This is a limitation inherent in the information model and it is therefore prudent to consider which conflicts may arise in advance and how these should be resolved.

Bibliography

IEC 61400-1:2005, *Wind turbines – Part 1: Design requirements*

IEC 61400-12-1:2005, *Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC 61400-12-2:2013, *Wind turbines – Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry*

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

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

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

IEC 61400-25-4:2008, *Wind turbines – Part 25-4: Communications for monitoring and control of wind power plants – Mapping to communication profile*

IEC 61400-25-5:2006, *Wind turbines – Part 25-5: Communications for monitoring and control of wind power plants – Conformance testing*

IEC 61400-25-6:2010, *Wind turbines – Part 25-6: Communications for monitoring and control of wind power plants – Logical node classes and data classes for condition monitoring*

ISO 3977-9:1999, *Gas turbines – Procurement – Part 9: Reliability, availability, maintainability and safety*

IEEE 762-2006, *IEEE Standard for Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity*

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