

VGB-Standard

Technical and Commercial Key Indicators for Power Plants

9th edition 2019
(Former VGB-RV 808)

VGB-S-002-03-2019-10-EN

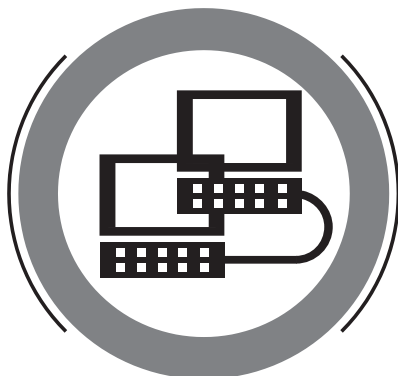


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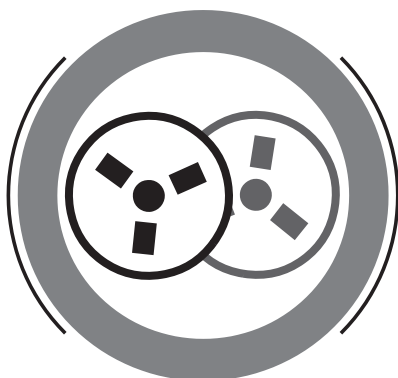
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Phone: +49 201 8128-200
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Note on proposals for amendments

*Proposals for amendments may be sent to the email address **vgb.standard@vgb.org**. For clear assignment of the contents, the subject line should include the designation number of the relevant document.*

List of changes

VGB-Standard	Date of change	Chapter	Description
VGB-S-002-03-2019-10-EN	November 2017	Chapter 1.3.9	Definition updated
VGB-S-002-03-2019-10-EN	May 2018	Chapter 1.12.3.8	Figure 1 updated
VGB-S-002-03-2019-10-EN	May 2018	Chapter 2.3.8	Definition updated
VGB-S-002-03-2019-10-EN	March 2019	Chapter 1.1.1	Definition updated

Preface

This VGB Standard allows the user to make a technical and economic assessment of power plants. In addition, the effect of price effects and the legal requirements on the power plant operation can be analyzed using the VGB-Standard. In detail, the user receives analysis options in the assessment of power plant processes, the assessment of plant operation and the determination of economic success.

The operation of power plants or the utilization of different technologies in energy conversion depends on a number of restrictions, in the competitive environment, primarily on the costs as well as on the specific political framework in the electricity markets.

With the shown evaluation criteria for example the efficiency, availability and reliability of the individual technologies can be determined, compared with one another and determine the own position of the power plant. This results in the possibility to influence its own competitive position.

The present revision contains adaptations and additions resulting from changed political boundary conditions. These include both higher requirements resulting from new publication and registration obligations of production facilities and their production data as well as changed operating conditions due to increasing global efforts to get out of fossil based energy production. On the basis of these findings, a revision of the definitions and parameters in the project group "Definitions and Evaluations" has resulted in the essential new and changed terms and definitions that are summarized in this VGB Standard.

With the definitions and rules contained in this VGB Standard, different considerations in the international environment can continue to be carried out. Examples which may be mentioned are:

- Commercialization and optimizing the application of power plant capacities (inclusive of system services)
- Comparative evaluation of cost-optimized fuel application at minimum CO₂ emissions
- Formulation of targets and goals
- Implementation of benchmarking comparison (national or international)
- Support for transparency processes
- Provision of parameters and indicators for public relations etc.

The VGB-Standard VGB-002-03-2019-10-EN "Technical and Commercial Indicators of Power Plants" is continuously being updated and adopted to current developments. It can be ordered via the internet www.vgb.org.

Suggestions for improvement for future editions are welcome and will be gladly accepted by the contact person of the VGB Technical Group “Performance Indicators”:

<https://www.vgb.org/en/performanceindicators.html>

Essen, October 2019

VGB PowerTech e.V.

Authors

This VGB-Standard was created by the VGB project group “Definitions and Evaluations”.

Members of the project group:

Cord Bredthauer, Uniper Kraftwerke GmbH

Uwe Dorn, LEAG Lausitz Energie Kraftwerke AG

Henrik Møller Jørgensen, Fjernvarme Fyn A/S

Ralf Kirsch, Vattenfall Europe Generation AG

Franz-Peter Laube, PreussenElektra GmbH

Jean-François Lehougre, EDF-DPIT

Stefan Prost, VGB PowerTech e.V.

Dr. Jörn Rassow, EnBW Energie Baden-Württemberg AG

Dr. Ralf Uttich, RWE Generation SE

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4th Edition 1991 (First English edition)

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6th Edition 1999

7th Edition 2008

8th Edition 2016

9th Edition 2019

Content

1	Indicators	17
1.1	Availability: Perception and Definition	17
1.1.1	Availability and utilization	19
1.1.2	Classification of the Unavailability (UA)	21
1.2	Availability indicators	23
1.2.1	Time availability (base)	23
1.2.2	Time availability during peak times	23
1.2.3	Energy availability	24
1.2.4	Market-assessed availability	24
1.2.5	Time UA Base/peak	25
1.2.6	Energy UA Base/peak	25
1.3	Reliability and dispatchability indicators	26
1.3.1	Time reliability	26
1.3.2	Energy reliability	26
1.3.3	Start-up reliability	27
1.3.4	Market-assessed supply reliability	27
1.3.5	Dispatch reliability	28
1.3.6	Schedule compliance	29
1.3.7	Dispatchability	29
1.3.8	Market-assessed dispatchability	30
1.3.9	Unplanned Automatic Grid Separation UAGS7	31
1.4	Definition and utilization	32
1.4.1	Time utilization	32
1.4.2	Energy utilization	33
1.4.3	Market-assessed utilization	34
1.5	Failure rate	35
1.5.1	Time failure rate	35
1.5.2	Energy failure rate	35
1.5.3	Dispatching (energy) failure rate	36
1.6	Other indicators	37
1.6.1	CHP indicator	37
1.6.2	Greenhouse-gas indicator	37
1.7	Overview about terms and basic parameters	38
2	Definitions	40
2.1	Hierarchy and relation of definitions	40
2.2	Hierarchy and relation of definitions	41
2.3	Time-related terms	42
2.3.1	Begin of data recording	43
2.3.2	End of data recording	43
2.3.3	Reference period	43
2.3.4	Peak times reference period	43
2.3.5	Available time/Available time during peak-times	43
2.3.6	Operating time	44
2.3.7	Available time not in operation	44
2.3.7.1	Stand-by time	44
2.3.7.2	Available not dispatchable time (external influence time)	44

2.3.8	Unavailable time (UA-time).....	45
2.3.8.1	Planned UA-time.....	45
2.3.8.2	Unplanned UA-time	45
2.3.8.3	Postponable unplanned UA-time	45
2.3.8.4	Not postponable unplanned UA-time	45
2.4	Capacity-related terms.....	46
2.4.1	Nominal capacity	47
2.4.2	Available capacity	49
2.4.3	Dispatchable capacity.....	49
2.4.4	Capacity generated.....	49
2.4.4.1	Gross-(generated-) capacity	49
2.4.4.2	Net-(generated-) capacity	50
2.4.4.3	Auxiliary power capacity	50
2.4.5	Schedule capacity.....	50
2.4.6	Available unproducibile capacity.....	50
2.4.6.1	Stand-by capacity	50
2.4.6.2	Available unproducibile capacity (external influences)	51
2.4.7	Unavailable capacity (UA-capacity)	51
2.5	Energy-related terms	57
2.5.1	Nominal energy.....	58
2.5.2	Nominal energy during peak times	58
2.5.3	Available energy	58
2.5.4	Available energy during peak times	58
2.5.5	Dispatchable energy	58
2.5.6	Generated energy.....	58
2.5.7	Schedule energy.....	58
2.5.8	Available energy not generated	59
2.5.8.1	Stand-by energy	59
2.5.8.2	Available unproducibile energy (external influence energy)	59
2.5.9	Unavailable energy (UA-energy).....	59
2.5.9.1	Planned UA-energy	60
2.5.9.2	Unplanned UA-energy	60
2.5.9.3	Unplanned postponable UA-energy.....	60
2.5.9.4	Unplanned not postponable UA-energy.....	60
3	Plant (Unit) determination	62
4	Principles and hierarchy of events	64
5	Capacity fluctuations by different temperatures of cooling water and air	67
6	Excess energy.....	67
7	Market assessed supply reliability.....	67
8	Exceeding and falling below planned unavailabilities	68
8.1	General.....	68
8.2	Extension	68

9	Retrofitting measures (Retrofit).....	69
10	External influences	69
10.1	Capacity restrictions by external influences	69
10.1.1	Fuel.....	70
10.1.2	Mothballing of the plant.....	70
10.1.3	Climate	71
10.1.4	Grid related restrictions.....	71
10.1.5	Shortage of personnel	71
10.1.6	Other matters.....	72
11	Combined heat and power generating plants (CHP)	72
11.1	Nominal capacity and nominal energy from co-generation plants.....	76
11.2	Equivalent electrical energy through thermal generation	76
11.3	Energy availability	77
11.4	Energy utilization	77
12	Successful start-up rate	78
13	Special regulations	79
13.1	Measures in available plants	79
13.2	Failure of flue gas cleaning	79
13.3	Nuclear power plants	79
13.4	Missing operating permit.....	80
13.5	Advancing of planned unavailabilities	81
14	Data recording	82
14.1	Use of gross or net values	82
15	Calculation of average values	82
15.1	Fundamentals.....	82
15.2	Average value for several plants for one calendar year or one operating year.....	83
15.2.1	Average energy availability $k_{W\text{mittel}}$ for I Plants	84
15.2.2	Average operating time $t_{B\text{mittel}}$ for I Plant	84
15.2.3	Average utilization duration $t_{a\text{Nmittel}}$ for I plant.....	84
15.3	Average value for several plants for several calendar years or several operating years	85
15.3.1	Average energy availability $k_{W\text{mittel}}$ for I plants and J calendar years or M operating years:.....	86
15.4	Classification and comparison of units.....	87
16	Analysis of the unavailability of thermal power plants	89
16.1	History of VGB guideline VGB-R 140	89
16.2	Unavailability analysis from thermal power plants	89
16.3	Identification System for Power Stations (KKS) and Reference Designation System for Power Plants (RDS-PP®)	90
16.4	Range of determination	92
16.5	Recording of event data.....	94
16.6	Evaluation.....	100

17	Power plant information system KISSY.....	103
17.1	KISSY access and data input	103
17.2	Evaluations and reports	105
18	Structure of event characteristic key system EMS and overview	108
18.1	Application recommendations.....	110
18.2	Event characteristic key 1 "Type of event"	111
18.3	Event characteristic key 2 "Operating status before event"	112
18.4	Event characteristic key 3 "Operating status after event"	113
18.5	Event characteristic key 4 "Impact on unit"	114
18.6	Event characteristic key 5 "Outage impact on the system/components".	116
18.7	Event characteristic key 6 "Cause"	117
18.8	Event characteristic key 7 "Damage mechanism"	121
18.9	Event characteristic key 8 "Damage"	125
18.10	Event characteristic key 9 "Recognition of failure"	127
18.11	Event characteristic key 10 "Maintenance form"	130
18.12	Event characteristic key 11 "Measures against recurrence"	131
18.13	Event characteristic key 12 "Urgency of measures"	133
19	Use of the technical assessment of energy conversion plants for the electricity market and grid safety.....	134
20	Examples of use	136
20.1	Example 1: "Unplanned not available load reduction"	136
20.2	Example 2: "Blackout"	137
20.3	Example 3: "Unplanned not available block unavailability"	138
20.4	Example 4: "Blackout after faulty operation"	139
20.5	Example 5: "BDEW"	140
20.6	Example 6: "Capacity terms of technical resource / BDEW"	141
20.7	Example 7: "Capacity terms Power Plant Object / PPO of hydro pumped storage power plant / BDEW"	142

General Remarks

Apart from investment cost, fuel and running cost also determine the economic success of power plant operation. In this respect availability is playing a very important part. It is an indicator for assessing the technical and economic potential and capacity as well as the reliability of a plant and reflecting the advances in technology and engineering.

The guideline at hand contains the terms, definitions, technical profile as well as recording and calculations guides necessary for determining availability. These apply mainly to thermal power plants for electricity generation but can also be used for plants for combined heat and power generation. Relevant economic parameters important for marketing the final product, i.e. the converted energy, are also defined.

In general it is possible to gain an overview about the technical and economical capacity of a generation unit as well as data about the quality of operation and maintenance.

Indicators are basically used for the technical and economical comparison (benchmarking). Mostly dimensionless parameters are applied that were derived from terms related to dimensions.

The consequent consideration of the definitions and rules gathered in this guideline are advantageous in the following internal and industry-wide applications:

- Support
 - When planning, preparing and optimizing maintenance
 - When planning fuel application
 - When optimizing the power plant portfolio and power plant application
 - When making an economic analysis
- Determination of statistically confirmed standards and comparative values on the basis of a large number of plants for the qualitatively and economic assessment and evaluation of power plants and systems in view of e.g. conception, construction, quality of design and construction and operational approval.
- Presentation and documentation of operating results
 - Internal and external comparison of e.g. plant groups and types, capacity ranges, power plant sites
 - Analytical assessment of the level and timely development of availability
 - Analyze of unavailability
- Provision of data and results, among others for
 - Public relation activities

- Investigations and analyses
- Acquisition

In cases of international comparison it has to be assured that the country-specific reference base (market parameters, stock exchange prices) are duly considered.

Alphabetical List of Abbreviations

Symbol	Designation	Chapter
DB	Profit margin (= market price – production cost)	7
DB+	Profit margin, only positive otherwise null	1.4.3
e_{CO_2}	Greenhouse-gas indicator	1.6.2
e_f	Emission factor	1.6.2
e_{ox}	Oxidation factor	1.6.2
f_{FP}	Schedule	1.3.6
H_u	Lower heating value	1.6.2
k_b	Dispatchability	1.3.7
K_{bm}	Market-assessed dispatchability	1.3.8
k_t	Time availability (base)	1.2.1
$k_{t\ Pe}$	Time availability during peak times	1.2.2
k_{tn}	Time UA Base/peak	1.2.5
$k_{tn\ Pe}$	Time UA Base/peak	1.2.5
k_W	Energy availability	1.2.3
k_{Wm}	Market-assessed availability	1.2.4
k_{Wn}	Energy UA Base/pea	1.2.6
$k_{Wn\ Pe}$	Energy UA Base/pea	1.2.6
M_B	Fuel provided	1.6.2
n_{KWK}	CHP indicator	1.6.1
n_t	Time utilization	1.4.1
n_W	Energy utilization	1.4.2
n_{Wm}	Market-assessed utilization	1.4.3
P_B	Capacity generated	2.4.4
$P_{B\ br}$	Gross-(generated-) capacity	2.4.4.1
$P_{B\ ne}$	Net-(generated-) capacity	2.4.4.2
$P_{Eig\ B}$	Auxiliary power capacity	2.4.4.3
P_{FP}	Schedule capacity	2.4.5
p_l	Dispatching (energy) failure rate	1.5.3
P_N	Nominal capacity	2.4.1
P_{ng}	Available unproducible capacity	2.4.6
P_{ns}	Available unproducible capacity (external influences)	2.4.6.2

Symbol	Designation	Chapter
P_{nv}	Unavailable capacity (UA-capacity)	2.4.7
P_R	Stand-by capacity	2.4.6.1
p_t	Time failure rate	1.5.1
P_v	Available capacity	2.4.2
p_v	Dispatch reliability	1.3.5
p_w	Energy failure rate	1.5.2
r_m	Market-assessed supply reliability	1.3.4
s_e	Number of successful start-ups	1.3.3
s_n	Number of unsuccessful start-ups	1.3.3
t_{aN}	Utilization period	1.4.2
t_B	Operating time	2.3.6
t_N	Reference period	2.3.3
$t_{N Pe}$	Peak times reference period	2.3.4
t_{ng}	Available time not in operation	2.3.7
t_{ns}	Available not dispatchable time (external influence time)	2.3.7.2
t_{nv}	Unavailable time (UA-time)	2.3.8
$t_{nv p}$	Planned UA-time	2.3.8.1
$t_{nv u}$	Unplanned UA-time	2.3.8.2
$t_{nv ud}$	Postponable unplanned UA-time	2.3.8.3
$t_{nv un}$	Not postponable unplanned UA-time	2.3.8.4
t_R	Stand-by time	2.3.7.1
t_v	Available time/Available time during peak-times	2.3.5
$t_{v Pe}$	Available time/Available time during peak-times	2.3.5
UAGS	Unplanned Automatic Grid Separation UAGS7	1.3.9
W_B	Generated energy	2.5.6
W_b	Dispatchable energy	2.5.5
W_{FP}	Schedule energy	2.5.7
W_N	Nominal energy	2.5.1
$W_{N Pe}$	Nominal energy during peak times	2.5.2
$W_{ne KWK}$	Produced CHP energy	1.6.1
W_{ng}	Available energy not generated	2.5.8

Symbol	Designation	Chapter
W_{nR}	Negative balancing energy	1.4.2
W_{ns}	Available unproducibile energy (external influence energy)	2.5.8.2
W_{nv}	Unavailable energy (UA-energy)	2.5.9
$W_{nv\ p}$	Planned UA-energy	2.5.9.1
$W_{nv\ u}$	Unplanned UA-energy	2.5.9.2
$W_{nv\ ud}$	Unplanned postponable UA-energy	2.5.9.3
$W_{nv\ un}$	Unplanned not postponable UA-energy	2.5.9.4
W_R	Stand-by energy	2.5.8.1
w_t	Time reliability	1.3.1
W_v	Available energy	2.5.3
w_v	Energy reliability generated energy	1.3.2
$W_{v\ Pe}$	Available energy during peak times	2.5.4
z	Start-up reliability	1.3.3

Technical and Commercial Indicators for Power Plants

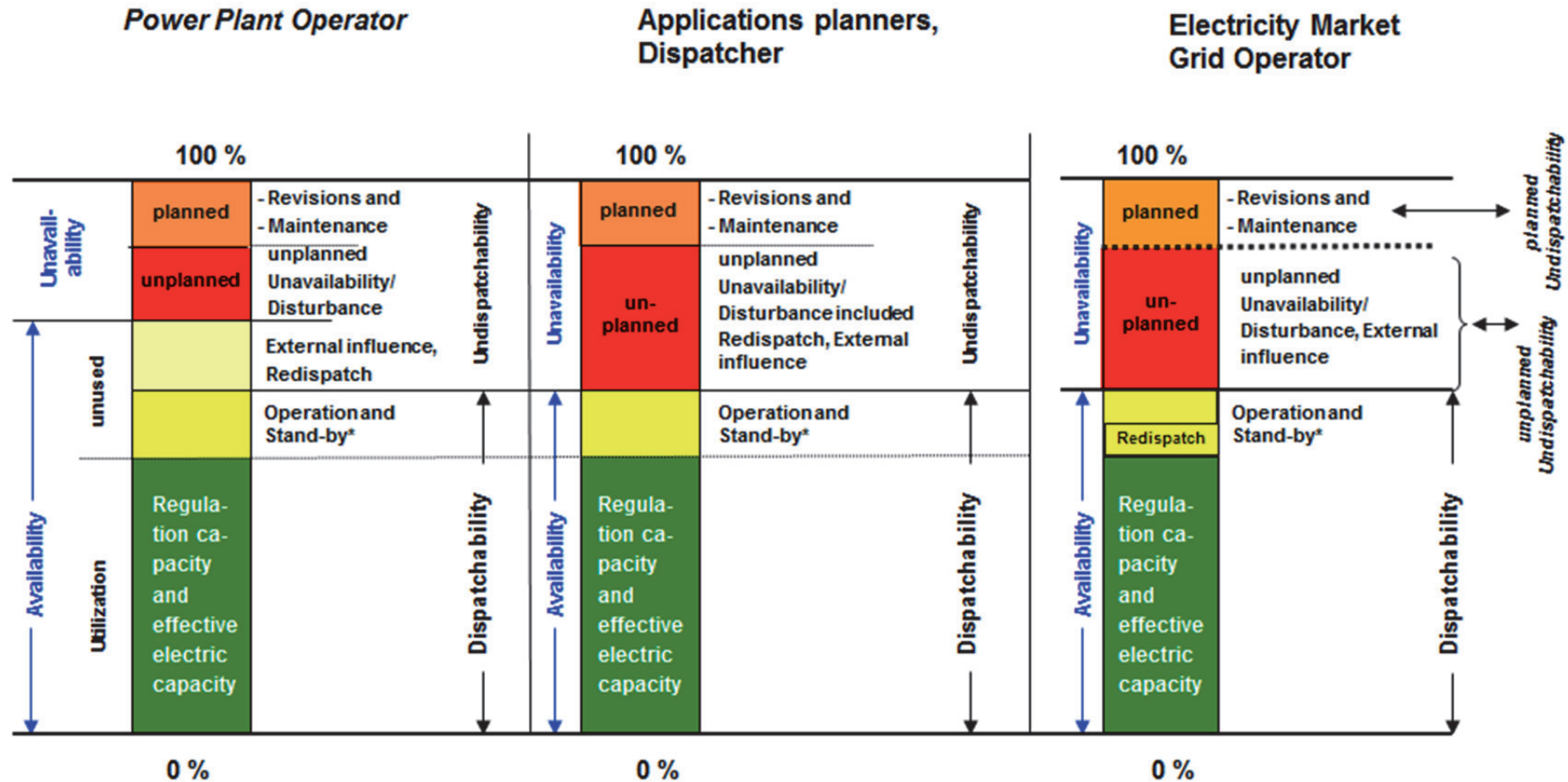
– Fundamentals and Determination –

1 Indicators

The most obvious performance indicator for a unit is the technical availability. For the load dispatcher who transfers and deals the energy to the different markets, the reliability of the plant is an important indicator for him. If the reliability of a power plant is reduced, all the causes of this unavailability must be explained and estimated. The outcome of this follows to other definitions of indicators like the utilization i.e. the exploitability of a power plant. For special applications like for example co-generation plant or environmental points of view, some other indicators were developed in order to bring lot of important information about the operational processes. Those have been defined below.

1.1 Availability: Perception and Definition

The different perceptions of indicators for the unit operator and the load dispatcher are shown by the Figure 1. The assignments of the colours to the definitions made are effective for the whole volume. All the following terms and definitions refer both to the previous technical perception (Market: Base) and to the now liberalised electricity market perception (Peak, Market assessed).



Operation and Stand-by *: Capacity provision for reserve and provision of control capacity
 External influence: Fuel, climate, grid restrictions, et al.

Figure 1: Analysis level unavailability, availability, dispatchability (reference level net).

1.1.1 Availability and utilization

The availability characterizes the ability of a unit or of a unit part to convert energy independent of the actual operation. Events besides the sphere of influence of the plant management, which result in a capacity delimitation by external influences or due to a lack of load, do not reduce the availability.

The most obvious performance indicator is the energy availability. It is a measure for the energy which can be generated by a plant due to its technical and operational state. In connection with the energy utilization it is the extensive performance indicator for the overall evaluation of a plant. Additionally it facilitates making comparative statements on the quality of different plants.

Unlike the energy availability is the time availability a measure for the time dispatchability of a plant and that is independent of the size of the particularly available capacity. If a plant can only be operated at reduced capacity because of unavailability, it is with regard to time fully available. Therefore the numerical value of the time availability is normally larger than the energy availability.

The time availability is easy to determine and is suitable to evaluate plants or plant parts comparatively, e.g. waste incineration plants, for which it is not possible to determine energy-related indicators.

With the example of an idealized operational diagram, the calculation of energy availability, energy utilization and time availability is shown in Figure 2. At the same time it represents the basic differences in the performance indicators.

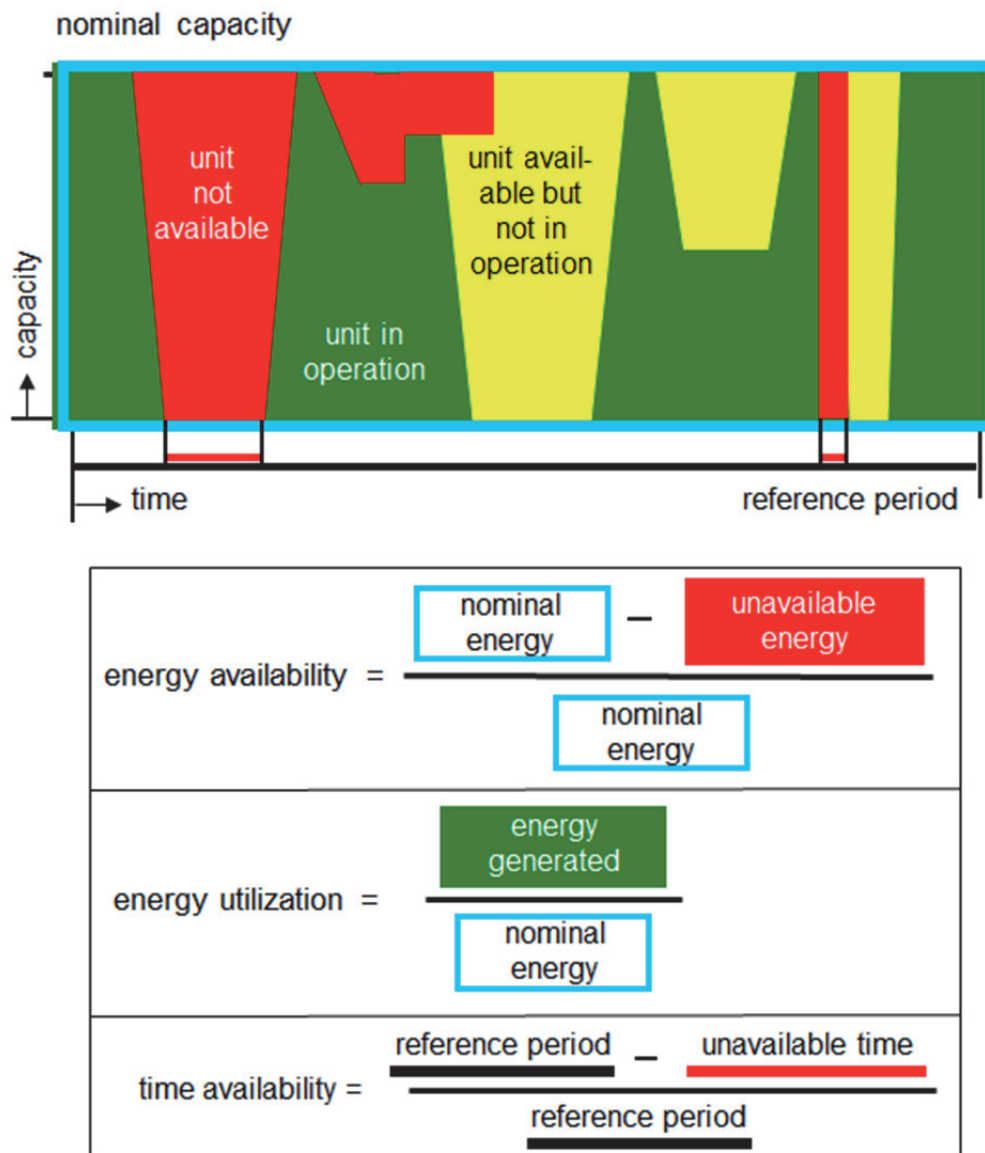


Figure 2: Operating diagram and performance indicators.

The actual dispatchable capacity, i.e. the exploitability of the plant (see VGB-S-002-01 and Chapter 1.3.7) is important for the load dispatcher.

The difference between availability and exploitability is that part of capacity which cannot be utilised because of external influences.

Moreover we can distinguish:

- The utilization is a measure for the real utilization of a plant or a plant part.
- The failure rate is of special use for the planning of operation.
- The start-up reliability is important to evaluate units with frequent start-ups, e.g. gas turbines.

1.1.2 Classification of the Unavailability (UA)

The unavailability of a unit is its' incapacity to produce electricity or heat. The various causes can include: a unit internal problem, which can be solved by maintenance – (repair, replacement, etc.). Unavailability cannot be influenced by the operational management but stays under the control of plant management.

External influences are by definition out of the control of the plant management and are not considered as unavailability but as a part of undispachability.

Unavailabilities are distinguished in relation to the temporal urgency for a shutdown and the derating respectively (Figure 3).

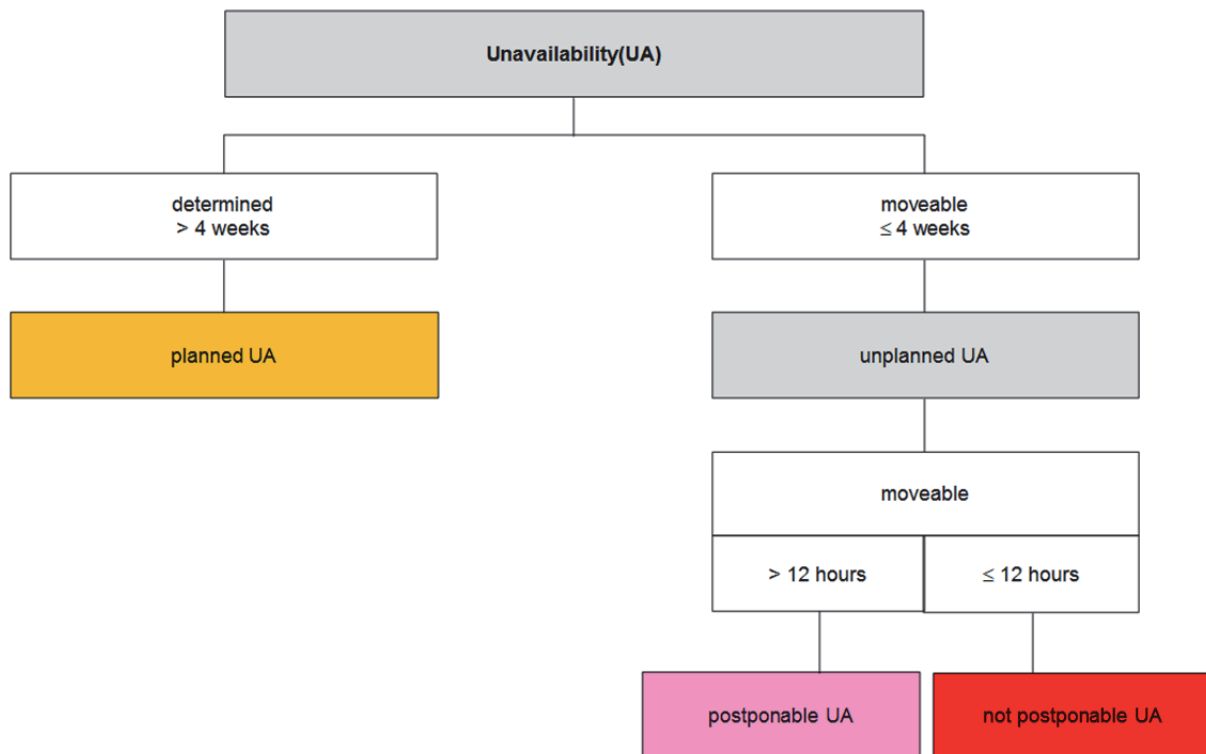


Figure 3: Classification of unavailability.

planned unavailability	The beginning and duration of the unavailability have to be determined more than 4 weeks before start.
unplanned unavailability	The beginning of unavailability is known less than four weeks before its occurrence.
postponable	The beginning of unavailability can be postponed for 12 hours or up to 4 weeks.
not postponable	The beginning of unavailability is spontaneous or can be only postponed for less than 12 hours.

1.2 Availability indicators

Designation	Symbol/Formula	Definition	Application
1.2.1 Time availability (base)	$k_t = \frac{t_v}{t_N} = \frac{t_N - t_{nv}}{t_N}$	<p>Time availability is the quotient of available time and nominal time (calendar time).</p> <p>Available time is the difference between nominal time and unavailable time.</p>	<p>It is independent of the capacity available in a particular case. Where required, further differentiation can be achieved using planned and unplanned unavailable times.</p>
1.2.2 Time availability during peak times	$k_{tPe} = \frac{t_{vPe}}{t_{NPe}} = \frac{t_{NPe} - t_{nvPe}}{t_{NPe}}$	<p>Time availability at peak times is the quotient of available time during peak times and the number of peak hours in nominal time.</p> <p>Available time during peak times is the difference between the number of peak hours in nominal time and the unavailable time during peak times.</p>	<p>Time availability at peak times is the quotient of available time during peak times and the number of peak hours in nominal time.</p> <p>Available time during peak times is the difference between the number of peak hours in nominal time and the unavailable time during peak times. Time availability at peak times is a measure of a plant's deployability at peak times. It is particularly suited as a measure for plants that are to be deployable mainly in the mid-merit and peak load.</p>

Designation	Symbol/Formula	Definition	Application
1.2.3 Energy availability	$k_w = \frac{W_v}{W_N} = \frac{W_N - W_{nv}}{P_N \cdot t_N}$	<p>Energy availability is the quotient of available energy and nominal energy.</p> <p>Available energy is the difference between nominal energy and unavailable energy. Nominal energy is the product of nominal capacity and nominal time (calendar time).</p>	<p>Energy availability is a measure of the energy that a plant can produce in view of its technical and operational condition. Unlike time availability, it also takes account of partial unavailabilities.</p>
1.2.4 Market-assessed availability	$k_{wm} = \frac{\sum_{i=1..N} (W_{N,i} - W_{nv,i}) \cdot DB_{+i}}{\sum_{i=1..N} W_{N,i} \cdot DB_{+i}}$	<p>Market-assessed availability is the quotient of</p> <p>available energy weighted with a positive profit margin</p> <p>nominal energy weighted with a positive profit margin</p> <ul style="list-style-type: none"> – each relative to the time span considered 	<p>Market-assessed availability indicates the ability of a plant or part of a plant to convert energy profitably, irrespective of actual deployment. Events outside the plant's sphere of influence that result in capacity restrictions due to external influences or lack of demand do not reduce the market-assessed availability.</p> <p>The parameter corresponds to energy availability weighted with positive profit margins.</p>

Designation	Symbol/Formula	Definition	Application
1.2.5 Time UA Base/peak	$k_{tn} = 1 - k_t$ $(k_{tn\ Pe} = 1 - k_{t\ Pe})$ $k_{tn} = \frac{t_{nv}}{t_N}$ $k_{tn} = \frac{t_{nv\ p} + t_{nv\ u}}{t_N}$	<p>Time unavailability (time UA) is the complement of time availability at 100 %.</p> <p>The time UA is the quotient of the unavailable time and the nominal time (calendar time).</p> <p>The unavailability time is the sum of planned and unplanned UA time.</p>	<p>The unavailability time is a measure of the temporal inability of a plant for reasons that lie within the plant.</p> <p>It is independent of the amount of the respective unavailable capacity. If necessary, a further differentiation can be made by using planned and unplanned unavailability times.</p>
1.2.6 Energy UA Base/peak	$k_{Wn} = 1 - k_W$ $(k_{Wn\ Pe} = 1 - k_{W\ Pe})$ $k_{Wn} = \frac{W_{nv}}{W_N}$ $k_{Wn} = \frac{W_{nv\ p} + W_{nv\ u}}{P_N * t_N}$	<p>Energy unavailability (energy UA) is the complement of energy availability at 100 %.</p> <p>The energy UA is the quotient of the unavailable energy and the nominal energy.</p> <p>The unavailability energy is the sum of planned and unplanned UA energy. The nominal energy is the product of nominal capacity and nominal time (calendar time).</p>	<p>Energy UA is a measure of lost energy for reasons that lie within the plant.</p> <p>Different to time unavailability it takes also into account the partial unavailabilities.</p>

1.3 Reliability and dispatchability indicators

Designation	Symbol/Formula	Definition	Application
1.3.1 Time reliability	$W_t = \frac{t_B}{t_B + t_{nv\ un}}$	Time reliability is the quotient of operating time and the sum of operating time and unplanned not postponable UA time.	Reliability is a synonym for the dependability of a plant as regards unplanned (not postponable) events.
1.3.2 Energy reliability – unplanned (total)	$W_v = \frac{W_B}{W_B + W_{nv\ u}}$	Energy reliability – unplanned (total) is the quotient of generated energy and the sum of generated energy and unplanned (total) UA energy.	Reliability – unplanned (total) is a synonym for the dependability of plants as regards unplanned events.
– unplanned, not postponable	$W_v = \frac{W_B}{W_B + W_{nv\ un}}$	Energy reliability – unplanned not postponable is the quotient of generated energy and the sum of generated energy and unplanned not postponable UA energy.	Reliability – unplanned not postponable is a synonym for the dependability of plants as regards unplanned events.

Designation	Symbol/Formula	Definition	Application
1.3.3 Start-up reliability	$Z = \frac{s_e}{s_e + s_n}$	Start-up reliability is the quotient of the number of successful start-ups (s_e) and the sum of successful (s_e) and unsuccessful start-ups (s_n) (see Chapter 12).	Start-up reliability is used to assess plants and units whose lifetime also depends largely on the number of start-ups, e.g. gas turbines or emergency generating sets.
1.3.4 Market-assessed supply reliability	$r_m = 1 - \frac{\sum(WB_i - W_{Fpi} \cdot DB_i)}{\sum(W_{Fpi} \cdot DB_i)}$	Market-assessed supply reliability is the quotient of the amount, weighted with the profit margin, of the difference between generated energy and the schedule energy schedule energy weighted with the profit margin, each relative to the period observed. The initial parameters are established by analogy with price developments, viz. by the hour.	Supply reliability is a measure of a plant's economic deployability on the wholesale market. Going beyond the technical deployability, it assesses the economic benefit of any deployment.

Designation	Symbol/Formula	Definition	Application
1.3.5 Dispatch reliability – unplanned (total)	$p_v = \frac{W_B}{W_B + W_{nv\ u} + W_{ns}}$	Dispatch reliability – unplanned (total) is the quotient of generated energy and the sum of generated energy, unplanned UA energy and external-influence energy.	Dispatch reliability – unplanned (total) is a measure of a plant's reliability outside planned unavailabilities. The parameter can also be used for peak-load plants.
– unplanned, not postponable	$p_v = \frac{W_B}{W_B + W_{nv\ un} + W_{ns}}$	Dispatch reliability – unplanned not postponable is the quotient of generated energy and the sum of generated energy, unplanned not postponable UA energy and external-influence energy.	Dispatch reliability – unplanned not postponable is a measure of a plant's reliability outside planned unavailabilities. The parameter can also be used for peak-load plants.

Designation	Symbol/Formula	Definition	Application
1.3.6 Schedule compliance	$f_{FP} = \frac{W_B}{W_{FP}}$	Schedule compliance is the quotient of generated energy and scheduled energy requirement to be met by a production plant within a given time period.	Schedule compliance is used for collecting and reviewing the compliance of schedules in energy conversion facilities. This indicator can be used to assess balancing group deviations.
1.3.7 Dispatchability	$k_b = \frac{W_b}{W_N} = \frac{W_N - W_{nv} - W_{ns}}{W_N}$	Dispatchability is the quotient of dispatchable energy and nominal energy.	(Energy) dispatchability is a measure of the energy that a plant is able to generate in view of its technical and operational condition and in view of the condition impacted by external influences.

Designation	Symbol/Formula	Definition	Application
1.3.8 Market-assessed dispatchability	$k_{bm} = \frac{\sum_{i=1..N} (W_{N,i} - W_{nv,i} - W_{ns,i}) \cdot DB_{+i}}{\sum_{i=1..N} W_{N,i} \cdot DB_{+i}}$	<p>Market-assessed dispatchability is the quotient of</p> <ul style="list-style-type: none"> – dispatchable energy weighted with a positive profit margin and – nominal energy weighted with a positive profit margin <p>each relative to the time span considered.</p>	<p>Market-assessed dispatchability is the ability of a plant or a part of a plant to profitably convert energy in view of its technical and operational condition and of the condition impacted by external influences, viz. irrespective of actual deployment.</p> <p>The parameter corresponds to the energy dispatchability, weighted with positive profit margins.</p> <p>Note: For a trader, the market-assessed dispatchability is important; for a producer, it is the market-assessed availability for which he is responsible.</p>

Designation	Symbol/Formula	Definition	Application
1.3.9 Unplanned Automatic Grid Separation UAGS7	$UAGS_7 = \frac{\text{Count} \cdot 7000}{t_b}$	The indicator “Unplanned Automatic Grid Separation” is defined as the count of unplanned automatically complete grid separations (triggering of the protection system e.g. turbine trip), standardized to a given operating time (e.g. 7,000 h).	<p>The factor “Unplanned Automatic Grid Separation” reflects the improvement in plant safety from reducing the count of undesired and unplanned thermohydraulic transients that lead to grid separation. It also indicates how well the plant is operated and serviced.</p> <p>A consideration of the count of hours in which the plant was available to the load dispatcher is an indicator of the efficacy of the efforts to reduce UAGSs. It provides a basis for comparing plant values with each other and with the average values for the entire sector if the grid separation of the various units is standardized (e.g. 7,000 h).</p>

1.4 Definition and utilization

Designation	Symbol/Formula	Definition	Application
1.4.1 Time utilization	$n_t = \frac{t_B}{t_N}$	Time utilization is the quotient of operating time and nominal time (calendar time).	Time utilization is a measure of a plant's actual temporal deployment. It is independent of the level of the operating capacity concerned.

Designation	Symbol/Formula	Definition	Application
1.4.2 Energy utilization	$n_W = \frac{W_B}{W_N} = \frac{W_B}{P_N \cdot t_N}$	Energy utilization is the quotient of generated energy and nominal energy.	Energy utilization is a measure of the energy that a plant actually produces (plus negative balancing energy).
Energy utilization with negative balancing energy	$n_W = \frac{W_B + W_{nR}}{W_N} = \frac{W_B + W_{nR}}{P_N \cdot t_N}$	<p>Energy utilization with negative balancing energy is the quotient of generated energy plus balancing energy and nominal energy.</p> <p>Nominal energy is the product of nominal capacity and nominal time (calendar time).</p> <p>Operating energy is the product of operating capacity and operating time (meter value) plus operating capacity and operating time for the negative balancing energy (meter value).</p>	<p>The equivalent terms “utilization duration” and “full-load utilization hours” are also frequently used:</p> $t_{aN} = \frac{W_B}{P_N}$ <p>The link between energy utilization and utilization period is:</p> $t_{aN} = n_W \cdot t_N$ <p>Negative balancing energy is energy that reduces the generated energy of the power plant when it is used for assuring the supply of grid services (e.g. primary, secondary, or tertiary control, etc.)</p>

Designation	Symbol/Formula	Definition	Application
1.4.3 Market-assessed utilization	$n_{wm} = \frac{\sum_{i=1 \dots N} W_{B,i} \cdot DB_{-i}}{\sum_{i=1 \dots N} W_{N,i} \cdot DB_{+i}}$	<p>Market-assessed utilization is the quotient of</p> <ul style="list-style-type: none"> – generated energy weighted with the positive or negative profit margin and – nominal energy weighted with the positive profit margin, <p>each relative to the time span considered.</p>	<p>Market-assessed utilization is a measure of the profitable energy that a plant actually produces.</p> <p>The parameter corresponds to energy utilization, weighted with profit margins.</p>

1.5 Failure rate

Designation	Symbol/Formula	Definition	Application
1.5.1 Time failure rate	$p_t = \frac{t_{nv\ u}}{t_B + t_{nv\ u}}$	The time failure rate is the quotient of unplanned unavailability time and the sum of operating time and unplanned unavailability time.	The time failure rate indicates a plant's non-deployability outside planned downtimes and outside available non-deployment times.
1.5.2 Energy failure rate – unplanned (total)	$p_w = \frac{W_{nv\ u}}{W_B + W_{nv\ u}}$	The energy failure rate – unplanned (total) is the quotient of unplanned (total) unavailable energy and the sum of generated energy and unplanned (total) unavailable energy	The energy failure rate – unplanned (total) is a measure of unproducibile energy outside planned unavailabilities and outside available, unproduced energy due to stand-bys and external influences.

Designation	Symbol/Formula	Definition	Application
1.5.3 Dispatching (energy) failure rate – unplanned (total)	$p_I = \frac{W_{nv\ u}}{W_B + W_{nv\ u} + W_{ns}}$	The dispatching (energy) failure rate – unplanned (total) is the quotient of unplanned (total) unavailable energy and the sum of unplanned (total) unavailable energy, external-influence energy and generated energy.	The dispatching (energy) failure rate – unplanned (total) is a measure of the unproducible energy outside planned unavailabilities and outside available energy. Therefor it is an early-warning indicator in a risk-management system.

1.6 Other indicators

Designation	Symbol/Formula	Definition	Application
1.6.1 CHP indicator (combined heat and power)	$n_{\text{KWK}} = \frac{W_{\text{neKWK}}}{W_{\text{Nne}}}$	The CHP indicator is the quotient of net produced CHP energy and net nominal energy.	Assessment of a plant as to its CHP share relative to its net nominal energy.
1.6.2 Greenhouse-gas indicator	$e_{\text{CO}_2} = \frac{M_{\text{B}} \cdot H_{\text{u}} \cdot e_{\text{f}} \cdot e_{\text{ox}}}{W_{\text{Bne}}}$	A plant's greenhouse-gas indicator is the quotient of CO ₂ produced and net generated energy.	This indicator gives the CO ₂ emissions in t/MWh for the generation of electric energy and heat.

1.7 Overview about terms and basic parameters

It is defined: (The list is sorted in alphabetical order).

Number peak-hours within reference period	$t_{N\ Pe}$	Operating time	t_B
Number of successful start-ups	s_e	Fuel provided	M_B
Number of unsuccessful start-ups	s_n	Greenhouse-gas indicator	e_{co2}
Energy failure rate	p_W	Profit margin (= market price – production cost)	DB
Energy utilization	n_W	Profit margin, only positive otherwise null	DB+
Energy unavailability	$k_{Wn} = 1 - k_W$	Emission factor	e_f
Energy availability	k_W	Produced CHP energy	W_{ne} KWK
Energy availability during peak times	$k_{W\ Pe}$	Schedule energy	W_{FP}
Energy reliability	w_v	Schedule capacity	P_{FP}
External influence energy	W_{ns}	Schedule	f_{FP}
External influence capacity	P_{ns}	Planned UA-energy	$W_{nv\ p}$
Utilization period	t_{aN}	Planned UA-capacity	$P_{nv\ p}$
Dispatchable energy	W_b	Planned UA-time	$t_{nv\ p}$
Dispatchability	k_b	CHP indicator	n_{KWK}
Stand-by energy	W_R	Dispatching failure rate	p_l
Stand-by capacity	P_R	Dispatching reliability	p_v
Stand-by time	t_R	Market-assessed utilization	n_{Wm}
Generated energy	W_B	Market-assessed dispatchability	K_{bm}

Capacity generated (gross or net)	P_B (br o.ne)	Market-assessed availability	k_{Wm}
Nominal energy	W_N	Unplanned (not postponable) UA-capacity	$P_{nv\ u(n)}$
Nominal energy during peak times	$W_{N\ Pe}$	Unplanned automatic grid separation	UAGS
Non dispatchable energy	W_{nb}	Lower heating value	H_u
Unavailable energy (UA-energy)	W_{nv}	Available energy	W_v
Unavailable energy during peak times	$W_{nv\ Pe}$	Available energy during peak times	$W_{v\ Pe}$
Unavailable capacity (UA-capacity)	P_{nv}	Available energy not generated	W_{ng}
Unavailable time (UA-time)	t_{nv}	Available unproducible capacity	P_{ng}
Unavailable time during peak times	$t_{nv\ Pe}$	Available time not in operation (during peak times)	$t_{ng\ (Pe)}$
Oxidation factor	e_{ox}	Market-assessed utilization	r_m
Peak times reference period	$t_{N\ Pe}$	Time failure rate	p_t
Start-up reliability	Z	Time utilization	n_t
Unplanned postponable UA-energy	$W_{nv\ ud}$	Time unavailability	$k_{tn} = 1 - k_t$
Unplanned postponable UA-capacity	$P_{nv\ ud}$	Time availability (during peak times)	$k_t\ (Pe)$
Unplanned postponable UA-time	$t_{nv\ ud}$	Time reliability	w_t
Unplanned (not postponable) UA-energy	$W_{nv\ u(n)}$		

In order to avoid some misunderstandings, terms like availability, utilization and failure rate can be always used respectively with the added terms of time or energy.

2 Definitions

2.1 Hierarchy and relation of definitions

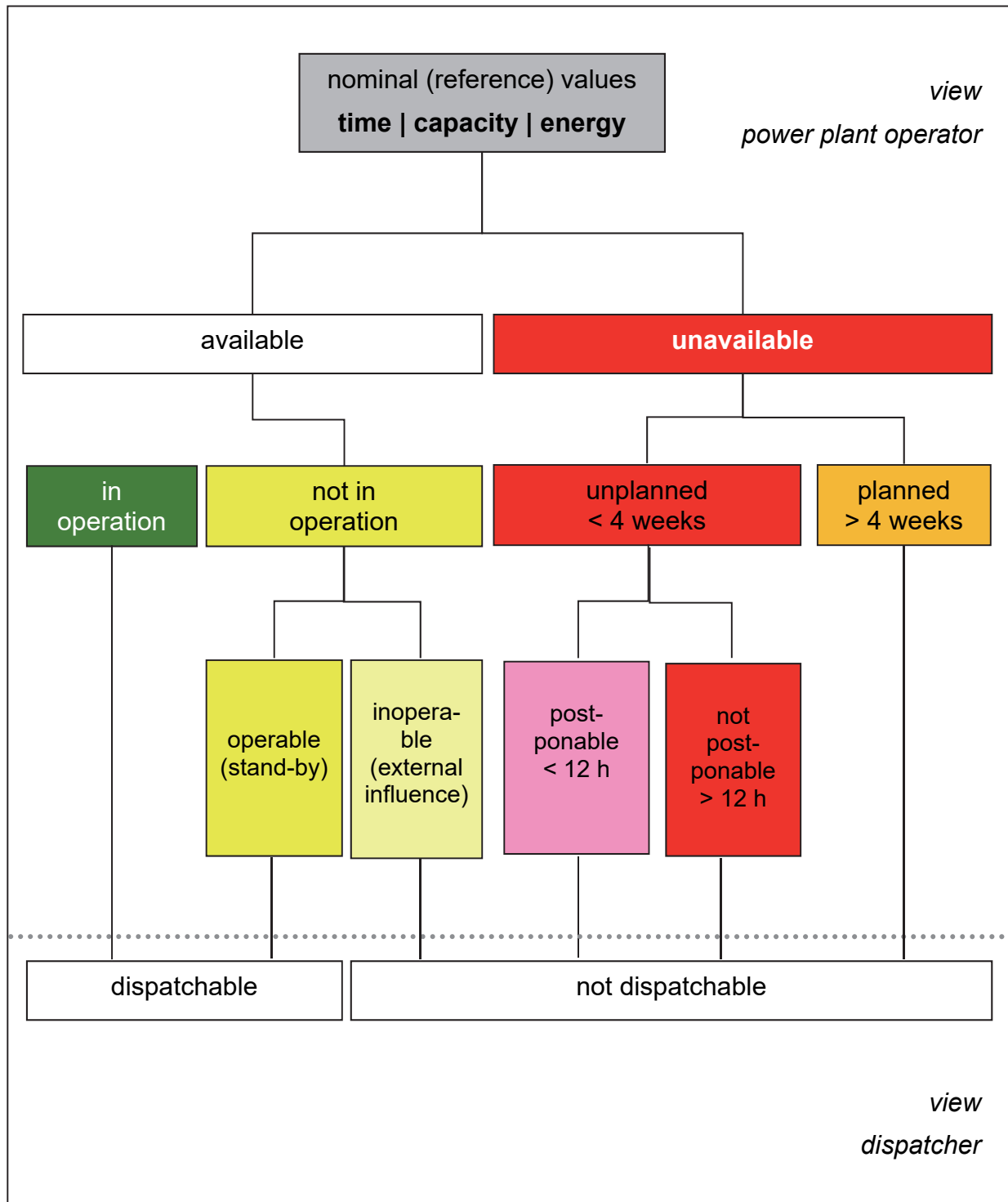


Figure 4: Hierarchy of definitions (survey).

2.2 Hierarchy and relation of definitions

Time Indicators	Capacity Indicators	Energy Indicators
Nominal period t_N	Nominal capacity P_N	Nominal energy W_N $W_N = P_N \cdot t_N$
available time t_v $t_v = t_N - t_{nv}$	available capacity P_v $P_v = P_N - P_{nv}$	available energy W_v $W_v = W_N - W_{nv}$
operating time t_B	operating capacity P_B	operating energy W_B
available time not in operation t_{ng} $t_{ng} = t_v - t_B$ $= t_R + t_{ns}$	available capacity not in operation P_{ng} $P_{ng} = P_v - P_B$ $= P_R + P_{ns}$	available energy not generated W_{ng} $W_{ng} = W_v - W_B$ $= W_R + W_{ns}$
stand-by time t_R $t_R = t_{ng} - t_{ns}$	stand-by capacity P_R $P_R = P_{ng} - P_{ns}$	stand-by energy W_R $W_R = W_N - W_{nv} - W_B - W_{ns}$
available not dispatchable time (external influence time) (external influence time) t_{ns}	available not dispatchable capacity (external influence capacity) (external influence capacity) P_{ns}	unavailable unproduced energy (external influence energy) (external influence energy) $W_{ns} = P_{ns} \cdot t_{ns}$
unavailable time t_{nv} $t_{nv} = t_{nv p} + t_{nv u}$	unavailable capacity P_{nv} $P_{nv} = P_{nv p} + P_{nv u}$	unavailable energy W_{nv} $W_{nv} = W_{nv p} + W_{nv u}$
planned unavailable time $t_{nv p}$	planned unavailable capacity $P_{nv p}$	planned unavailable energy $W_{nv p}$
unplanned unavailable time $t_{nv u}$ $t_{nv u} = t_{nv ud} + t_{nv un}$	unplanned unavailable capacity $P_{nv u}$ $P_{nv u} = P_{nv ud} + P_{nv un}$	unplanned unavailable energy $W_{nv u}$ $W_{nv u} = W_{nv ud} + W_{nv un}$
unplanned postponable unavailability time $t_{nv ud}$	unplanned postponable unavailability capacity $P_{nv ud}$	unplanned postponable unavailability energy $W_{nv ud}$
not postponable unplanned unavailable time $t_{nv un}$	not postponable unplanned unavailable capacity $P_{nv un}$	not postponable unplanned unavailable energy $W_{nv un}$

2.3 Time-related terms

Following time-related definitions (Figure 5) refer exclusively to the states “plant in operation” or “plant out of operation”. During the state “plant in operation” it is unimportant which capacity is in operation.

The reference period can be, as technical point of view, the calendar time (Base) or can be, with a market point of view, the electricity stock exchange time reference (i. e. Peak-time reference).

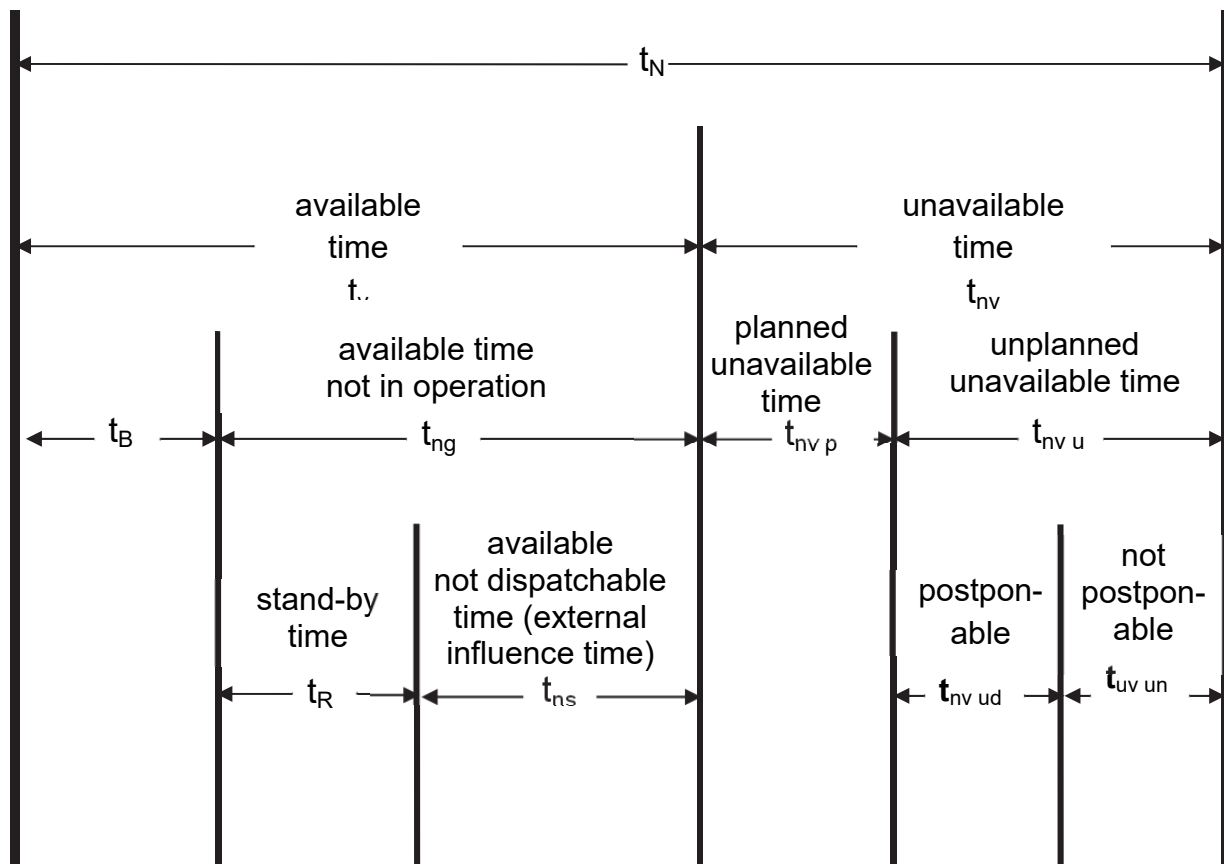


Figure 5: Diagram of time-related terms.

Designation	Symbol	Term definition and description
2.3.1 Begin of data recording		The data recording for availability determinations start-ups with the commissioning of the plant to the responsibility of the operator after the end of trial operation.
2.3.2 End of data recording		The data recording for availability determinations ends with the decommissioning (termination) of the plant.
2.3.3 Reference period	t_N	The reference period is the total recording period without any interruption (calendar time).
2.3.4 Peak times reference period	$t_{N\ Pe}$	The peak-time reference period within the nominal time comprises all exchange-typical peak times (e. g., in Germany: Monday to Friday all hours from 08:00 a.m. 08:00 p.m.; holidays falling on these days are normal work-days).
2.3.5 Available time/Available time during peak-times	t_v	The available time is the period in which a plant converts energy or can convert it independent of the level of the achievable capacity. $t_v = t_N - t_{nv}$
	t_{vPe}	The available time during peak times reduces the time span being considered to the peak hours.

Designation	Symbol	Term definition and description
2.3.6 Operating time	t_B	The operating time is the period in which a plant converts energy. Connecting in parallel is seen as the beginning of the operating time and the separation of the generator from the grid as the end.
2.3.7 Available time not in operation	t_{ng}	<p>The available time not in operation is the period in which a plant is available but not in operation and/or cannot be operated due to external influences.</p> $t_{ng} = t_v - t_B$ $= t_R + t_{ns}$
2.3.7.1 Stand-by time	t_R	<p>The stand-by time is the period in which the plant can be operated but will not be operated.</p> $t_R = t_{ng} - t_{ns}$
2.3.7.2 Available not dispatchable time (external influence time)	t_{ns}	The available dispatchable time is the period in which the plant cannot be operated due to external influences.

Designation	Symbol	Term definition and description
2.3.8 Unavailable time (UA-time)	t_{nv}	<p>The unavailable time is the period in which the plant cannot be operated for reasons, which are inside the plant or which cannot be influenced by the management.</p> <p>The unavailable time is composed of a planned and an unplanned part.</p> $t_{nv} = t_{nv\ p} + t_{nv\ u}$
2.3.8.1 Planned UA-time	$t_{nv\ p}$	<p>The planned unavailable time is the period in which a plant cannot be operated due to a shut-down planned on a long-term basis. The beginning and duration of the shutdown have to be determined more than 4 weeks in advance.</p>
2.3.8.2 Unplanned UA-time	$t_{nv\ u}$	<p>The unplanned unavailable time is the period in which a plant cannot be operated due to an unplanned shutdown, where as the shutdown may not be postponed or only up to 4 weeks.</p> <p>The unplanned unavailable time is divided into a postponable and a not postponable part.</p> $t_{nv\ u} = t_{nv\ ud} + t_{nv\ un}$
2.3.8.3 Postponable unplanned UA-time	$t_{nv\ ud}$	<p>The postponable unplanned unavailable time is that part of unplanned unavailable time which may be postponed from 12 hours up to 4 weeks.</p>
2.3.8.4 Not postponable unplanned UA-time	$t_{nv\ un}$	<p>The not postponable unplanned unavailable time is that part of unplanned unavailable time which may not be postponed or only up to 12 hours.</p>

2.4 Capacity-related terms

The fundamental reference indicator for availability determinations is the nominal capacity. The nominal capacity of a plant is based on a value which is normally set up compulsively for the whole service life and admits load changes very restrictedly.

Designation	Symbol	Term definition and description
2.4.1 Nominal capacity	P_N	<p>The nominal capacity of a plant is the highest continuous capacity on nominal conditions, which is reached by a new plant at commissioning time. This value is binding for the whole service life.</p> <p>Capacity changes are only permitted with essential changes of nominal conditions and with constructive measures in the plant.</p> <p>Until the exact determination of this highest continuous capacity on nominal conditions the ordered value has to be indicated as nominal capacity in accordance with the supply agreements.</p> <p>If the ordered value does not clearly conform to the real approval and operating conditions to be expected, one has to ascertain, until confirmed measuring results are on hand, an average capacity value as nominal capacity in advance. It is to be determined in such a way that additional and reduced generations within an average year are compensated (e. g. due to the cooling water temperature curve, as is shown in Figure 6).</p> <p>The final setting of the nominal capacity of a power plant unit will be made after the commissioning of the plant, normally after the presentation of results from the acceptance measurements. Here it is of special importance that the nominal conditions refer to a year's average value, i.e. that the seasonal influences (e.g. the inlet temperature of cooling water and air), the electric and steam-side auxiliary consumption as well as the capacity factor of the grid are compensated during one regular year and that ideal-typical conditions at the acceptance measurement such as e.g. special steam cycles are converted into normal operating conditions.</p>

Designation	Symbol	Term definition and description
		<p>In contrast to the maximum capacity, the nominal capacity must not be adjusted to a temporary capacity change. It is also not allowed to make a change of the nominal capacity in the case of capacity decreases as a consequence of or for the avoidance of damages. In the same way a decrease of the nominal capacity is not admissible due to ageing, wear or soiling.</p> <p>A change of the nominal capacity may be only made</p> <ul style="list-style-type: none"> – if additional investments, e. g. retrofitting measures improving efficiency, are made with the aim to increase the capacity of the plant, – plant parts are definitely shut down or removed with an intentional acceptance of capacity losses, – due to external influences (Chapter 10) the plant is continuously, i. e. for the rest of its service life, operated outside the design area determined in the supply agreements, – or the plant is only allowed to be operated with a reduced capacity till the end of the service life due to an authoritative direction, even if no technical defect exists.

Designation	Symbol	Term definition and description
2.4.2 Available capacity	P_v	<p>The available capacity is the achievable capacity due to the technical and operational condition of the plant.</p> $P_v = P_N - P_{nv}$
2.4.3 Dispatchable capacity	P_b	<p>The dispatchable capacity is the difference of available capacity and external influence.</p> $P_b = P_v - P_{ns}$ <p>The non dispatchable capacity results in analogy to the UA capacity.</p>
2.4.4 Capacity generated	P_B	<p>The operating capacity gross or net is the capacity operated at the relevant time.</p> <p>The operating capacity can be greater than the nominal capacity, e.g. excess capacity due to good cooling-water conditions (see Figure 6).</p>
2.4.4.1 Gross-(generated-) capacity	$P_{B \text{ br}}$	<p>The gross operating capacity of a plant is the delivered capacity at the terminals of the generator.</p>

Designation	Symbol	Term definition and description
2.4.4.2 Net-(generated-) capacity	$P_{B\ ne}$	<p>The net operating capacity of a plant is the capacity which is delivered to the supply system (transmission and distribution system, consumer) less a possible obtainment of capacity in the operating time. It results alternatively from the gross capacity reduced by the electric auxiliary capacity during the operation.</p> $P_{B\ ne} = P_{B\ br} - P_{Eig\ B}$
2.4.4.3 Auxiliary power capacity	$P_{Eig\ B}$	<p>The operating auxiliary capacity is that electric capacity which is necessary for secondary and auxiliary plant units during the operation of a plant (generator connected to the grid).</p>
2.4.5 Schedule capacity	P_{FP}	<p>The gross or net schedule capacity of an energy conversion facility is the operating capacity that is agreed and preset with the power plant/unit. It is usually measured as average hourly capacity .</p>
2.4.6 Available unproducible capacity	P_{ng}	<p>The available unproducible capacity is that part of available capacity which is ready for operation but will not be used and/or cannot be used due to external influences.</p> $P_{ng} = P_v - P_B$ $= P_R + P_{ns}$
2.4.6.1 Stand-by capacity	P_R	<p>The stand-by capacity is the capacity beyond the operating capacity which may be operated but is not operated by the load dispatcher.</p> $P_R = P_{ng} - P_{ns}$

Designation	Symbol	Term definition and description
2.4.6.2 Available unproducibile capacity (external influences)	P_{ns}	<p>The available unproducibile capacity is the capacity which could be generated by the plant but cannot be used by the load dispatcher because of external influences, i.e. for reasons which are outside the plant.</p> <p>Due to the determination of the nominal capacity as aver-age nominal capacity of a year, one has to take into ac-count that the available indispatchable capacity as remaining link, calculated by</p> $P_{ns} = P_N - P_{nv} - P_B - P_R$ <p>may cause deviations from the exact value for shorter evaluation periods than one regular year. If in special cases the available indispatchable capacity has also to be determined exactly for shorter evaluation periods than one calendar year, the instantaneous values have to be inserted into above correlation.</p>
2.4.7 Unavailable capacity (UA-capacity)	P_{nv}	<p>The unavailable capacity is the not moveable capacity of a plant, which is related to the nominal capacity for reasons which are within the plant or cannot be influenced by the plant management.</p> $P_{nv} = P_N - P_v$ <p>The classification of the UA-capacity into a planned and an unplanned part is carried out according to Figure 4.</p>

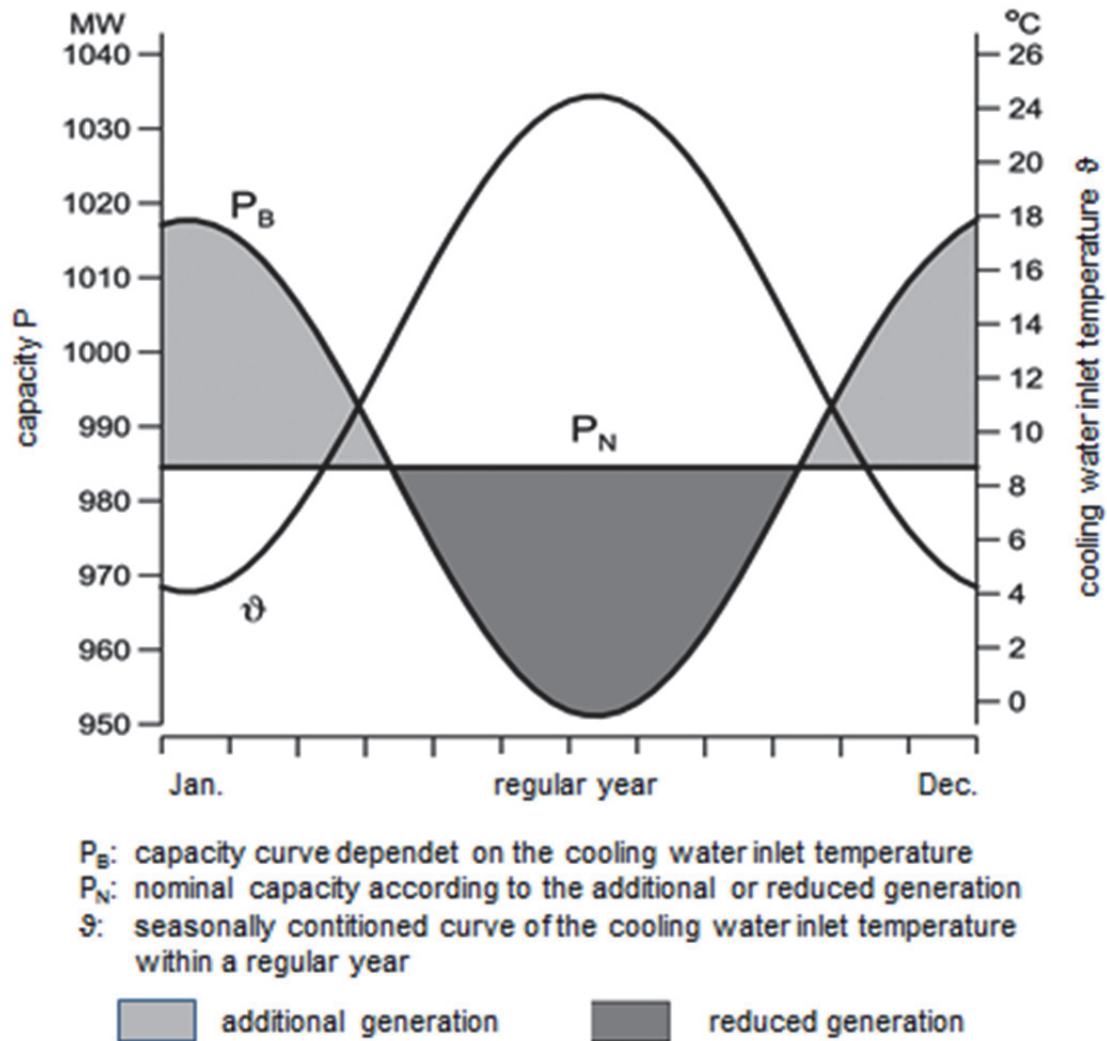


Figure 6: Example for the determination of the nominal capacity due to the correlation between operating capacity and cooling water inlet temperature.

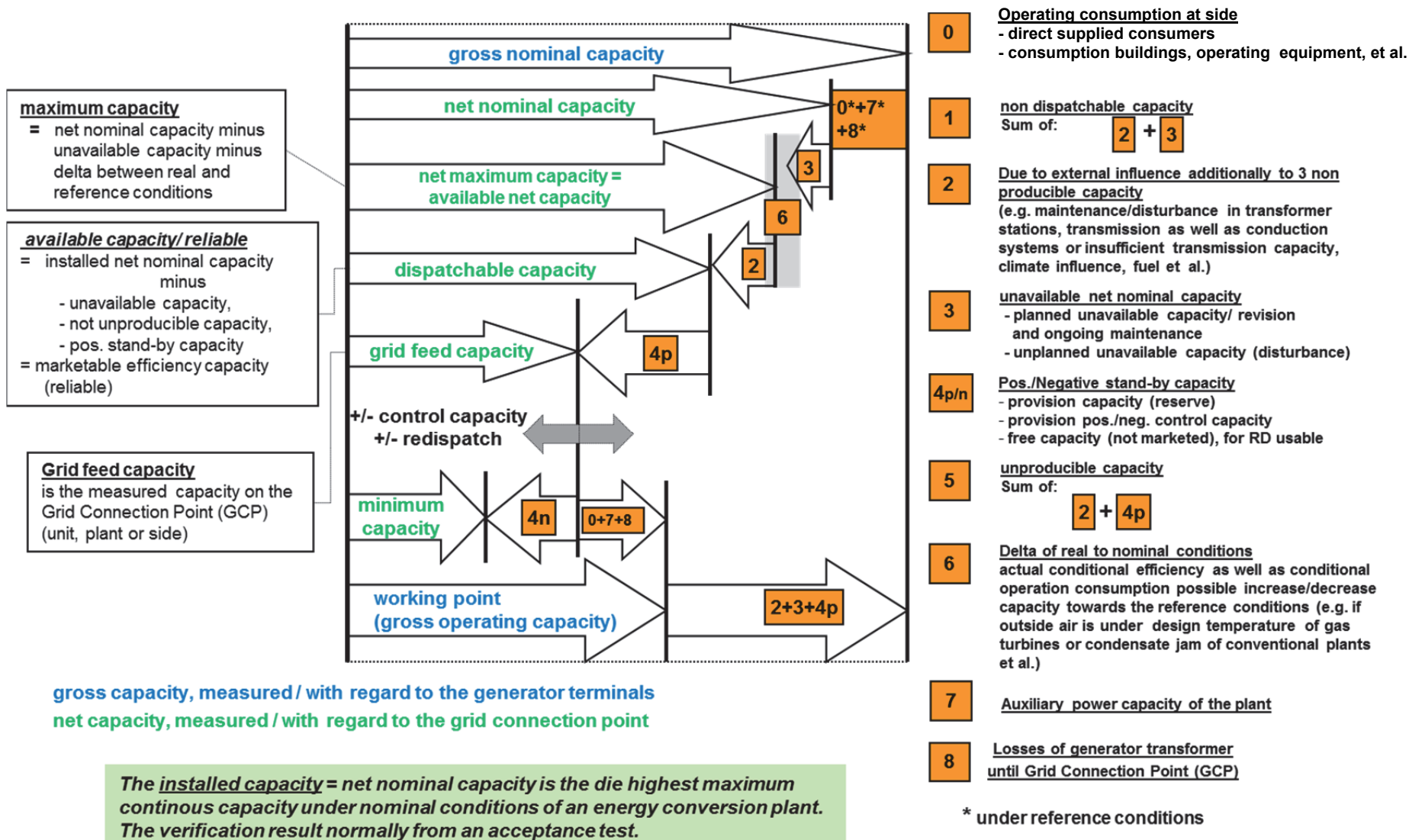
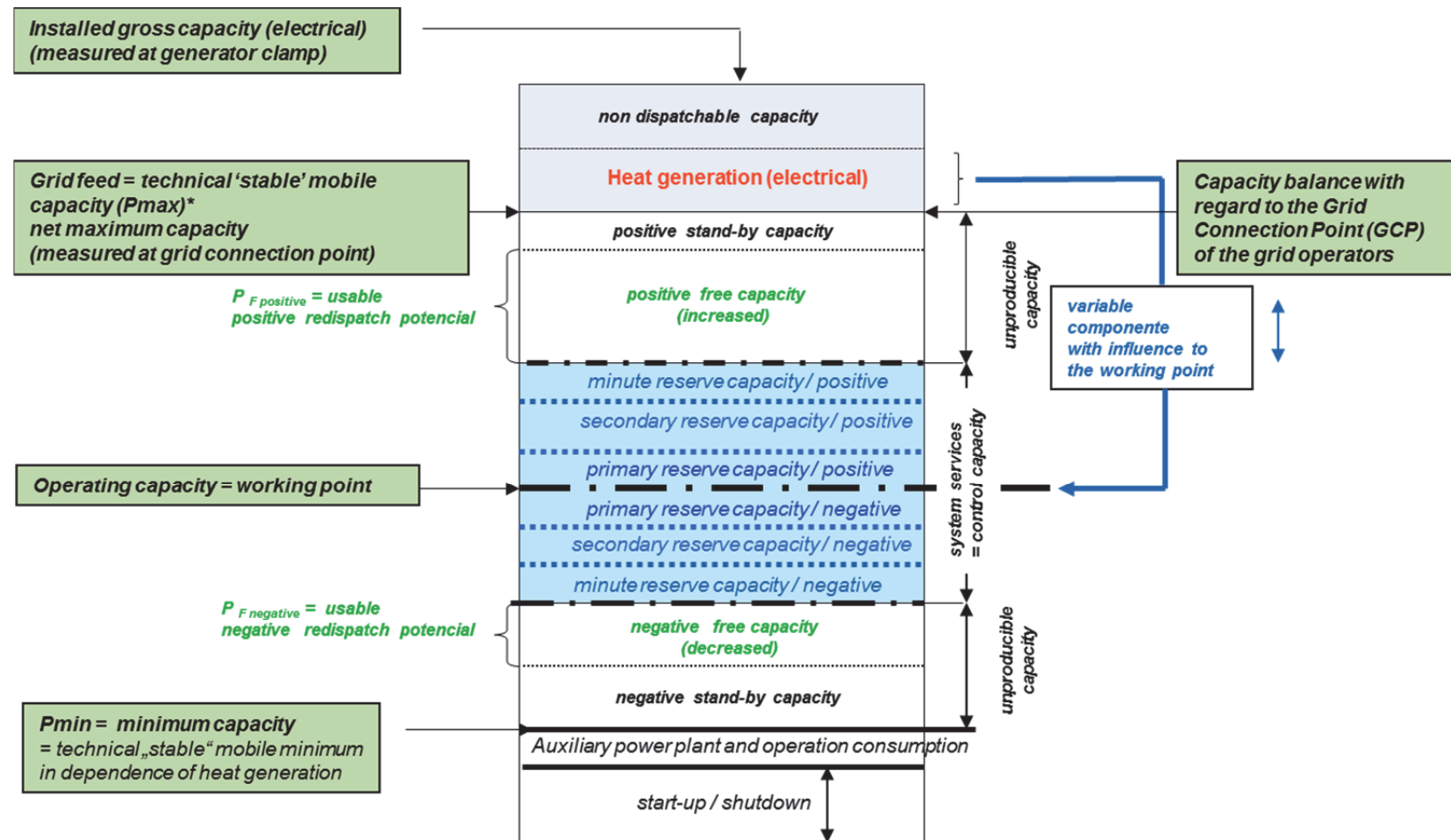


Figure 7: Capacity Terms' of energy conversion plants.



Provision capacity and reserve capacity = stand-by capacity
 * Consideration without increased efficiency range

Figure 8: Terms for energy- and heat operated plants.

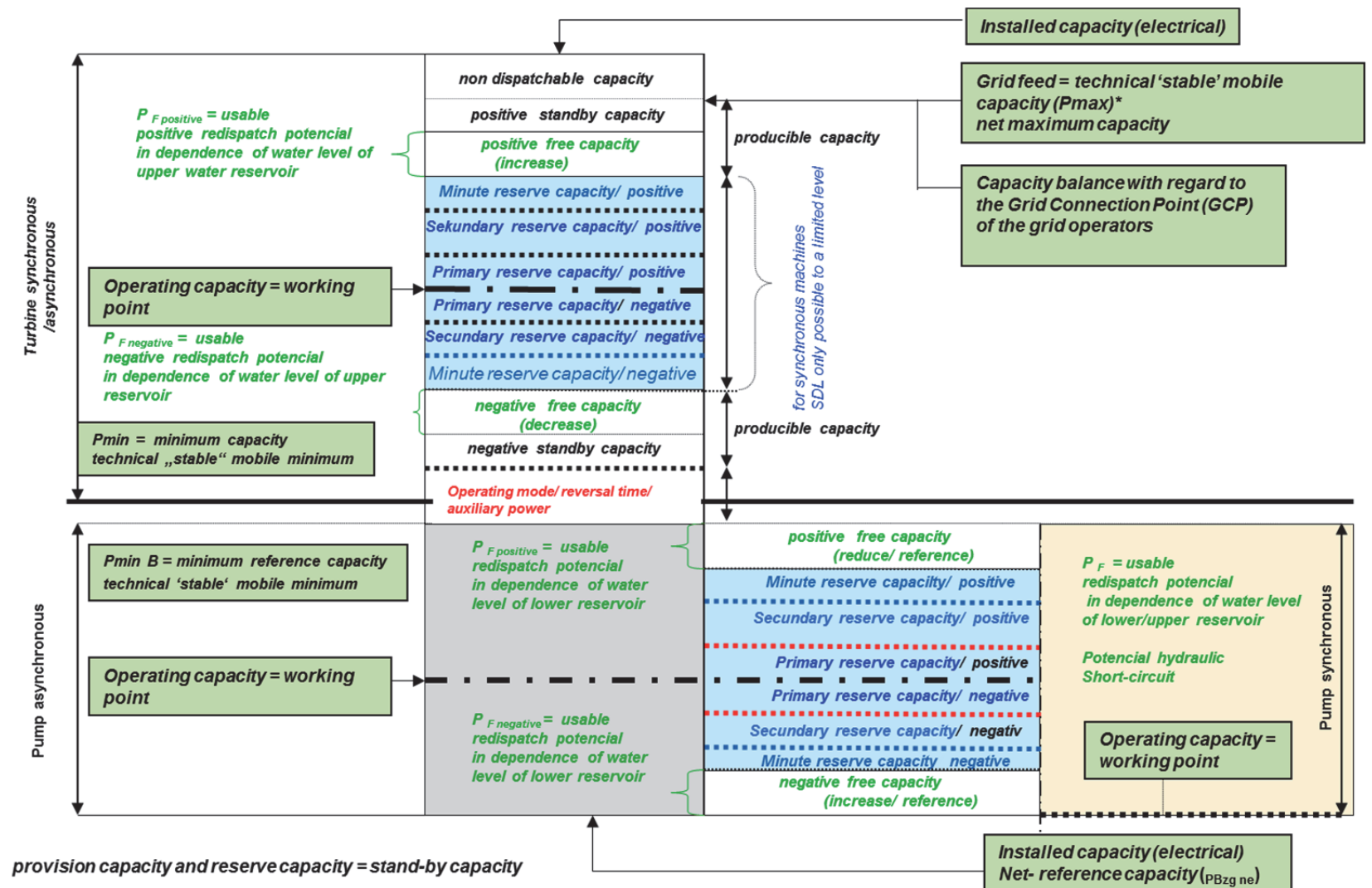
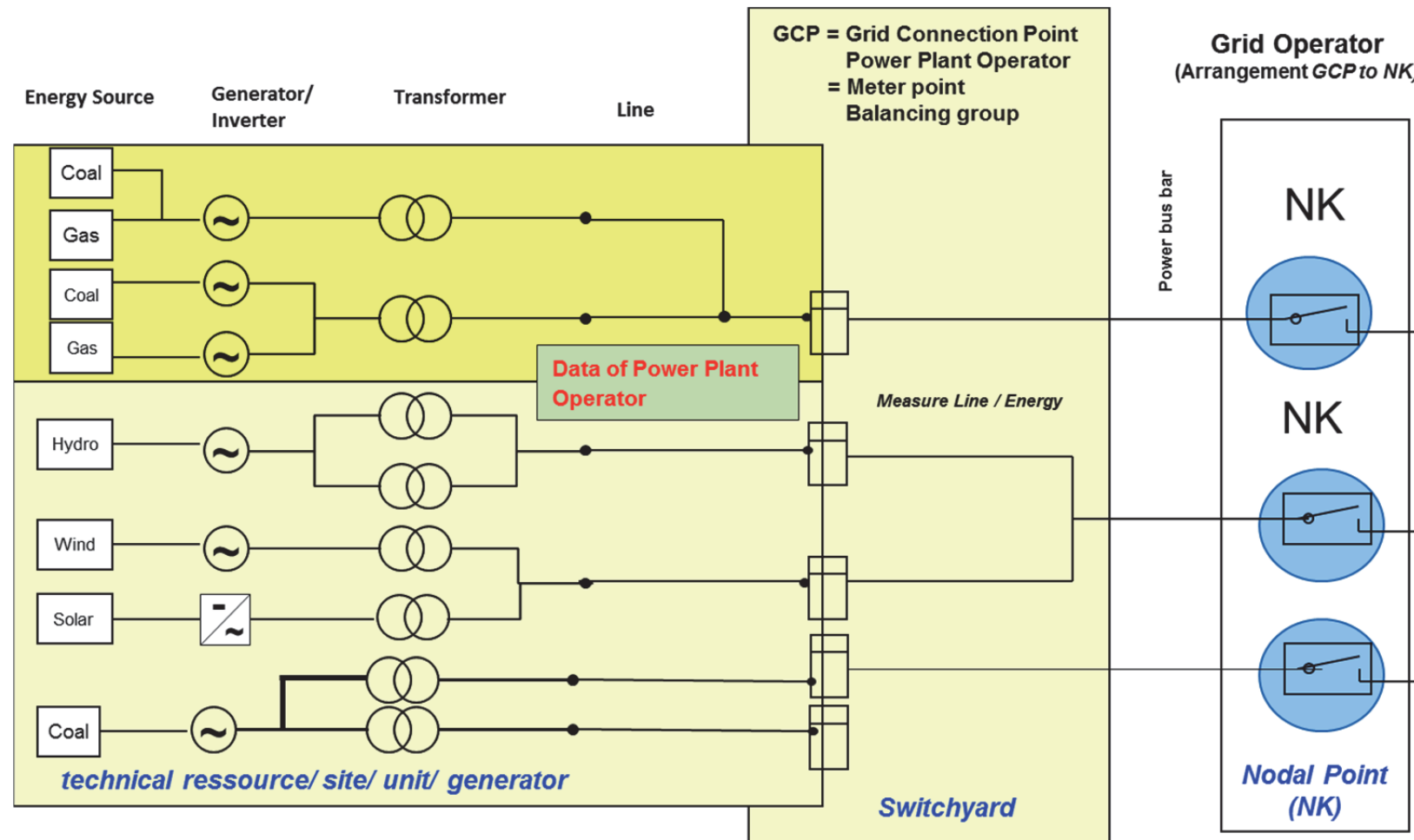


Figure 9: Capacity terms of hydro pumped storage power plant.



The Grid Connection Point (GCP) characterizes the level of physical supply or use of electricity (from effective capacity and control capacity) in or out of the public main grid.
 Several GCP in a location are the sum of the physical supply to the public mains grid or the removal.

Figure 10: Interconnection point in the data exchange between Operator, Grid Operator.

2.5 Energy-related terms

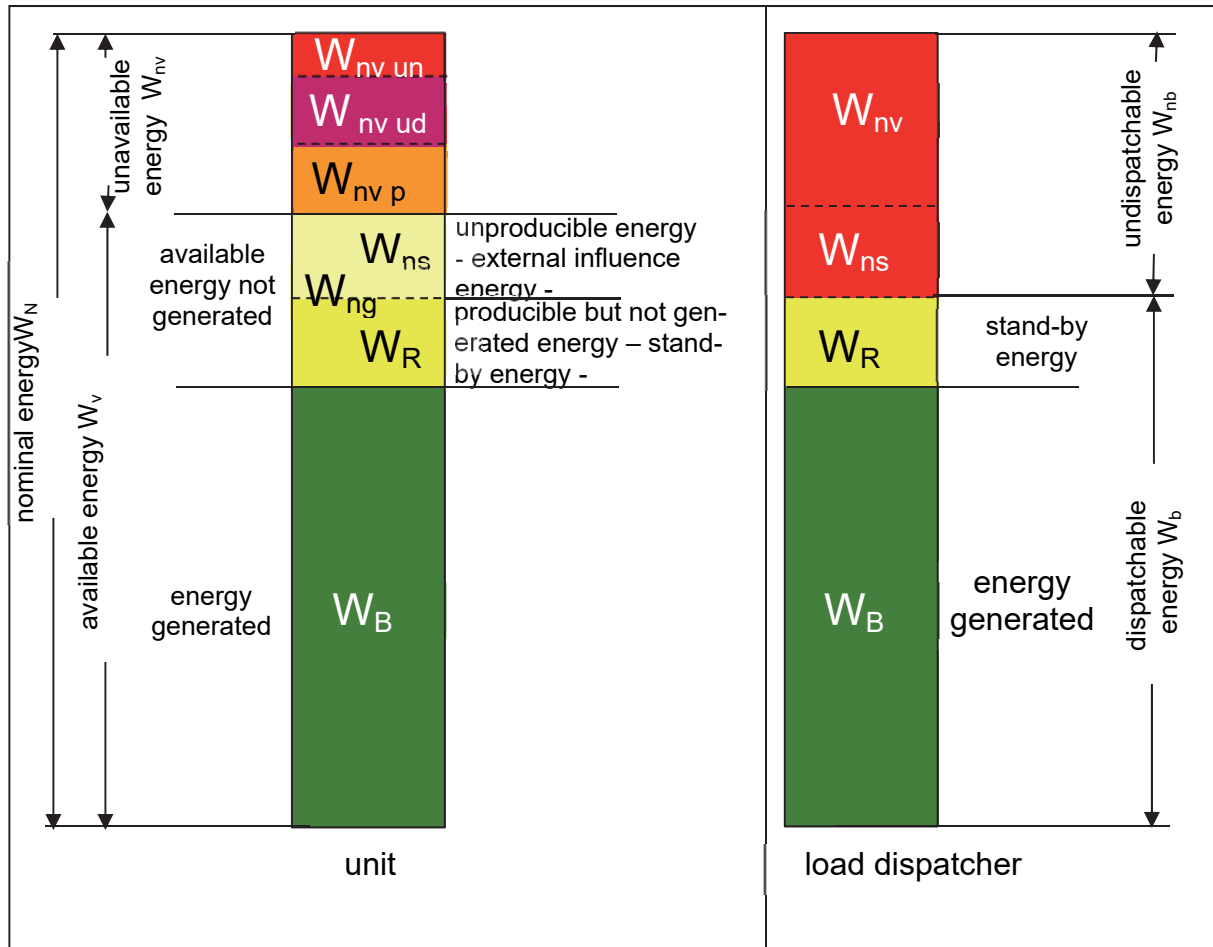


Figure 11: Diagram of energy-related definitions.

Designation	Symbol	Terms of definition and designation
2.5.1 Nominal energy	W_N	The nominal energy is the product of nominal capacity and reference period. $W_N = P_N \cdot t_N$
2.5.2 Nominal energy during peak times	$W_{N\ Pe}$	Nominal energy during peak times is the product of nominal capacity and nominal time limited to the peak times. $W_{N\ Pe} = P_N \cdot t_{N\ Pe}$
2.5.3 Available energy	W_v	The available energy is the energy which can be generated in the reference period due to the technical and operational condition of the plant. $W_v = W_N - W_{nv}$
2.5.4 Available energy during peak times	$W_{v\ Pe}$	The available energy is the producible energy in peak times in view of the plant's technical and operational condition. $W_{v\ Pe} = W_{N\ Pe} - W_{nv\ Pe}$
2.5.5 Dispatchable energy	W_b	The dispatchable energy of a production unit is the sum of generated energy and stand-by energy. $W_b = W_v - W_{ns}$ The non dispatchable energy resulted in analogy to UA-energy.
2.5.6 Generated energy	W_B	The dispatchable energy of a production unit is the sum of generated energy and stand-by energy.
2.5.7 Schedule energy	W_{FP}	The schedule energy is the energy that must be produced on the basis of the schedule set by the dispatcher.

Designation	Symbol	Terms of definition and designation
2.5.8 Available energy not generated	W_{ng}	<p>The available energy not generated is that part of available energy which is not generated and/or cannot be generated due to external influences.</p> $W_{ng} = W_v - W_B$ $= W_R + W_{ns}$
2.5.8.1 Stand-by energy	W_R	The stand-by energy is the energy which may be generated in addition to the energy generated but is not generated.
2.5.8.2 Available unproducible energy (external influence energy)	W_{ns}	The available unproducible energy is the energy which cannot be generated due to external influences, i.e. for reasons which are outside the plant. Pay also attention to the note in Chapter 2.4.6.
2.5.9 Unavailable energy (UA-energy)	W_{nv}	<p>The unavailable energy is the energy which cannot be generated for reasons which are inside the plant or cannot be influenced by the management.</p> <p>The unavailable energy is calculated from the sum of unavailable capacities multiplied by the respective periods:</p> $W_{nv} = \sum (P_{nv} \cdot t)$ <p>The respective period t is not always identical to the unavailable period t_{nv} according to Chapter 2.5.8.</p> <p>The unavailable energy is composed of a planned and an unplanned part.</p> $W_{nv} = W_{nv p} + W_{nv u}$

Designation	Symbol	Terms of definition and designation
2.5.9.1 Planned UA-energy	$W_{nv\ p}$	The planned unavailable energy is that unavailable energy the respective beginning and duration of which have to be determined more than 4 weeks in advance.
2.5.9.2 Unplanned UA-energy	$W_{nv\ u}$	<p>The unplanned unavailable energy is that unavailable energy the beginning of which cannot be postponed or only up to 4 weeks.</p> <p>The unplanned unavailable energy is subdivided into a postponable and a not postponable part.</p> $W_{nv\ u} = W_{nv\ ud} + W_{nv\ un}$
2.5.9.3 Unplanned postponable UA-energy	$W_{nv\ ud}$	The unplanned postponable unavailable energy is that part of unplanned unavailable energy the beginning of which can be postponed more than 12 hours up to 4 weeks.
2.5.9.4 Unplanned not postponable UA-energy	$W_{nv\ un}$	The unplanned not postponable unavailable energy is that part of unplanned unavailable energy the beginning of which cannot be postponed or only up to 12 hours.

Analysis of the unavailability of Power Plants

– Execution Instructions –

B DETERMINATION OF PERFORMANCE INDISCATORS

– Rules and regulations –

3 Plant (Unit) determination

For the comparability of availability results attention is to be paid to the factual delimitations of power plant systems.

In most cases the availability determination is carried out for units. The delimitation of a plant (unit) is made, as far as the grid is concerned, at the high-voltage terminals of the machine transformer and, as far as the fuel is concerned, at the commissioning point to the power plant.

If several units have a joint equipment, e.g. a joint fuel supply, a joint chimney, a joint flue gas cleaning one has to consider that the unavailabilities of this joint equipment are added to each respective unit.

For plants with combined generation of Heat and Power (CHP) the delimitation for the heat generation is normally the commissioning point.

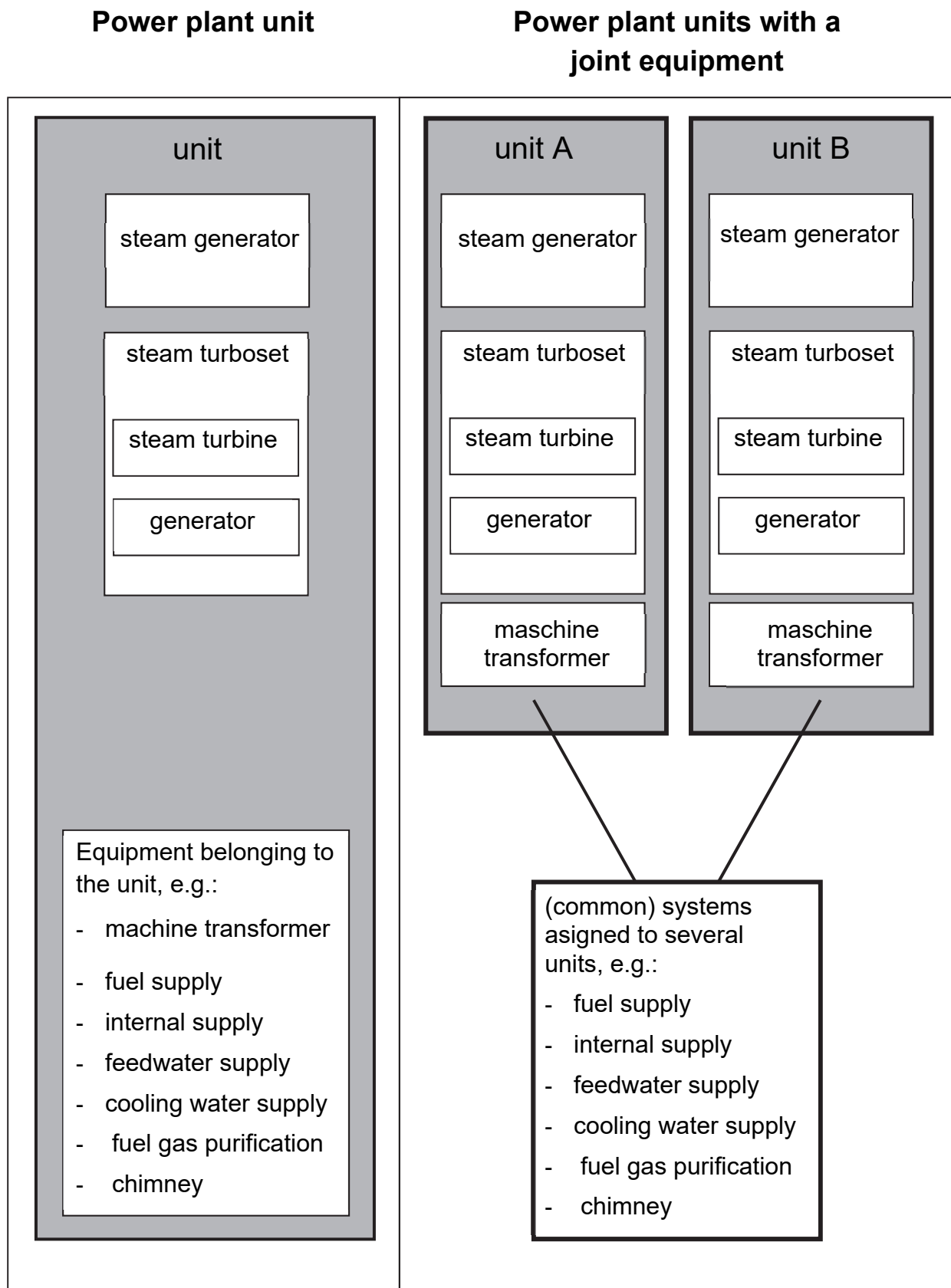


Figure 12: Factual delimitation of power plant systems.

4 Principles and hierarchy of events

It is important to notice that the unavailability has basically to be referred to the nominal capacity.

The allocation made for an unavailability into

- planned
- unplanned postponable
- unplanned not postponable

continues for the whole duration of the unavailability, (exception see Chapter 13.5).

Hierarchy of events

If there are, at the same time, several reasons for a shutdown or a capacity decrease of a plant (Figure 13 to Figure 16) following order of priority applies to the evaluation:

- 1. unavailability planned**
- 2. unavailability unplanned**
- 3. external influence**
- 4. stand-by**

If there are at the same time an unavailability and an external influence or a stand-by, it is necessary to determine the available energy, as if external influence and stand-by respectively did not exist (Figure 15 and Figure 16).

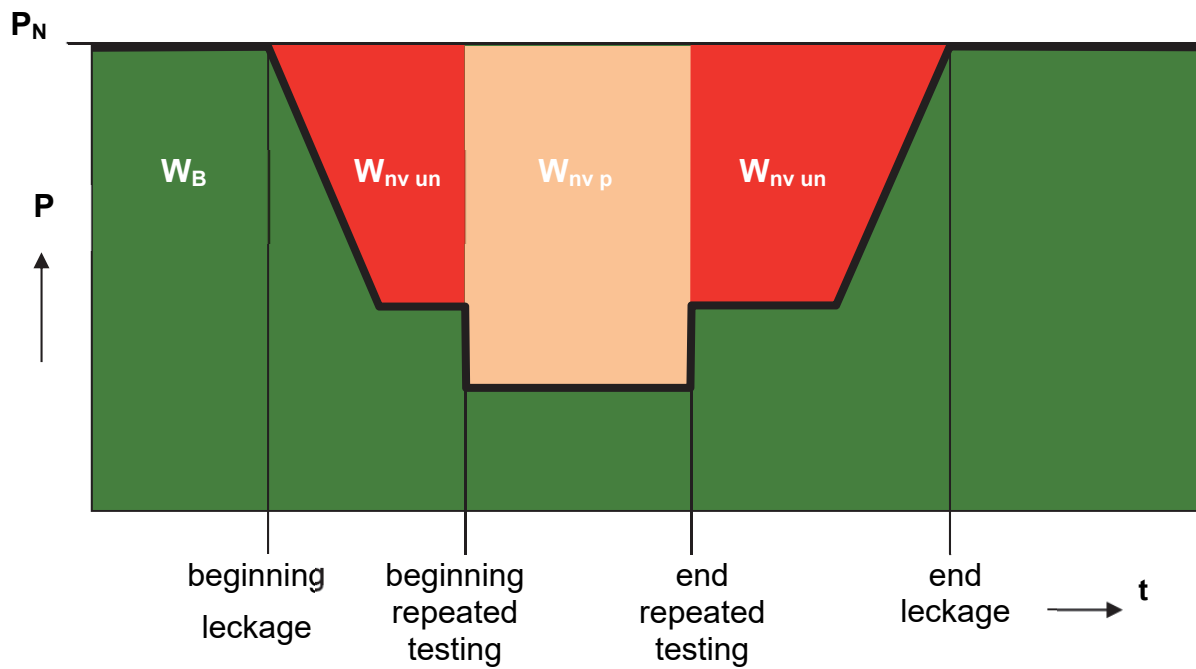


Figure 13: Example for the determination of the unavailability with the simultaneous presence of a planned (e. g. repeated testing) and an unplanned partial unavailability (e. g. leakage).

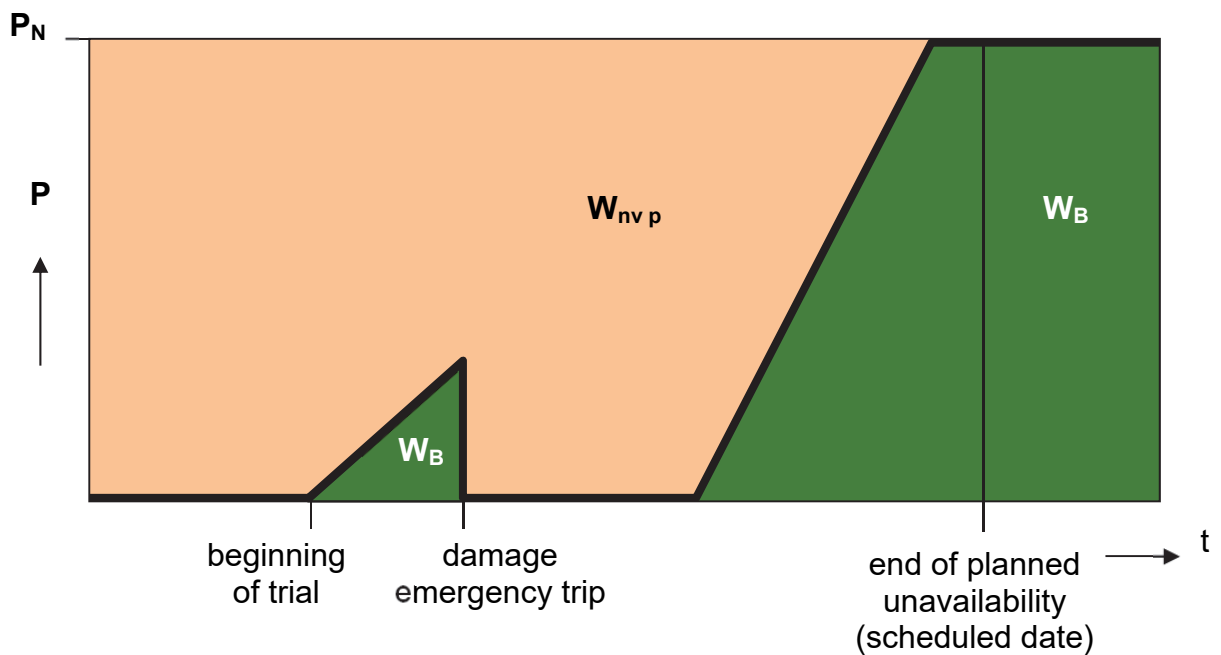


Figure 14: Example for the determination of the unavailability with the simultaneous presence of a planned unavailability (e.g. revision) and an unplanned event (e. g. turbine emergency trip).

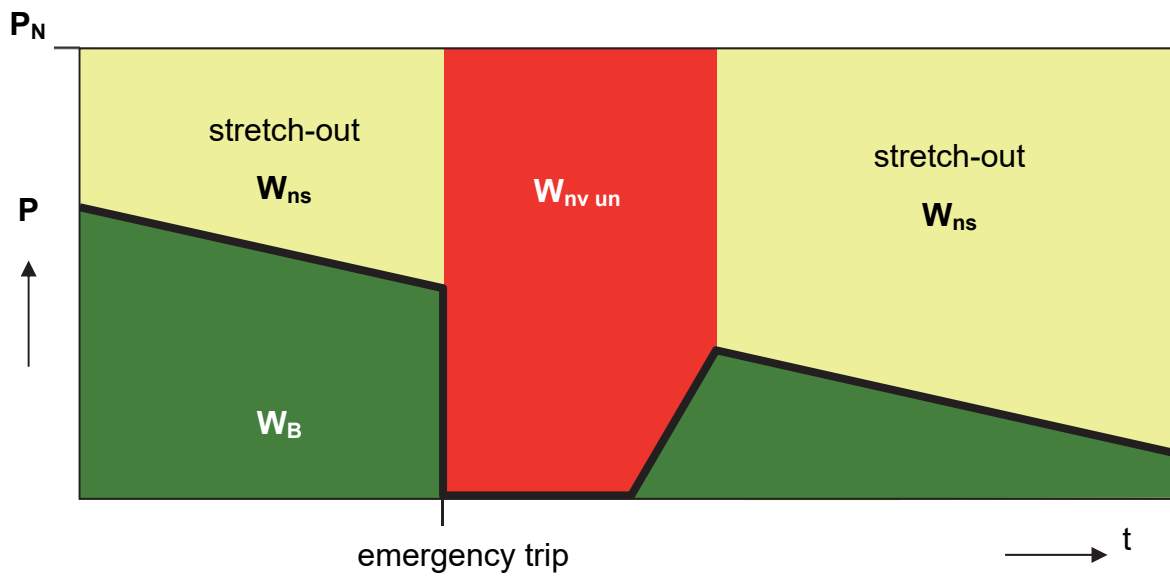


Figure 15: Example for the determination of the unavailability with the simultaneous presence of an unplanned unavailability (e. g. turbine emergency trip) and an external influence (e.g. stretch-out-operation with nuclear power plants)

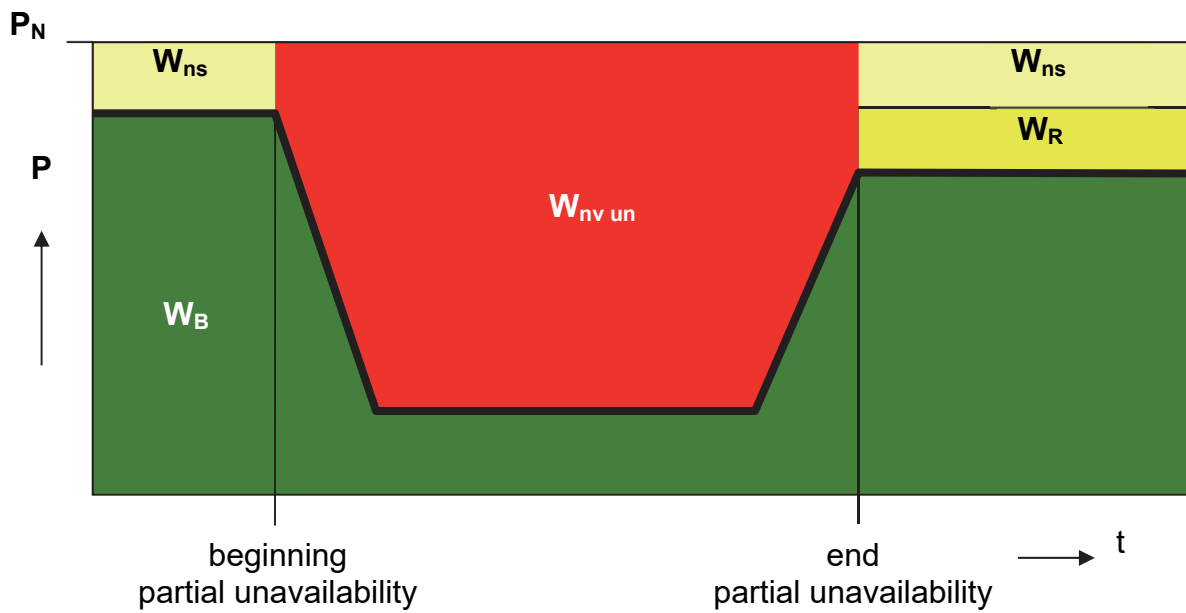


Figure 16: Example for the determination of the unavailability with the simultaneous presence of an unplanned partial unavailability (e. g. feed water pump failure), an external influence (e. g. cooling water temperature beyond design) and a stand-by (e. g. lack of load).

5 Capacity fluctuations by different temperatures of cooling water and air

The capacity fluctuations which result from seasonally caused different cooling water inlet temperatures at the condenser and/or air inlet temperatures with gas turbines form the basis of the nominal capacity definition, see Figure 6.

Reduced capacities within the fluctuation range, e.g. during the summer months, are thus, according to the definition, no unavailable capacities and even no external influence capacities.

6 Excess energy

According to the definition excess energies (energies above the nominal capacity) are not considered when determining the energy availability.

So values of > 1 and/or $> 100 \%$ are not possible.

In contrast to the energy availability are excess energies included into the consideration for the energy utilization, so that values of > 1 and/or $> 100 \%$ are possible.

Unavailable energy above the nominal capacity is basically not taken into consideration.

7 Market assessed supply reliability

The market assessed supply reliability is a financial approach to benchmark the economical operation of a power unit in the market. Considering both the deviation between operational and scheduled work in a time slice, and the assessment of the deviation with the profit margin (market price, e.g. EEX in Germany, reduced by the specific variable costs) concerning to this time slice it is possible to decide, whether a power unit has been dis-patched economically or not.

Looking at the specific variable costs at least the fuel costs should be considered (including the greenhouse gas costs for conventional power plants).

The schedule (power plant schedule) is obligatory for the supply of electrical capacity and electrical work in a time slice (e.g. 15 minutes).

8 Exceeding and falling below planned unavailabilities

8.1 General

According to Chapter 2, a planned unavailability ends at that time (scheduled date) which was fixed at least 4 weeks before the beginning of the unavailability. This date may be fallen below or exceeded (extension, see Chapter 1).

In case of falling below the planned unavailability ends in time with the grid synchronization, with regard to the capacity it ends when the required capacity has been reached (see Figure 14).

If a trial/test operation is carried out before the end of the planned unavailability (scheduled date), which will be interrupted due to a malfunction or a damage, the assignment of the unavailability continues corresponding to the hierarchy of event (see Chapter 1).

8.2 Extension

Any exceeding of the target date of a planned unavailability is an extension and must be recorded separately. Reasons for an extension may be both planned and unplanned.

An extension is planned, when it is determined at least 4 weeks before the target date. As with the planned unavailability, the duration, i. e. the new target date, has also to be determined with the planned extension. All other extensions are not postponable unplanned unavailabilities (see Figure 17).

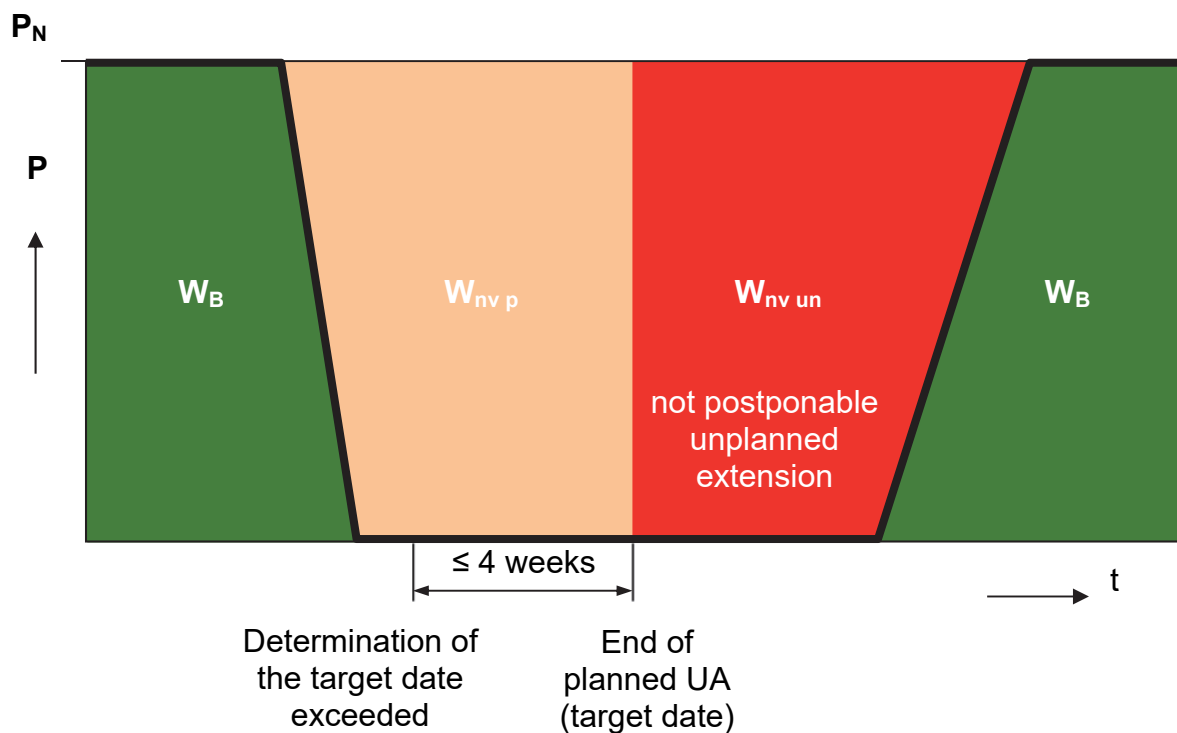


Figure 17: Extension of a planned unavailability due to a damage.

9 Retrofitting measures (Retrofit)

Shutdowns due to retrofitting or improvement do not interrupt the data recording for the availability determination.

10 External influences

External influences are defined as external events, which occur to a power plant or unit, affecting the capacity or dispatchability but not the availability. These events (i. e. climate, regulatory rules) cannot be affected by the power plant management.

10.1 Capacity restrictions by external influences

Capacity restrictions of a plant due to external influences which cannot be affected by the management or when just a little, do not decrease the availability. **These capacity restrictions by external influences are defined as available indispatchable capacity, as far as the reason for the capacity losses are substantiated by following listed or comparative events and these do not lead to a technical damage or a malfunction in the plant.**

10.1.1 Fuel

- fuel shortage (e. g. supply difficulties, icing)
- fuel quality (outside the design band)
- stretch-out-/stretch-in-phases in nuclear power plants
- reduced capacity by fuel limitation.

Fuel related reductions in capacity may be caused by management decisions according to commercial reasons. Therefore those are not external influences.

10.1.2 Mothballing of the plant

Shutdowns in connection with preservation measures, e.g. preparing the plant as a cold stand-by capacity, are also considered as external influences, as far as the plant otherwise is fully technically available.

Availability statistics can be falsified by the cold stand-by of a power plant (100 % available according to external influences), especially when the power plant stays on cold preservation for a long time. For statistical evaluations the situation of cold stand-by must be taken into account by diminishing of the reference period. The reference period begins with the first new start-up announcement of the power plant after a mothballing period and ends if the plant must be preserved once more again.

In Germany this concerns, for example, capacity and climate reserve (as of 2015). The non dispatchable energy of a correspondingly conserved plant is to be carried out as external influence.

This means that these undisturbed plants have a technical availability of 100 %, although they are not available for the commercial market. Independent of this, all incidents are to be reported to VGB until the final decommissioning.

These plants are managed separately by the VGB and do not enter into the standard evaluation from the year after the conservation, but are still part of the years of technical-scientific reports.

10.1.3 Climate

- water shortage due to e.g. icing, ice floes, screenings, high/low water, infiltration of fish etc.
- temperature of cooling water and air (outside the design band, and approved values of the plant respectively), see Chapter 5.
- smog, emissions into the surroundings of the plant
- Power limitation due to extraordinary external influences

10.1.4 Grid related restrictions

The delimitation of the plant on the grid side is at the high-voltage terminals of the machine transformer.

All results which lead to an impairment of the energy leakage into lines, coupling parts etc., are to be assessed as outside influence.

All events causing a disturbance of the energy transmission concerning the grid lines or electric coupler system, etc., are considered as external influence:

- The measures which do not permit the transfer and the release of the energy when they are out of the responsibility of the plant operator. (e.g. maintenance work/disturbances in the transformer stations or in high voltage lines which do not permit the transmission capacity).
- The measures to the security or to the reliability of the electricity supply system, which are ordered by the grid operator.

Note:

A start-up based on a redispatch command from the grid operator is neither an unavailability nor a technical performance restriction and therefore also not part of the UA-/AV-statistics.

10.1.5 Shortage of personnel

Missing stand-by ability due to a reduction of the shift personnel in certain low load periods for economic reasons, e.g. shutdowns during the weekend.

10.1.6 Other matters

- Strike, siege, occupation, terror assault, shipping and flying accident, earthquake, force majeure
- Open day
- No safety authorities permission for restart of an available Nuclear Power Plant
- Missing environmental certificates
- Forced restrictions of the authorities for operation

Plants that temporarily or permanently provide steam or heat must be handled as described in the following chapter for cogeneration plants. The change in the type of energy conversion from energy to steam or heat or vice versa does not have any external influence.

Note:

If the concerned plant is considered as a pure electricity generation plant, a conversion of the steam/heat quantity into the equivalent electrical energy is to be carried out.

11 Combined heat and power generating plants (CHP)

Availability determinations of plants with co-generation are only useful when they facilitate an evaluation of the total plant, i.e. when they are performed including the heat generation.

This requires the definition of the total capacity, i.e. of the nominal capacity of the co-generation plant. Three cases are possible:

Case (a): The electrical capacity corresponds to the total capacity

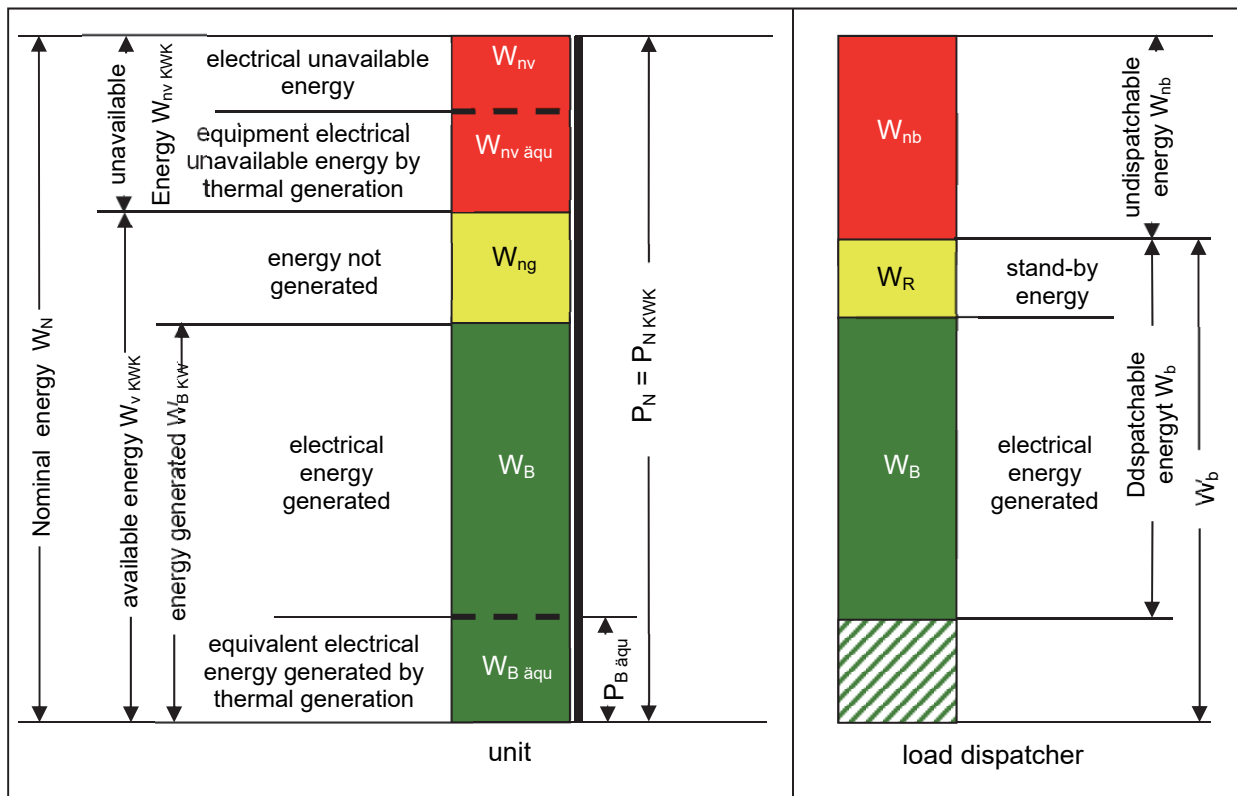


Figure 18: Co-Generation plant (CHP) with an extraction condensing turbine, case a.

Case (b): The electrical capacity and the thermal capacity add up to the total capacity

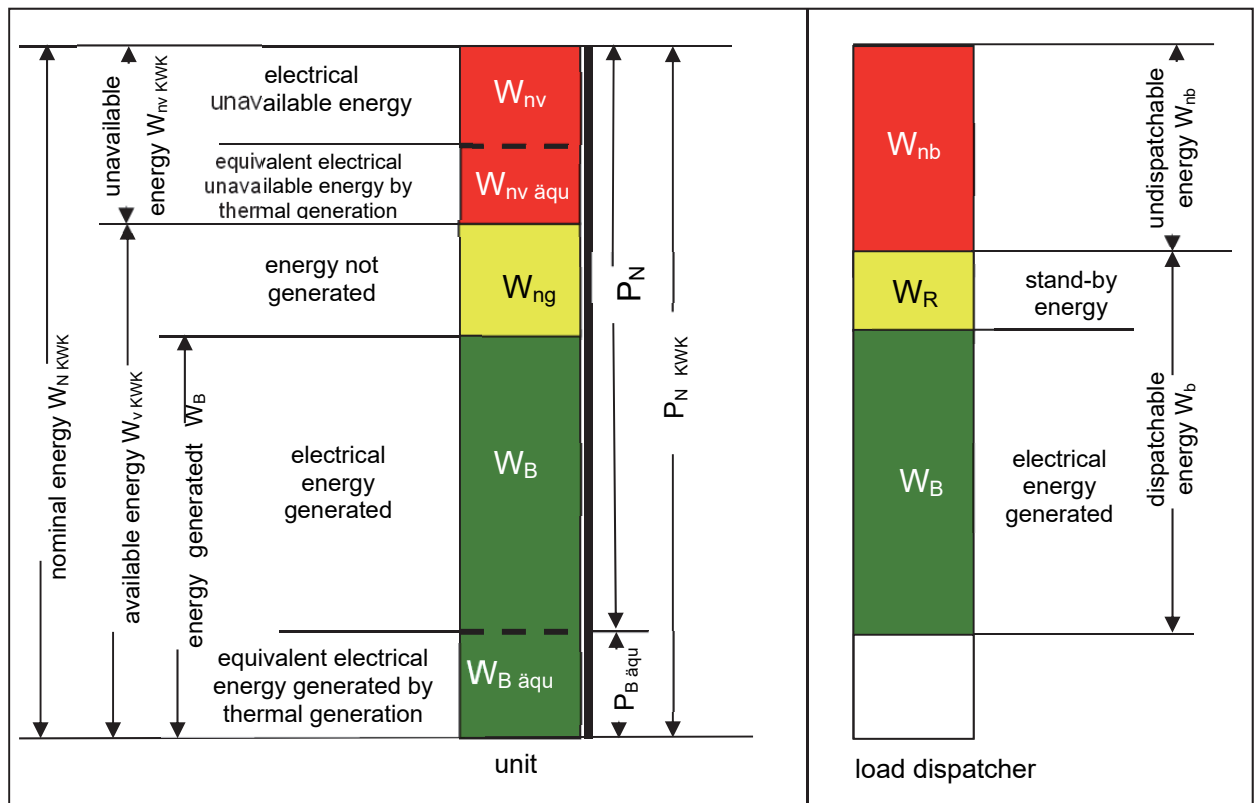


Figure 19: Co-generation plant (CHP) with an extraction condensing turbine, case b.

Case (c): The electrical and the thermal capacity intersect in one partial area, i. e. the sum of both is higher than the total capacity

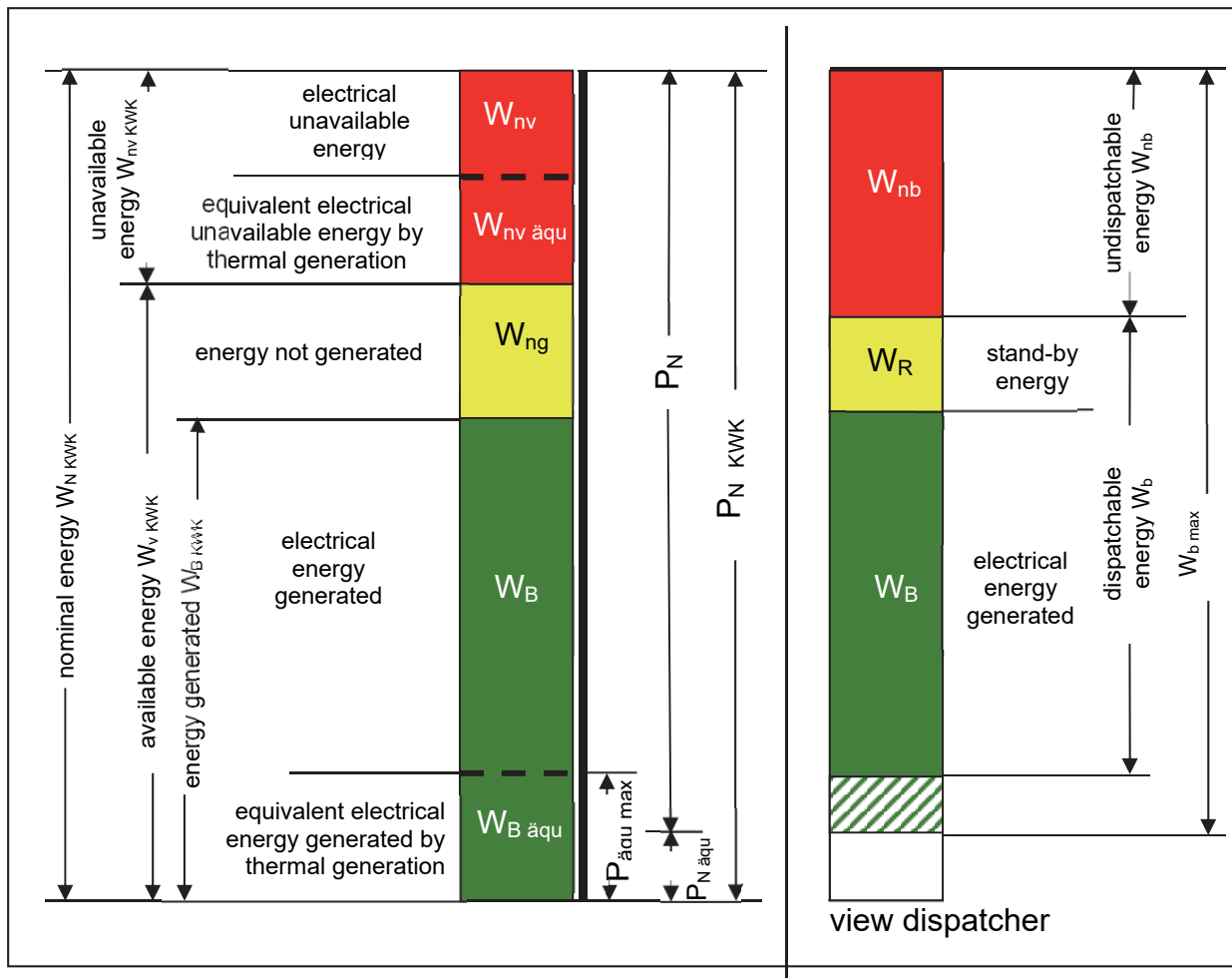


Figure 20: Co-generation plant (CHP) with an extraction condensing turbine, case c.

11.1 Nominal capacity and nominal energy from co-generation plants

When defining the total capacity of the co-generation plant $P_{N\text{ CHP}}$ one always has to proceed from the highest electrical permanent capacity (nominal capacity P_N according to Chapter 2.4.1). In case b) and c) this must be complemented by the thermal capacity which goes beyond P_N , expressed in an equivalent electrical capacity $P_{N\text{ equ}}$.

$$P_{N\text{ KWK}} = P_N + P_{N\text{ equ}}$$

$P_{N\text{ KWK}}$: nominal capacity of the co-generation plant

P_N : highest electrical permanent capacity

$P_{N\text{ equ}}$: equivalent electrical capacity of the thermal generation, which goes beyond P_N

The nominal capacity $P_{N\text{ CHP}}$ has to be defined at commissioning. Changes of capacity are permitted only with essential changes of the nominal conditions (e. g. remaining changes of the heat acceptance conditions) and with constructive measures at the plant.

According to that the nominal energy of a co-generation plant is.

$$W_{N\text{ KWK}} = W_N + W_{N\text{ equ}}$$

$W_{N\text{ KWK}}$: nominal energy of the co-generation plant

W_N : electrical nominal energy (see Chapter 2.5.1)

$W_{N\text{ equ}}$: equivalent electrical nominal energy through thermal generation, which goes beyond W_N

11.2 Equivalent electrical energy through thermal generation

The equivalent electrical energy is the product of the steam quantity and the specific energy of the steam dependent on the steam condition. This corresponds to the energy which could be generated in the turbine unit by an extraction steam quantity.

$$W_{\text{equ}} = \sum_i (D_i \cdot a_i)$$

W_{equ} : equivalent electrical energy through thermal generation

D : extraction steam quantity in t

i : extraction point

a : specific energy in kWh/t

11.3 Energy availability

$$k_W = \frac{W_{\text{N KWK}} - W_{\text{nv KWK}}}{W_{\text{N KWK}}} \quad \text{mit} \quad W_{\text{nv KWK}} = W_{\text{nv}} + W_{\text{nv equ}}$$

W_{nv} : unavailable electrical energy (see Chapter 2.5.9)

$W_{\text{nv equ}}$: equivalent unavailable electrical energy through thermal generation

11.4 Energy utilization

$$n_W = \frac{W_{\text{B KWK}}}{W_{\text{N KWK}}} = \frac{W_{\text{B}} + W_{\text{Bequ}}}{W_{\text{N KWK}}}$$

$W_{\text{B KWK}}$: generated energy of the co-generation plant

W_{B} : electrical energy generated (see Chapter 2.5.6)

W_{Bequ} : equivalent electrical energy generated through thermal generation

12 Successful start-up rate

The successful start-up rate is the ratio of the number of successful start-ups to the number of total requested start-ups over a given period of time. (see Chapter 1.3.3).

A start-up is technically considered as a successful start-up, when the connection of the unit to the grid (closing the line circuit breaker) succeeds and stays in a stable state:

For the determination of the successful start-up rate, it is important to take into account just the start-ups arising when the unit is considered available. All start-ups during maintenance phases or test-start are not taken into account in the determination of this indicator.

A successful start-up is one which, with the respect to the start-up requested, corresponds to the exact level of power and the exact timing specified in the scheduled drafted by the grid administrator. A tolerance of $\pm \frac{1}{4}$ hour is granted and the connection must be maintained at least $\frac{1}{2}$ hour at a stable level.

For gas turbines and all emergency units those conditions are stronger: The unit must be connected at least 10 minutes after the start-up order has been received by the load dispatcher.

13 Special regulations

13.1 Measures in available plants

Measures in an available but not operated plant, which take no more than 30 minutes, do not reduce the availability.

Measures which take more than 30 minutes are unavailabilities, even when the operations can be interrupted at any time and the plant can be started in its usual start-up period.

A disregarding of this rule would result in inadmissible distortions of the availabilities.

13.2 Failure of flue gas cleaning

Basically any capacity restriction of the unit caused by the flue gas cleaning plant is unavailability.

According to each country specifications for pollution control (e.g. 13. BImSchV in Germany) it may be allowed to continue the operation of a boiler and thus the power plant unit even in case of the flue gas desulphurization plant failure when the failure period does not exceed a fixed period of hours per year.

The same special regulations may be applied to DeNOx plants.

13.3 Nuclear power plants

The regulations are apply in conformity with the operation manual at start-ups due to fuel saving program.

In adaptation to the availability determination of WANO [5] capacity restrictions by Stretch-in/stretch-out have been defined for nuclear power plants since January 1, 1991 as an available undispatchable capacity (external influence capacity), as far as there does not exist an unavailability at the same time (Chapter 4 and Figure 15).

According to the instruction manual those regulations set up in Chapter 4 and Figure 15 are valid with start-ups after a fuel-saving program.

13.4 Missing operating permit

Shutdowns and operating mode with reduced capacity respectively are, due to a missing/cancelled operating permit, unavailabilities only when there are technical defects within the plant.

If assumed technical and/or organizational defects are not confirmed and if inspections or tests have not been executed to prove this, these events are to be evaluated retroactively as available undispatchable capacity/unproducible energy due to external influences.

If inspections and tests were required to prove the technically perfect condition of the plant, it is allowed only to consider the period after the end of inspections/tests until the re-granting of the operating permit to determine the available undispatchable capacity/unproducible energy due to external influences.

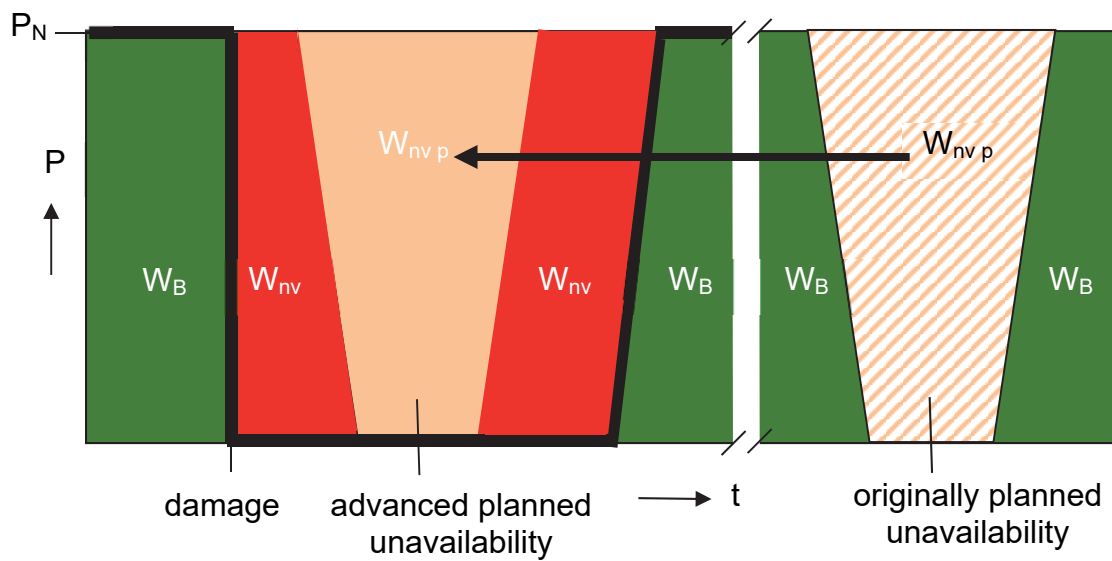


Figure 21: Advancing of a planned unavailability on the occasion of a damage.

13.5 Advancing of planned unavailabilities

On the occasion of an unplanned unavailability one advances an unavailability which is planned for a later time.

In contrast to the original assignment (see Chapter 4) the unavailability has to be assessed as planned from the beginning of the advanced unavailability for the original duration (scheduled value) (Figure 21). This is also true when the planned unavailability is advanced for economic reasons, as far as it is possible to prove that there are no operational and/or safety-related reasons for advancing.

14 Data recording

14.1 Use of gross or net values

For the determination of availability one can calculate with gross or net values. By restricting the energy generated to the operating time of the unit (connected to the grid) one avoids a negative capacity/energy when using the net capacity for the determination of the energy generated (e.g. with reference to the shutdown auxiliary consumption from the grid).

Small differences result from e.g. the conversion from non-electrical drives to electrical drives and other changes in the electrical auxiliary consumption (see Chapter 11.2).

15 Calculation of average values

Beside uniform definitions and determination methods, also definite and uniform regulations are necessary to compare availability considerations. The following sections show how the average values are to be formed for one or several calendar or operating years.

15.1 Fundamentals

It is valid for the following formulas and figures:

$i = 1, 2, \dots, I$ plant numbering

$j = 2002, 2003, \dots, J$ calendar years, e.g. 2002, 2003

$m = 0, 1, 2, \dots, M$ operating years of the plants

- The calendar year in which commercial operation began is the operating year zero ($m = 0$).
- One operating year corresponds to one calendar year (January 1 to December 31).

Exceptions usually are the years of the beginning of the commercial operation and of the decommissioning.

t_N reference period (see Chapter 2.3.3), corresponds to the number of hours of the considered calendar year:

normal year $t_N = 8,760 \text{ h}$

leap year $t_N = 8,784 \text{ h}$

15.2 Average value for several plants for one calendar year or one operating year

The different average value calculations can be seen in the following matrix, e. g. for the available energy W_v :

	Year of commercial operation of unit 1 (m=0) j=2002	j=2003	Year of commercial operation of unit 2 (m=0) j=2004	Year of commercial operation of unit 3+4 (m=0) j=2005	j=2006	...	j=J
unit 1 (i=1)	$W_{v,1}$ (m=0)	$W_{v,1}$ (m=1)	$W_{v,1}$ (m=2)	$W_{v,1}$ (m=3)	$W_{v,1}$ (m=4)		$W_{v,1}$ (m=M)
unit 2 (i=2)			$W_{v,2}$ (m=0)	$W_{v,2}$ (m=1)	$W_{v,2}$ (m=2)		$W_{v,2}$ (m=M)
unit 3 (i=3)				$W_{v,3}$ (m=0)	$W_{v,3}$ (m=1)		$W_{v,3}$ (m=M)
unit 4 (i=4)				$W_{v,4}$ (m=0)	$W_{v,4}$ (m=1)		$W_{v,4}$ (m=M)
...							
unit I (i=I)					$W_{v,I}$ (m=0)		$W_{v,I}$ (m=M)



$W_{v,i,j}$ for a certain calendar year (e. g.: j = 2005)



$W_{v,i,m}$ for a certain operating year (e. g.: m = 1)

15.2.1 Average energy availability $k_{W\text{mittel}}$ for I Plants

in the calendar year j:	in the operating year m:
$k_{W,j}^{\text{mittel}} = \frac{\sum_{i=1}^I W_{v,i,j}}{\sum_{i=1}^I W_{N,i,j}}$ $= \frac{W_{v,1,j} + W_{v,2,j} + \dots + W_{v,I,j}}{W_{N,1,j} + W_{N,2,j} + \dots + W_{N,I,j}}$	$k_{W,m}^{\text{mittel}} = \frac{\sum_{i=1}^I W_{v,i,m}}{\sum_{i=1}^I W_{N,i,m}}$ $= \frac{W_{v,1,m} + W_{v,2,m} + \dots + W_{v,I,m}}{W_{N,1,m} + W_{N,2,m} + \dots + W_{N,I,m}}$

The calculation of the other parameters is made analogously, replacing the:

time availability k_t : W_v by t_v , W_N by t_N

time utilization n_t : W_v by t_B , W_N by t_N

energy utilization n_W : W_v by W_B

15.2.2 Average operating time $t_{B\text{mittel}}$ for I Plant

in the calendar year j:	in the operating year m:
$t_{B,j}^{\text{mittel}} = n_{t,j}^{\text{mittel}} \cdot t_N$	$t_{B,m}^{\text{mittel}} = n_{t,m}^{\text{mittel}} \cdot t_N$

The calculation of the average operating time for several plants with the help of the average time utilization n_t of these plants makes it possible also to include and correctly evaluate plants, whose takeover or decommissioning has taken place within a calendar or operating year.

15.2.3 Average utilization duration $t_{aN\text{mittel}}$ for I plant

in the calendar year j:	in the operating year m:
$t_{aN,j}^{\text{mittel}} = n_W^{\text{mittel}} \cdot t_N$	$t_{aN,m}^{\text{mittel}} = n_W^{\text{mittel}} \cdot t_N$

The calculation of the average utilization period for several plants with the help of the average energy utilization n_w of these plants makes it possible also to include and correctly evaluate plants, whose takeover or decommissioning has taken place within a calendar or operating year.

15.3 Average value for several plants for several calendar years or several operating years

The different average value calculations can be seen in the following matrix, e.g. for the available energy W_v :

	Year of commercial operation unit 1 (m=0) j=2002	j=2003	Year of commercial operation unit 2 (m=0) j=2004	Year of commercial operation unit 3+4 (m=0) j=2005	j=2006	...	j=J
unit 1 (i=1)	$W_{v,1}$ (m=0)	$W_{v,1}$ (m=1)	$W_{v,1}$ (m=2)	$W_{v,1}$ (m=3)	$W_{v,1}$ (m=4)		$W_{v,1}$ (m=M)
unit 2 (i=2)			$W_{v,2}$ (m=0)	$W_{v,2}$ (m=1)	$W_{v,2}$ (m=2)		$W_{v,2}$ (m=M)
unit 3 (i=3)				$W_{v,3}$ (m=0)	$W_{v,3}$ (m=1)		$W_{v,3}$ (m=M)
unit 4 (i=4)				$W_{v,4}$ (m=0)	$W_{v,4}$ (m=1)		$W_{v,4}$ (m=M)
...							
unit I (i=I)					$W_{v,I}$ (m=0)		$W_{v,I}$ (m=M)



$W_{v,i,j}$ for a certain calendar year (e. g.: j = 2005)



$W_{v,i,m}$ for a certain operating year (e. g.: M = 2)

15.3.1 Average energy availability $k_{W_{\text{mittel}}}$ for I plants and J calendar years or M operating years:

for J calendar years:

$$k_{W,j}^{\text{mittel}} = \text{20.. bis J} = \frac{\sum_{i=1}^I \sum_{j=20..}^J W_{v,i,j}}{\sum_{i=1}^I \sum_{j=20..}^J W_{N,i,j}}$$

$$= \frac{(W_{v,1,20..} + \dots + W_{v,1,J}) + (W_{v,2,20..} + \dots + W_{v,2,J}) + \dots + (W_{v,I,20..} + \dots + W_{v,I,J})}{(W_{N,1,20..} + \dots + W_{N,1,J}) + (W_{N,2,20..} + \dots + W_{N,2,J}) + \dots + (W_{N,I,20..} + \dots + W_{N,I,J})}$$

for M operating years:

$$k_{W,m}^{\text{mittel}} = \text{0 bis M} = \frac{\sum_{i=1}^I \sum_{m=0}^M W_{v,i,m}}{\sum_{i=1}^I \sum_{m=0}^M W_{N,i,m}}$$

$$= \frac{(W_{v,1,0} + \dots + W_{v,1,M}) + (W_{v,2,0} + \dots + W_{v,2,M}) + \dots + (W_{v,I,0} + \dots + W_{v,I,M})}{(W_{N,1,0} + \dots + W_{N,1,M}) + (W_{N,2,0} + \dots + W_{N,2,M}) + \dots + (W_{N,I,0} + \dots + W_{N,I,M})}$$

The calculation of the other parameters is made analogously, replacing the:

- time availability k_t : W_v by t_v , W_N by t_N
- time utilization n_t : W_v by t_B , W_N by t_N
- energy utilization n_W : W_v by t_B

It is only allowed to include such plants into the average value calculation, which have already reached or exceeded the operating year M.

15.4 Classification and comparison of units

The following diagrams may be used in order to benchmark two or more units:

- Percentile diagram
- Pareto diagram

The Percentile-Diagram is used to compare the relative position of one data among a homogeneous group of same statistical data. Here this type of diagram is used to compare the performance indicator of one unit or plant with the same indicator of other units or plants.

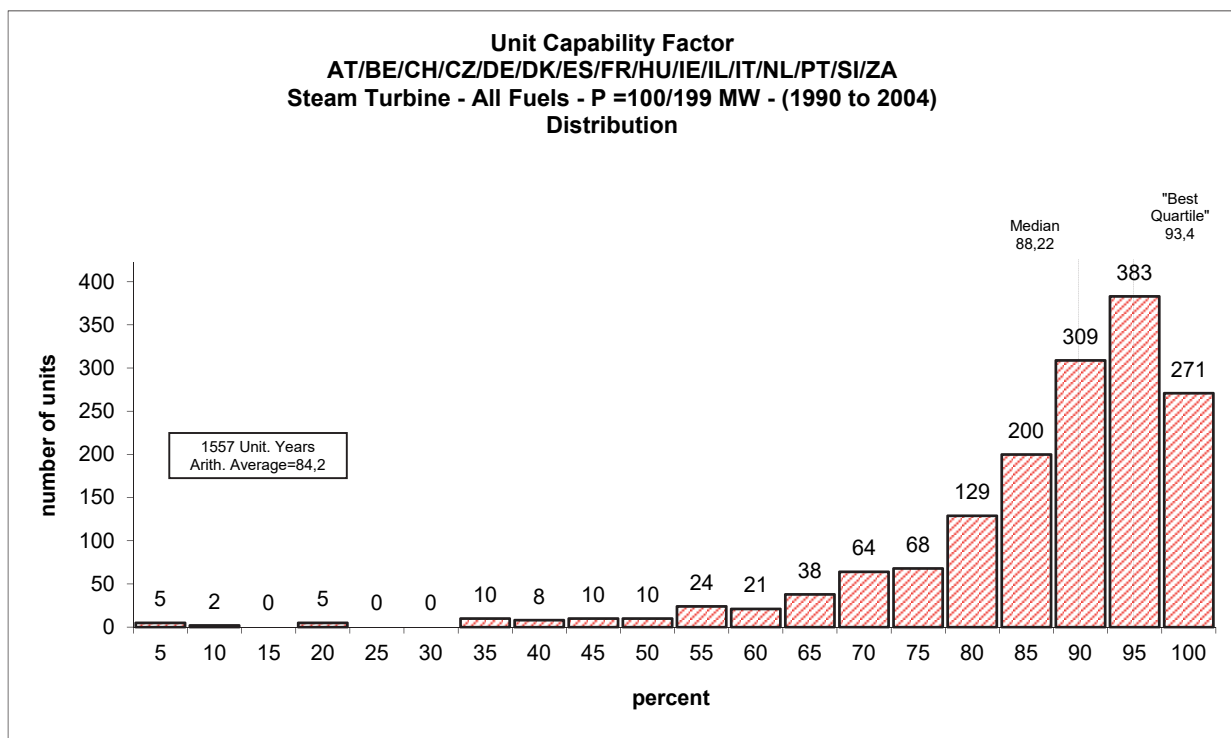


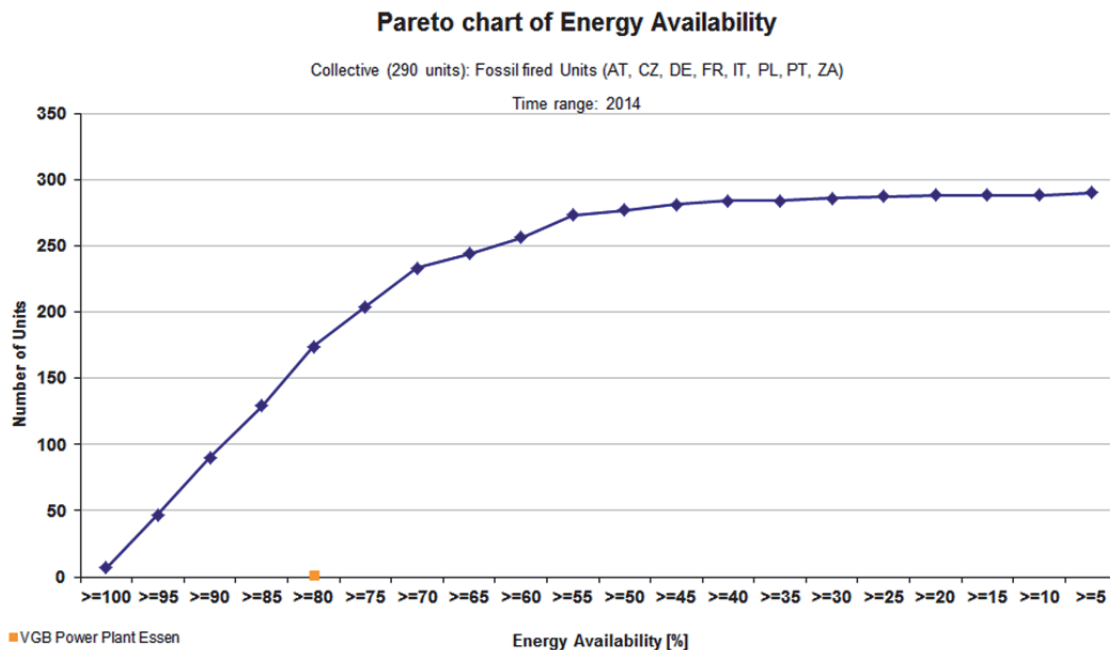
Figure 22: Example of frequency distribution [Eurelectric].

The distribution is shared in four quartiles. The under quartile (percentile 25) is called "Worst Quartile" and the upper quartile (percentile 75) "Best Quartile"(see Figure 22). The difference between the two quartiles represents exactly 50 % of the distribution and can be used as statistical spread.

Another important value used in this distribution is the median (percentile 50, middle quartile), which shares the group in two equal parts.

The Pareto principle is often described as '80 to 20 rule'. This rule means that in most situations approximately 80 % of the problem is justified by 20% of the possible causes.

The Pareto-Diagram is built with the accumulation of one performance indicator or failure list. The values of the performance indicator or the type of failure are downward classified and accumulated from left to right of the X-coordinate. The results often are graphically interpreted.



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Deilbachtal 173 • D-45257 Essen • kissy@vgb.org

Figure 23: Example of a Pareto chart.

16 Analysis of the unavailability of thermal power plants

16.1 History of VGB guideline VGB-R 140

The external availability determination of thermal power plants through the VGB was extended to the analysis of unavailabilities in the year 1988. The previous VGB Guideline “VGB Guideline 140” includes principles and special features, which have to be observed for a systematic and externally uniform determination of unavailable events and the reporting to the VGB. Simultaneously, it is the basis for plant-internal determinations which are normally more detailed.

The update of this guideline is now integrated at into the VGB Standard and will not be used as a separate document.

16.2 Unavailability analysis from thermal power plants

The unavailability analysis (UA-analysis) is a supplementary and continuing analysis with the purpose to find out and evaluate reasons and producers of unavailabilities. It gives information on operational and constructive weaknesses and enables to take measures which especially reduce the unplanned unavailability and thereby increase the availability above all in case of a request.

These principles as well as the existing guideline dictate the rules for the data determination and the data flow and show possibilities of evaluation in the unavailability analysis. The correlation between principles, determination and evaluation of data as well as between the unavailability analysis and the availability determination is shown in Figure 24.

With regard to the expenditure and the benefit, the UA-analysis is a significant step between the unavailability determination of an unit and a complete and large-scale statistics of damages.

The systematic of the unavailability analysis is shown in Figure 25 with the example of fossil-fueled unit plant. Starting from the availability determination [3], the unavailability is divided according to the criteria

- effect on the plant, time frame (Chapter 18.5)
- Type of incident (Chapter 18.2) and
- Causer (KKS-function) [4].

16.3 Identification System for Power Stations (KKS) and Reference Designation System for Power Plants (RDS-PP®)

New and withdrawn standards as well as revised EU directives with regard to plant identification and documentation had their considerable influence on the Identification System for Power Stations KKS (Kraftwerk-Kennzeichensystem) [4] of the VGB PowerTech. In the course of time, the KKS also had to cope with the development of power plant technology. In order to maintain acceptance on international markets and to ensure compliance with valid standards, manufacturers and operators alike have had to adapt the KKS to the current standards. Experiences and recognized improvement potentials in the application of the KKS complete the adaptation and creation of the KKS successor system. The new labeling system, which conforms to the standards, has received the name “Reference Designation System for Power Plants” (RDS-PP® [9]) and is also maintained by VGB PowerTech.

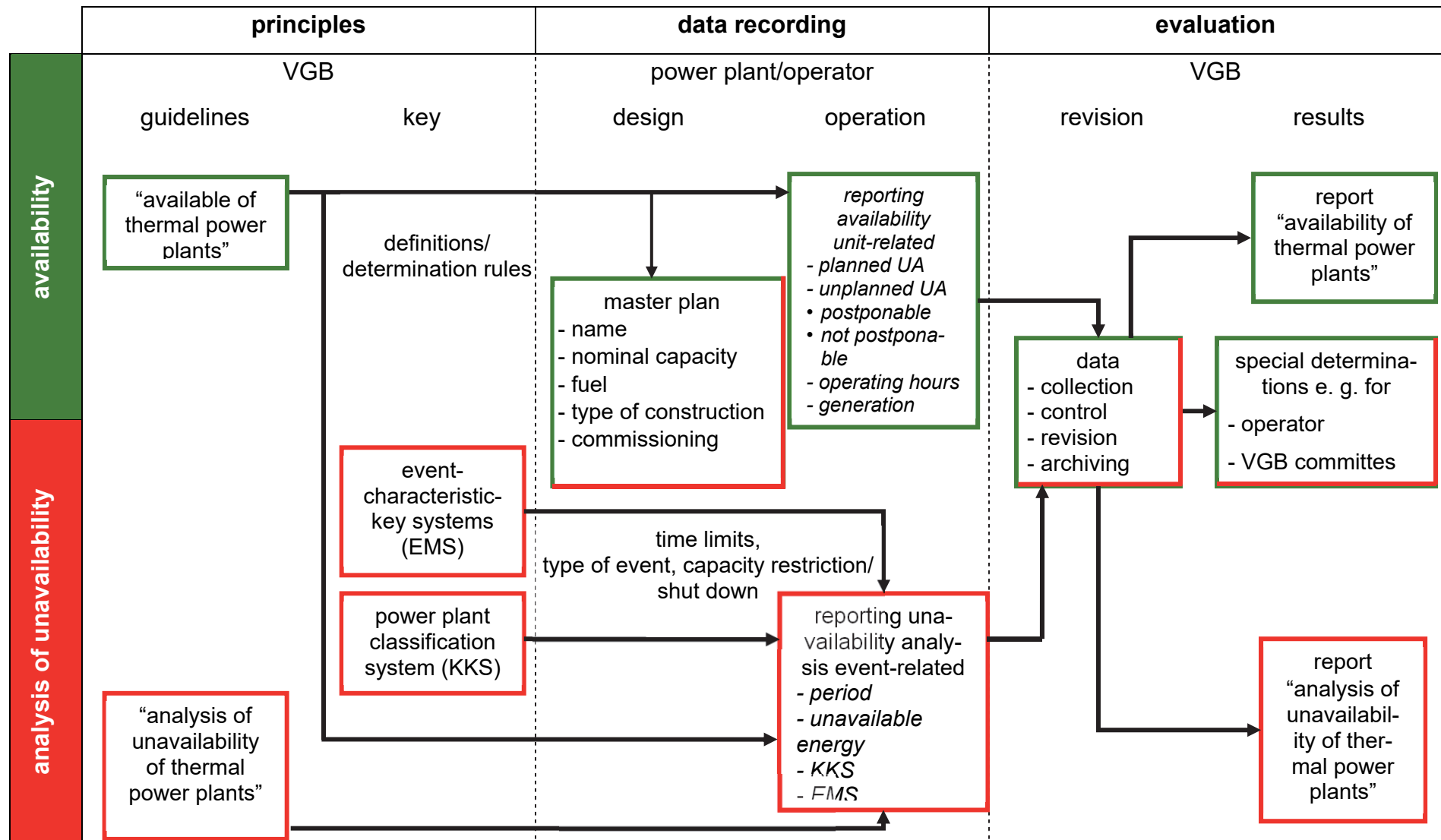


Figure 24: Information flow for determination and revision of data.

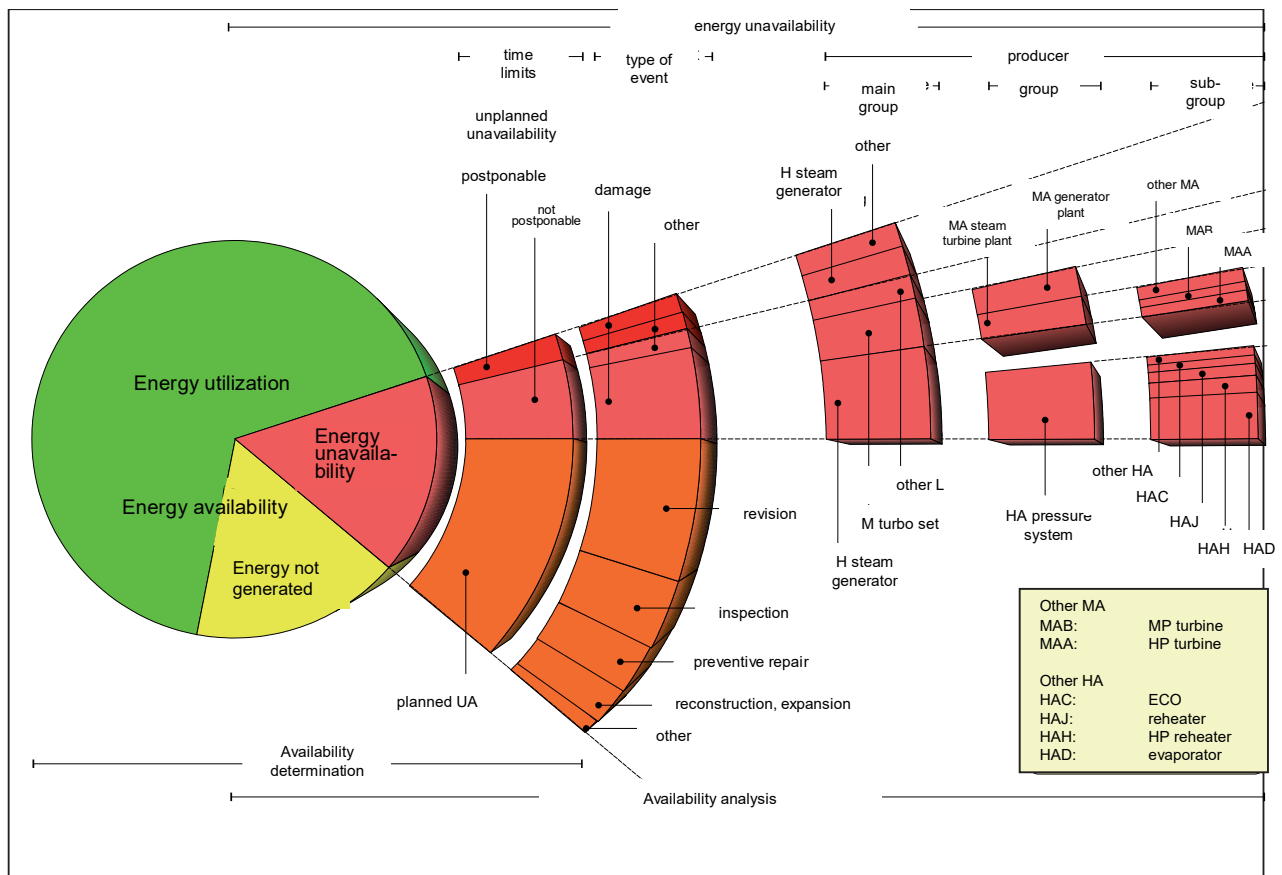


Figure 25: Example for a possible examination depth of the unavailability analysis.

16.4 Range of determination

Within the unavailability analysis, only those events have to be recorded, which lead to full and partial unavailabilities of a unit.

For carrying out it is necessary to collect the unavailabilities so as it corresponds to the rules which are valid in this connection, in accordance with the definitions of this guide. Only this way it is possible to receive excessive and comparable values within the requirements.

Over and above that, it is important that the relevant definitions of power plants are observed (Chapter 3). For unit plants they take place, from the side of the grid, with the high-voltage terminals of the machine transformer, from the side of the fuel, with the transfer point to the power plant.

Unavailabilities are such events which limit the ability of the plant or of the plant part to convert energy or meet their corresponding function because of plant-technical damages, defects or measures. Also capacity restrictions due to outside influences according to Chapter 10 have to be recorded additionally for questions of operational planning.

The data, which are required for the external unavailability analysis, are already available in parts both to the operator and to the VGB. To enable a clear classification of power plant units to the different evaluation modes, following design and operating data must be indicated in connection with the unavailable events (see VGB-S-002-33 Annex to VGB-S-002 series, 'Input and Output Forms'):

- company
- name of power plant
- unit designation
- nominal capacity (gross, net)
- reported year.

Following information is necessary to describe the event:

- period of unavailability (beginning and end)
- unavailable energy or unavailable capacity (gross or net),
- plant designation of the unavailable producer according to the KKS [4];
- depth of classification is the three-digit function key,
- designation of characteristics of the events according to the key types 1 and 4 of the EMS (Chapter 18.2 and 18.5),
- brief description.

With the key resp. designation systems (EMS/KKS resp. RDS-PP¹) the correspondingly valid version must be applied.

If there is a recording of the unit availability in parallel to the recording of the unavailability via single events, it must be guaranteed that the results of availability and unavailability are the same according to both ways of procedure.

Attention must also be paid to that the evaluation and classification of unavailabilities into

- a planned UA,
- a postponable unplanned UA,
- a not postponable unplanned UA.

do not diverge against other recordings.

The data transfer for the unavailability analysis to the VGB is to be made once a year. The electronic data transmission should be preferred and coordinated with the VGB.

¹ RDS-PP® is the internationally standardized successor system for KKS

16.5 Recording of event data

Within the scope of external availability determination with the VGB, the essential design and operating data of the participated power plant units are already at hand. Therefore only the **unavailable events** of the power plant units are to be recorded for the unavailability analysis.

Valid in general is:

- The evaluation of an event as an unavailable event depends on the principles and rules according to this guide.
- Only events, which result in a full and partial unavailability of an unit, are to be recorded. Events with the consequence of an island operation and without a capacity restriction are not to be recorded for external purposes.
- For every unit unavailability only one report each must normally be produced. This is also valid for planned unavailabilities (e. g. revision).
- To describe an event, one has to make the requested entry in all fields of the data sheet.
- For the recording of advanced planned measures (e. g. revision) see Chapter 13.5.

Further information regarding recording as well as recording examples:

- Rules for the recording of event data (Table 1)
- Encoding of event data (Table 2) with an example (Figure 26)
- Recording examples "Single Event"
- Examples "Temporarily Overlapping Events" (Figure 26 – Figure 28)
- Recording examples "Temporarily Overlapping Events" (see VGB-S-002-33 Annex to VGB-S-002 series, 'Unavailability incidents and temporarily overlapping incidents').

Table 1: Rules for the recording of event data.

Serial no.	Rule
1	<p>Beginning and end of an unavailability</p> <p>An unavailability during the operation starts when the capacity of the unit had to be reduced or was reduced automatically. The unavailability ends when the required capacity has been reached, see Figure 16.</p> <p>When an unavailability is detected during an inoperational time the moment of the unavailability starts with the determination of the partial or full failure of the available capacity. The unavailability ends with the moment when the unit can be operated again.</p>
2	<p>Unavailability over several capacity levels</p> <p>When the unavailability extends over several capacity levels, this event has to be established with a report, as far as the encoding of KKS and EMS is the same in all capacity levels and all capacity levels connect with each other unbrokenly.</p> <p>When, however, a partial unavailability goes over into a full failure with the same cause (KKS), two events have to be recorded (Figure 27).</p> <p>The unavailable energy/average unavailable capacity must be entered.</p>
3	<p>Temporarily overlapping unavailabilities</p> <p>When in addition to a partial unavailability (e. g. failure of a draft fan) there is another event with a different producer (e. g. generator damage), it has to be observed that the unavailable energy for the unit is not recorded twice during the temporarily overlapping of events (Figure 28); see Chapter 4.</p>
4	<p>Producer of an unavailability</p> <p>It has to be indicated the KKS function of the producer, who is responsible for the period of the full or partial failure, and if possible in a three-digit way. The KKS indication can be dropped, when the activities respectively measures refer to the complete unit (e. g. revision).</p>
5	<p>Effect on the plant – time limits</p> <p>Selection EMS 4/1</p> <p>e. g. code H = can be postponed more than 12 hours</p>
6	<p>Type of event of the unavailability</p> <p>Selection EMS 1</p> <p>e.g. code A2 =damage</p>

Serial no.	Rule
7	<p>Effect on the plant – main effect</p> <p>Selection EMS 4/2 e.g. code 4 = unit shutdown necessary.</p> <p>With events in combined/gas-and-steam plants only “4” is used, when gas and steam turbine area, with KWK plants power and heat delivery are isochronous and completely unavailable.</p>

Table 2: Encoding of event data.

(see 'Single Events' or see VGB-S-002-33 Annex to VGB-S-002 series, 'Unavailability incidents and temporarily overlapping incidents')

Question regarding the encoding	Information	Entry	Rule to be checked
When did the unavailability start?	Shift book: Capacity reduction after the evening peak at 18:31. Unit shutdown from the mains 19:02.	(1) 25.02., 18:31 (2) 25.02., 19:02	1 3
When was the unavailability finished?	Shift book: Generator was synchronized again after the end of repair at 12:00. Load dispatcher requirement achieved at 12:25.	(3) 26.02., 12:00 (4) 26.02., 12:25	
Which energy was not available because of this unavailability?	unavailable energy [2] Chapter 6	4.358,33 MWh	2 3
Which plant system resp. which KKS function was the main producer?	evaporator	HAD	4
How urgent was the elimination of the damage? (effect on the plant – time limits, EMS 4/1)	Leakiness was discovered at 11:30 by the shift worker, but the unit could continue running until the evening peak.	C	5
What was the reason for the unavailability? (type of event, EMS 1)	Incipient crack at the evaporator pipe by extension obstruction, repair necessary.	A2	6

Has the event caused a full or partial failure of the unit? (effect on the plant/main effect, EMS 4/2)	Unit had to be shut down completely for repair.	4	7
---	---	---	---

Single event

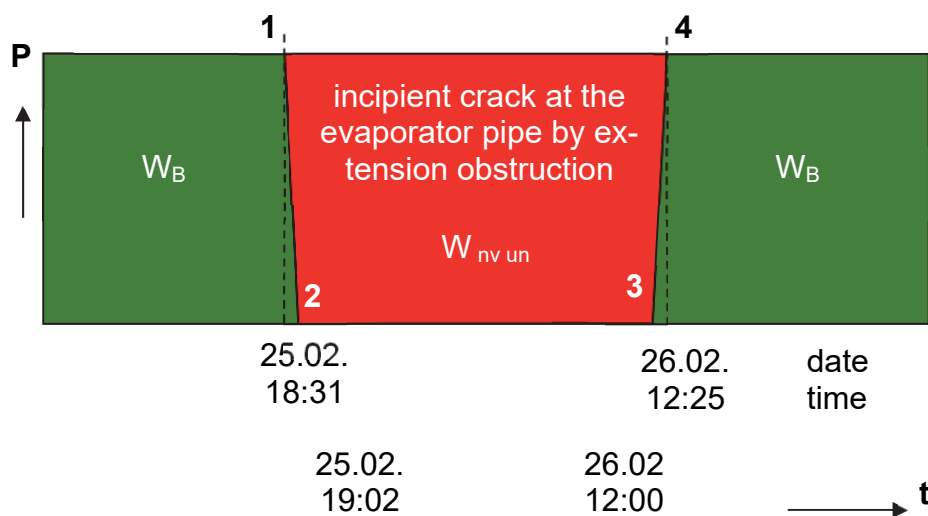


Figure 26: Unavailable event “incipient crack at evaporator pipe”.

Temporarily overlapping events

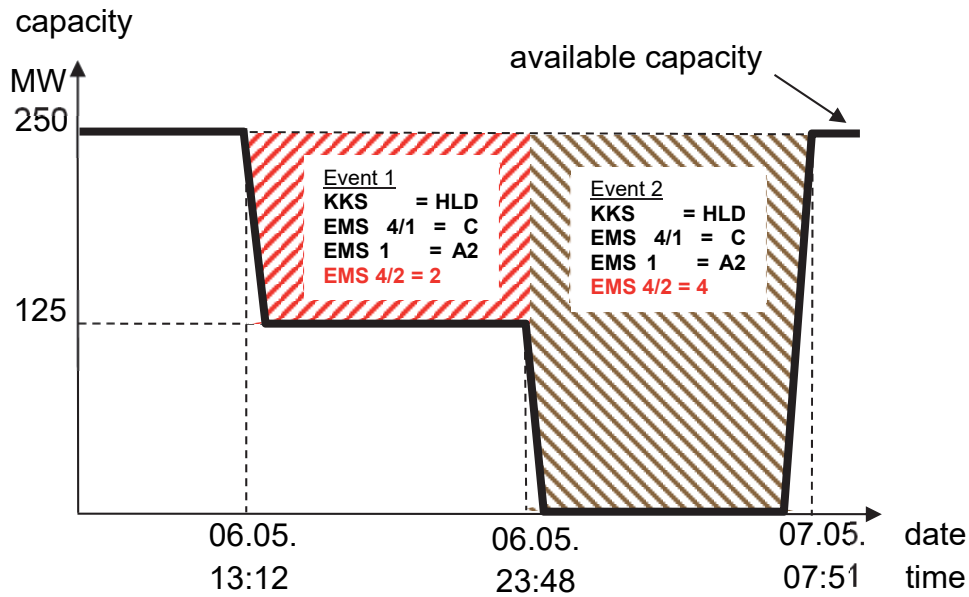


Figure 27: Unavailability over several capacity levels

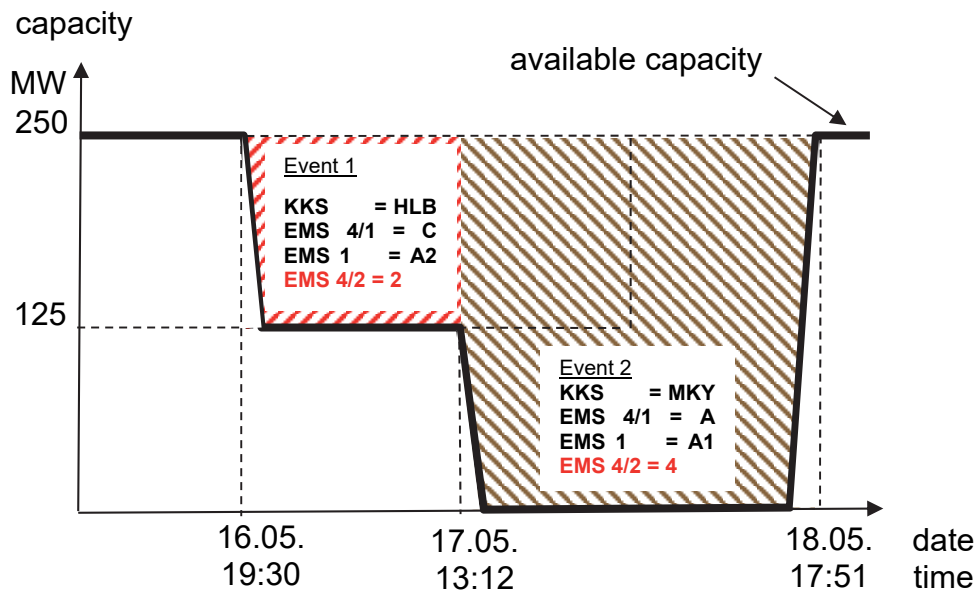


Figure 28: Failure of a draft fan and of the generator during capacity operation.

16.6 Evaluation

The evaluations of unavailabilities are made once a year. The results are compiled and published in the VGB Report “Analysis of Unavailability of Thermal Power Plants” [8].

The “unavailability analysis” is a supplementary and continuing examination of unit unavailabilities which are described in the VGB Reports “Availability of Thermal Power Plants” [3]. In addition to the analysis of e.g. the reasons for the planned parts of the unit unavailability above all for the postponable and not postponable unplanned unavailability it supplies information on the producers.

The analysis is made in different detail levels:

- the summary of producers under the **first** digit of the KKS function,
- the differentiating of producers, each after the **first three** digits of the KKS function, separated for the fuel-related and the fuel-independent areas of power plants.

In this connection, the plants included in the analysis are combined according to primary energies, capacity sizes, process characteristics (e.g. combined plants). Furthermore, the analysis of the unplanned unavailability happens according to the EMS keys:

- effect on the plant – time limits and main effect
- type of event.

Figure 29 shows how the unavailable data can be evaluated according to the criteria of data groups “design data”, “time aspect” and “event data”.

For the VGB unavailability analysis, some of these possibilities have been selected for the regular report [8]. They are to enable an entering into the unavailability analysis to the user. In addition to that, further possibilities of evaluation can be used through the VGB on request.

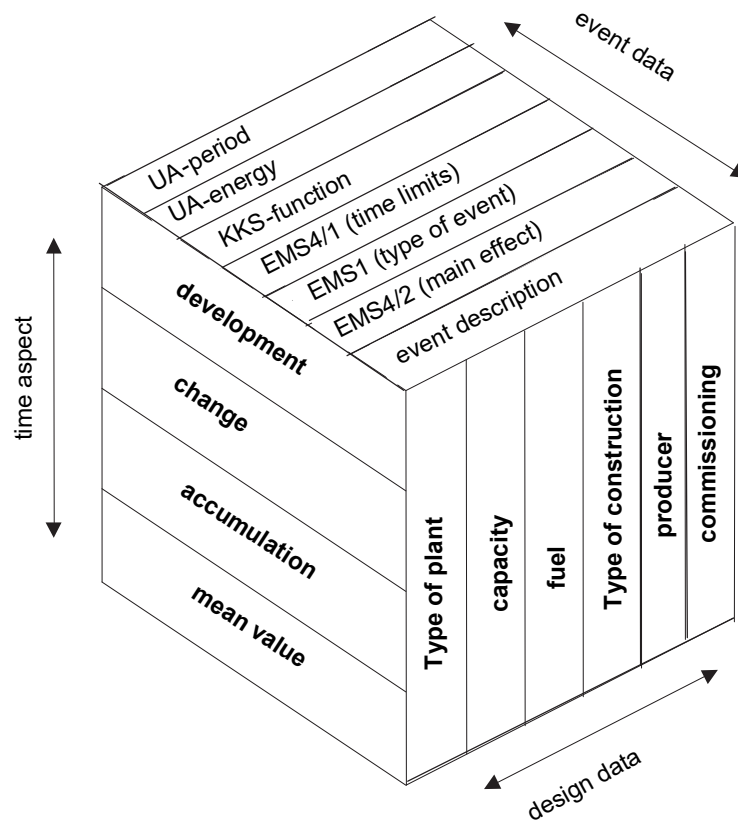


Figure 29: Possibilities of evaluation.

III. EMS Event characteristic key system

– Application and key part –

C Electronic Acquisition and Processing of Data by the VGB Data Bank and Statistics of Performance Indicators

17 Power plant information system KISSY

Operating figures are very important for operators. Therefore the electrical gathering of operating data and the determination of performance indicators are strategic tools for all VGB members, in order to optimize the productivity of a power plant in competition as well as the complete benchmarking of one power plant fleet with the same technology. With its modern online **Power Plant Information System (KISSY)** VGB is able to collect, to gather and to process a big amount of operating data.

KISSY is based on a relational data base installed on an Oracle-platform. This data base has currently contained the availability figures, performance indicators as well as events causing unavailability (UA-incidents) from international power plants since 1970.

Online with the internet interface, each ordinary member is able to feed in data for its own plant or fleet into the data bank, to interrogate the performances for its group as well as to establish some graphics.



17.1 KISSY access and data input

All members from VGB who decide to feed in performance data and events have an access to the KISSY data bank. For that the supplier receives a secure identification login and password, which permit the access to the internet KISSY website (through a SSL connection). All data coming from its own power plant fleet could be accessible for reading, writing, and revising.

VGB furnishes the access authorization to the KISSY data bank on inquiry.

The availability data are fed in KISSY depending on type of power plant (Figure 30 and Figure 31):

- at least annually for fossil fired plants,
- monthly for nuclear power plants.


 You are logged in as user: prosts
 

Selection ▾ Incidents Import Evaluation ▾ Links Logout

Select Power plant/unit:

- ☐ VGB datasheet via Internet
 - ☐ yearly availability data
 - ☐ monthly availability data
 - ☐ unavailability incidents

Figure 30: Screen 'Select type of plant/unit'

Availability of Thermal Power Plants

◀ Hard Coal Unit ▶
 ◀◀ 2015 ▶▶

General **Energy utilization, unit capability factor** Time utilization, Time availability Operational parameters Further indicators

		Formula	Unit		Input	Help	Check
	Based on			Selection mandatory	net		
4	Nominal energy	$W_N = P_N \times t_N$	GWh	<input checked="" type="checkbox"/>	876.00		
5	Energy generated	W_B	GWh	<input checked="" type="checkbox"/>	500.00		
6	Energy utilization	$n_W = W_B / W_N$	%		57.08		
	Unavailable energy						
7	-- planned (specified)	$W_{nv\ p\ Soll}$	GWh	<input type="checkbox"/>		?	
8	-- planned (effective)	$W_{nv\ p\ Ist}$	GWh	<input checked="" type="checkbox"/>	0.00	?	
*	-- unplanned (total)	$W_{nv\ u} = W_{nv\ ud} + W_{nv\ un}$	GWh		30.00		
9	---- unplanned (postponable)	$W_{nv\ ud}$	GWh	<input checked="" type="checkbox"/>	10.00	?	
10	---- (unplanned not postponable)	$W_{nv\ un}$	GWh	<input checked="" type="checkbox"/>	20.00	?	
11	--total	$W_{nv} = W_{nv\ p\ Ist} + W_{nv\ u}$	GWh		30.00		
12	---- thereof unavailable energy - extended	$W_{nv\ Verl.}$	GWh	<input type="checkbox"/>		?	
13	Energy availability	$k_W = (W_N - W_{nv}) / W_N$	%		96.58		
14	Available unproducibile energy (external influence energy)	W_{ns}	GWh	<input type="checkbox"/>	0.00	?	

[\[Copy from previous year \]](#)
[\[Request report \]](#)
[\[Check input \]](#)
[\[Save to database \]](#)
[\[Save and switch to next block \]](#)

Figure 31: Example of yearly operating and availability data of a power plant.

The user can feed in every event characteristics into the data bank with the help of a data mask (Figure 32).

Data Input: unavailability incidents				Hard Coal Unit - (12 Messages)		
				20.08.2014 15:30		
		Unit		Input	Help	Check
	Unavailability Incidents (complete and partial breakdown of power plant)					
1	Number of incident		<input type="checkbox"/>	20130201		
	Duration of incident					
2	Date of period-start (dd/MM/yyyy hh:mm)		<input checked="" type="checkbox"/>	09/02/2013 02:45	?	
3	Date of period-end (dd/MM/yyyy hh:mm)		<input checked="" type="checkbox"/>	12/02/2013 14:30	?	
	Reference for energy-data (gross or net)		Selection mandatory	gross		
4	Unavailability energy	MWh	<input checked="" type="checkbox"/>	57033.75		
4	Unavailability capacity	MW	<input checked="" type="checkbox"/>	681.00		
5	Affected plant system (denomination according to KKS (power plant identification system))		<input checked="" type="checkbox"/>	ETA Wet ash conveying system	?	
Characteristic parameters of incident						
6	Time frame		<input checked="" type="checkbox"/>	D - Start-up or recommissioning not possible (unless ite	?	
7	Type of incident		<input checked="" type="checkbox"/>	A2 Damage	?	
8	Main impact of incident		<input checked="" type="checkbox"/>	4 Plant out of operation	?	
9	Brief description		<input type="checkbox"/>	Test KISSY Sommerkurs 2014	?	

[\[New incident \]](#)
[\[Request report \]](#)
[\[Check input \]](#)
[\[Save to database \]](#)

Figure 32: Example of unavailability incidents.

The user can feed in every event characteristics into the data bank with the help of a data mask.

17.2 Evaluations and reports

VGB makes all data input into KISSY anonymous and classifies and categorizes them for benchmarking reasons. In these classifications and categories, you can find all the data concerning the same technology or the same characteristics. So it is possible to compare anonymous the performance of one power plant with other.

The essential groups of standard evaluations are:

- Fossil fired units,
- Nuclear power plants,
- CCGT plants,
- Gas turbines.

Ordered by:

- unit power,
- fuel,
- furnace type,
- mono-/duo-unit,
- under-/supercritical installations.

The evaluation can be done for:

- time availability,
- time utilization,
- energy availability,
- energy unavailability,
- capability factor.

All companies which feed in data into KISSY receive every year standardized reports presenting the availability by groups and analyzing the unavailability of power plant components in a cycle of ten years, for free.

Updates can be downloaded on the VGB website for all members inside a closer user's group, for free too. Non-members may buy all reports from VGB.

Special studies or reports may also be ordered from VGB for individual fees. Moreover the standardized evaluations can be realized online by the tools of the website.

D EMS Event-Characteristic-Key-System

– Application and Coding List –

History and purpose of the EMS

In the past different indication- and coding-systems for registering operational events were used in Germany by operators, producers and institutions with the aim of characterization of events:

- VGB-SMS (VGB damage-characterization-system) for registering of non-availability-events in power plants,
- GRS-coding for reports of significant events in nuclear power plants,
- GRS-coding for calculation of reliability indicators in nuclear power plants,
- IAEA-keys for registering of total and partial outages in nuclear power plants,
- VDEW-indicator-register for registering grid failures and damages, producer codes, key systems for probabilistic security analysis,
- key systems for implementation processes of integrated management systems

and others.

The present EMS was introduced in 2003 and has the claim to replace all former event describing key systems in Germany. With EMS double and multiple registering of an event and therefore different assessments are avoided and a definite coding for analysis is guaranteed. In addition EMS can be used as a basis for an international key system.

18 Structure of event characteristic key system EMS and overview

The EMS describes different aspects of an event with 12 key. Each key contains one or more groups. In some cases the groups are hierarchical structured. Event attributes are related to each group.

A long description and a code are existing for each key, each group, or each attribute. The code consists of one or more letters, or numbers, or a combination of both.

It is necessary for a definite and complete description of an event to specify each key and all groups with defined attributes.

Presented below is the structure of coding an attribute:

Key No.	Group No.	Attribute of event Code						
<table><tr><td></td><td></td></tr></table>			<table><tr><td></td></tr></table>		<table><tr><td></td><td></td><td></td></tr></table>			

The following Table 3 shows the 12 keys and their groups.

Table 3: Key overview.

No. of key	Name	Group	Name	Code
01	Type of event	1	Type of event	ANN
02	Operational status before beginning of event	1	Operational status before beginning of event	AN
03	Operational status after beginning of event	1	Operational status after beginning of event	AN
04	Impact on unit	1 2 3	time frame Main effect Effect to NPP	A N A
05	Outage impact on system/component	1	Outage impact on system/component	AN
06	Cause	1 2 3	Origin Influence/activity Failure/Impact on unit	AN AA NN
07	Failure mechanism	1 2	Type of failure stress	AN ANN
08	Failure	1	Failure	AN
09	Recognition of outage	1 2	occasion of recognition expression of outage	AN ANN/ AAN/AA
10	Maintenance method	1	Maintenance method	A
11	Measures against recurrence	1	Measures against recurrence	ANN
12	Urgency of measures	1 2	Urgency of beginning of repair Personal-engagement	A N

Alphanumeric:	A
Numeric:	N
One digit code:	A or N
Two digit code:	AA, AN or NN
Three digit code:	AAN or ANN

18.1 Application recommendations

- EMS should be combined with the Identification System for Power Stations (KKS) to relate the event to a function, aggregate or equipment.
- The EMS is an extensive key system from which keys, groups or single attributes can be chosen according to the requirements.
- Example: VGB uses only the relevant codes for registering the non-availability events of all units. Group 1, and 2 are omitted within the codes A0, B0, D0, and D1, and in key 4.
- The hierarchy within a group is presented by indentation of text.
- Also a coarser classification is possible with the hierarchical structured groups within the keys. In those cases where a deeper structure is omitted (shown by simple or double shift) the last respectively the both last digits can be omitted.
- Example: For internal reasons it can be committed to use the key 11 only with 2 digits (middle deeps of classification) or even 1 digit. In the first case all twice shifted, in the second case also the simple shifted attributes would be omitted.
- If you use in a hierarchical structured group the second or third depth of the structure, only the attributes of this level are to be used. The additionally use of attributes of a higher level is not allowed because the front digits of the code contain this information automatically.

Example: Key 1, group 1, attribute B4 "inspection": in this case the information of B0 "maintenance" is omitted (compare Chapter 18.2).

In some groups of EMS it is possible to register simultaneously several attributes in one group (multiple nominations) for each event. If multiple nominations are allowed it is necessary to define rules for registering and analyzing and for interpretation to consider the widened statement.

Remark: There are more fields for registering necessary.

- The number of hits will be enlarged while searching for events with identical attributes.
- In these cases it is necessary to give a remark if the results are referred to somebody else.
- The structure for registration in forms or templates is in principle identically for all keys of EMS.
- The code is to be filled in always left hand to avoid mistakes and allow analyses. In some keys the codes of group 3 do not exist. Therefore the fields on the right and/or the middle remain free.
- If it is allowed to choose multiple attributes in one group or a complete key, then there are n-times code fields to be filled in.

18.2 Event characteristic key 1 “Type of event”

Key	Group	Code	Text
01	1		Type of event
		A0	Outage
		A1	Failure without damage
		A2	damage
		B0	Maintenance
		B1	inspection/check of status
		B2	lubrication
		B3	servicing
		B4	inspection
		B5	preventive maintenance
		B6	cleaning
		B7	planned maintenance
		B8	change of fuel element
		C0	modification/extension
		D0	non operating
		D1	stand-by
		D2	external influence (without damage)
		D21	fuel
		D22	preservation of unit
		D23	climate
		D24	grid restrictions
		D241	Redispatch
		D25	lack of personnel
		D26	others
		E0	tests/ functioning tests/ functioning check
		F0	official testing/measure
		G0	leak of reactivity
		K0	commercial fueling
		Z0	other keys of events

Advice: An apportion of “external influence” (D2) can be achieved by combination with key 6, group 3.

18.3 Event characteristic key 2 “Operating status before event”

Key	Group	Code	Text
02	1		operating status
		A0	change of operating status
		A1	start up
		A2	shut-down
		A3	change of power
		A4	change of operational mode
		B0	stationary operation
		B1	zero power
		B2	minimum load
		B3	partial load
		B4	full load
		B5	over load
		B6	by-pass operation
		B7	isolated operation
		B8	phase shifting
		B9	pumping in pump storage power stations
		S0	Shut down
		S1	maintenance/change of fuel elements
		S2	cold shut down
		S3	hot-stand-by
		S4	reserve

Advice: The attributes in keys 2 and 3 are identically. Key 2 describes in difference to key 3 the operational status before beginning of the event.

18.4 Event characteristic key 3 “Operating status after event”

Key	Group	Code	Text
03	1		operating status
		A0	change of operating status
		A1	start up
		A2	shut-down
		A3	change of power
		A4	change of operational mode
		B0	stationary operation
		B1	zero power
		B2	minimum load
		B3	partial load
		B4	full load
		B5	over load
		B6	by-pass operation
		B7	isolated operation
		B8	phase shifting
		B9	pumping in pump storage power stations
		S0	Shut down
		S1	maintenance/change of fuel elements
		S2	cold shut down
		S3	hot-stand-by
		S4	reserve

Advice: The attributes in keys 2 and 3 are identically. Key 3 describes in difference to key 2 the operational status after beginning of the event.

18.5 Event characteristic key 4 “Impact on unit”

Key	Group	Code	Text
04	1		time-frame
		A	automatic load shedding/emergency tripping
		B	manual load shedding/emergency tripping
		C	controlled shut down within 12 hours
		D	restart up or putting in operation not possible (unless point E, K, L). The start-up cannot be started because of technical failures.
		E	exceeding of planned time according point J or K by unplanned measures (failures, damages, ...)
		F	start-up-delay. Once started it cannot be finished within ordered time with connecting to grid.
		G	prolongation of start-up. the increase of power after connecting to the grid is not possible according start-up-curve/instruction manual.
		H	more than 12 hours postponable
		J	more than 4 weeks ante planned
		K	annual revision
		L	exceeding of planned time according point J or K by prolongation of planned durance
		M	without effect (allowed only in combination with components)
	2		main effect
		1	without reduction in power ($P_2 = P_1$)
		2	Power limitation ($0 < P_2 < P_1$)
		3	isolated operation
		4	shutdown ($P_2 = 0$)

Key	Group	Code	Text
04	3		impact on nuclear power plants
		A	emergency power supply
		B	partial load reduction (automatic)
		C	actuation of main steam and relief valves
		D	actuation of main steam safety valves
		E	Actuation of primary safety relief valves (in relief tank)
		F	SCRAM automatic
		G	SCRAM manual
		H	main containment isolation
		J	reactor building isolation
		K	Ventilation isolation
		L	reactor core emergency cooling
		M	emergency feed water
		N	impact on other units

Advice: In group 2 means P1 the power before and P2 the power after beginning of the event.

18.6 Event characteristic key 5 “Outage impact on the system/components”

Key	Group	Code	Text
05	1		Effect of failure
		A0	No effect to component
		B0	Long-term failure of component
		C0	Failure of component
		D0	Failure of components or measuring or control
		E0	Failure of functional units
		F1 F2	Failure of part of line (operational) Failure of part of line also on request of core protection
		G1 G2	Failure of whole line Failure of whole line also on request of core protection
		H0	Failure of function of system
		J0	Failure of several functions of system
		X0	Effect of failure not clear
		Y0	Effect not analyzed
		Z0	Other effects of failure

Advice: The use of this key requires a clear separation between system and component from the user. The Identification System for Power Stations (KKS) should be used.

18.7 Event characteristic key 6 “Cause”

Key	Group	Code	Text
06	1		origin
		A0	project/planning
		A1	conceive
		A2	plan
		A3	design
		A4	construct
		A5	license
		B0	specification
		B1	specification from orderer
		B2	specification from contractor
		C0	manufacture/fabrication
		C1	manufacture/fabricate
		C2	assemble/disassemble/realization
		C3	inspect/check
		C4	storage
		D0	construction/ installation
		D1	assemble/disassemble/realization
		D2	inspect/check
		E0	putting into operation
		F0	operate
		F1	operation
		F2	standstill without works at considered equipment
		F3	standstill with works at considered equipment
		F4	temporarily out of work
		G0	change
		G1	alteration
		G2	retrofit
		G3	replace
		H0	disassembly/ scrapping/ demolition

Key	Group	Code	Text
06	1	J0	transportation
		J1	shipping
		J2	transport
		J3	store
		Z0	cause not from considered equipment
	2		effect/activity
		TA	Drawing blue print
		TB	Selection of material
		TC	Dimensioning/calculation
		TD	(also define strategy of maintenance)
		TE	designing
		TF	operate
		TG	adjust/tune/calibrate
		TH	treat (mechanical, ...)
		TJ	assemble
		TK	test/check
		TL	welding
		TM	solder
		TN	lubricate
		TO	cleaning
		TP	communication
		TQ	process observation
		TR	assessment of status
		TS	training
		TT	organization and administration
		TX	programming
		TY	activity not clear
		TZ	activity not analyzed
			other activities or no separation in addition to „origin“
		EA	dimension exceeding external impact
		EJ	dimension exceeding internal impact
		EX	impact not clear
		EY	impact not analyzed
		EZ	other impacts

Key	Group	Code	Text
06	2	UA	Interruption/restrictions by official order (license, order, ...)
		UE	Technical interruption/restriction of waste disposal (waste, rubbish, waste water, ...)
		UP	Technical interruption of product transmission (electricity, heat, gypsum, ...)
		UV	Technical interruption/restriction of supply (electricity, fuel, water, ...)
		UW	Other impact of civilization
		UX	interruption not clear
		UY	interruption not analyzed
		UZ	other interruption
	3		error/impact to unit
		10	error in performance/application
		11	failed measure
		12	wrong measure
		13	use of wrong/unsuitable material
		14	wrong/incorrect order
		15	use of unsuitable tools
		16	tester or measuring instruments mix up
		20	error in use of directions or instructions
		21	non-compliance with non unit specific directions
		22	non-compliance with internal directions
		23	directions and instructions incorrect
		24	not existing directions or instructions
		25	insufficient attention to rules/guidelines
		30	error in use of documents
		31	use of wrong documents
		32	use of incorrect documents
		33	error in used documents
		34	creation of incorrect documents

Key	Group	Code	Text
06	3	50	impact
		51	heat
		52	fire
		53	explosion
		54	frost/coldness
		55	freezing
		56	mechanical force
		57	foreign substances (also dirt, deposits)
		58	pollutant/chemical impact
		59	ice-drift
		60	radioactive radiation
		61	electromagnetic fields
		62	overvoltage/overcurrent
		63	precipitation (e.g. snow, rain, hail)
		64	high water
		65	low water
		66	flood
		67	mist/hoar-frost
		68	soak
		69	stroke of lightning
		70	storm
		71	earthquake/shock
		72	landslip
		73	animals
		97	not to be clarified
		98	not analyzed
		99	other impact

Advice: The best profit from this key will be achieved, if attributes of all 3 groups are used, but the number of attributes is reduced in each group to the reasonable necessary.

18.8 Event characteristic key 7 “Damage mechanism”

Key	Group	Code	Text
07	1		type of failure
		A0	wear out
		A1	wear out by gliding
		A2	wear out by rolling
		A3	wear out by bouncing
		A4	wear out by vibrations
		A5	erosion (wear out by flushing/blasting)
		A6	cavitation
		A7	strokes of drops
		E0	tiredness/exhaustion
		K0	corrosion
		K1	erosive corrosion
		K2	corrosion by tension
		K3	corrosion induced by stretching
		K4	corrosion induced by vibrations
		K5	localized/pitting corrosion
		K6	pitting corrosion
		K7	surface corrosion
		K8	crevice corrosion
		K9	contact corrosion
		L0	ageing
		L1	ageing of material
		L2	ageing of equipment
		L3	creep
		L4	other changes of material characteristics
		G0	violent usage
		G1	mechanical violent usage
		G2	thermal violent usage
		G3	electrical violent usage
		G4	chemical violent usage

Key	Group	Code	Text
07	1	S0	soiling
		V0 V1 V2	damaged before shrinkhole/pore/inclusion doubling
		W0	no damage
		X0	damage not clear
		Y0	damage not analyzed
		Z0	other kind of damage
	2		stress
			mechanical
		M00	push/impact
		M01	cavitation
		M02	roll
		M03	glide
		M04	adhesion
		M05	abrasion
		M06	current transfer
		M07	(spark erosion, elektrolytical decay)
		M08	abrasion by foreign particles
		M09	effect of foreign particles
		M10	deposits
		M11	blast
		M12	sticking together
		M13	lack of lubricant
		M14	adverse matching of materials
		M15	vibrations/weakness (low cycle)
		M16	vibrations/weakness (high cycle)
		M17	tension/bracing (statical)
			thermal
		T00	superheat/warm up
		T01	undercool/cool down
		T02	alternating thermal stress
		T03	welded together
		T04	fusion/soldered off
		T05	

Key	Group	Code	Text
07	2	E00	electrical
		E01	overvoltage/overcurrent
		E02	undervoltage/voltage collapse
		E03	increase of isolation resistance/contact resistance/interruption
		E04	worsening of isolation/short circuit/arc
		E05	deviation of frequency
		E06	faulty electrical or electronical part
		E07	drift
		E08	influence of magnetic fields
		E09	influence of electromagnetic fields
		E10	shut down by protection (only if primary trigger)
		C00	chemical
		C01	corrosive
		C02	chemical contamination
		C03	chemical reaction (direct proceeding)
		C04	resinous
		C05	dissolve/disintegration
		C06	unsuitable condition for chemical reactions
		C07	influence of smoke/steam/dust
		C08	explosion/detonation
		H00	hydraulic/pneumatic
		H01	loss of pressure
		H02	inclusion of gas
		H03	hit by water
		H04	inclusion of liquids
		H05	turbulence
		H06	hit by condensation
		H07	vibrations induced by flow
		H08	pressure impulse
		H09	pulsation

Key	Group	Code	Text
07	2	N00	normal operating loading
		X00	leading not clear
		Y00	other loadings not analyzed
		Z00	other loadings respectively not applicable

Advice: The best profit from this key will be achieved, if attributes of all 3 groups are used, but the number of attributes are reduced in each group to the reasonable necessary.

18.9 Event characteristic key 8 “Damage”

Key	Group	Code	Text
08	1		scene of failure
		A0	soil
		A1	loose deposit
		A2	moisten/soak/flood
		A3	mud-caked/slag/oversalt/agglomeration
		A4	freeze
		A5	clog
		A6	impurity
		A7	radioactive contamination
		B0	weakness of material
		B1	Surface milling
		B2	channel/notch
		B3	punctual removal of material
		B4	incipient crack/hairline crack
		B5	inclusion/shrinkhole/pore
		B6	lamination
		B7	porosity
		C0	deformation of material
		C1	extension/stretching
		C2	compression/pinch
		C3	twist/buckle
		C4	torsion
		C5	Enlargement
		C6	bump out/in
		C7	being oval
		D0	change of position
		D1	loosening
		D2	dissolve
		D3	squeeze/fit tightly
		D4	displace/disarrange
		D5	impermissible tolerance

Key	Group	Code	Text
08	1	E0	change of material characteristics
		E1	textural changes
		E2	change of concentration
		E3	change of viscosity
		E4	anneal/burn/scorch
		E5	rot
		E6	dry up
		E7	embrittlement by neutrons
		F0	separation of material
		F1	break/pull off
		F2	shear off
		F3	fissure/hole
		F4	smelt/anneal/cease glowing
		F5	electrical interruption
		F6	destruction
		G0	electrical change of material
		G1	short circuit
		G2	electrical interruption
		G3	contact resistance
		G4	electronic malfunction
		H0	fit tightly
		H1	fusion
		H2	sticking together
		J0	other deviation from setpoint
		J1	missing part
		J2	wrong part
		J3	faulty software
		K0	other change of material characteristics
		K1	dissociation
		K2	become muddy
		S0	no expression of failure
		X0	failure not clear
		Y0	failure not analyzed
		Z0	other expression of failure

Event characteristic key 9 “Recognition of failure”

Key	Group	Code	Text
09	1		occasion of recognition
		A0	request of system/component
		B0	request to an functional check
		C0	supervision in a control room
		C1	observation of a parameter
		C2	fault indignation
		C3	response of protective device
		D0	inspection/observation on the scene of action
		E0	inspection
		F0	recurrent check of status
		G0	check caused by technical reflection/operational experiences
		H0	maintenance/restauration/functional test after work
		J0	phase before operation

Key	Group	Code	Text
09	2		expression of failure
		A00	failure symptoms
		A01	noise
		A02	smell
		A03	fire/smoke
		A04	heat
		A05	discoloring
		A06	burn/scorch/char/burn out
		A07	pollution/clog/making muddy/contamination
		A08	freeze
		A09	leakage
		A10	moistening/soak/flood
		A11	vibration
		A12	loosen/dissolve of connection
		A13	repressive/blocking
		A14	displacement/dislocation/deformation
		A15	removal of material/weakness of material
		A16	breaking/snap/burst
		A17	electrical disconnection/interruption
		A18	arc
		A19	missing/wrong assembled part
		A20	wrong position of switches/armatures
		A99	other symptoms of failure

Key	Group	Code	Text
09	2	BB0	Functional defect
		BB1	Functional failure on request
		BB2	Functional change during actuation
		BB3	Characterization of function parameters
		BB9	Other functional deficiencies
		CC	deviation of measured variables and variables of status
		CD	
		CE	density
		CF	electrical variable
		CG	flow/flow rate (volume/mass flow)
		CH	distance/length/direction of rotation
		CI	time
		CJ	level
		CK	humidity
		CL	pressure/difference of pressures
		CM	quality variables
		CN	(analysis, material characteristics)
		CO	radiation variable
		CP	speed/revolutions/frequency (mechanical)/
		CQ	acceleration
		CR	temperature
		CS	combined variable
		CT	viscosity
		CU	force of weight/mass
		CV	neutron flux
		CW	vibrations/stretching
		CX	other measured and status variables
		CY	(also control, regulation, protection)
		CZ	
		Z00	other expressions of failure

Advice: consider the different types of coding (ANN/AAN/AA). the “expression of failure” (group 2) is the first recognition of deviation from the normal status of operation; perceptible/noticeable by human sense organs or by measuring instruments.

18.10 Event characteristic key 10 “Maintenance form”

Key	Group	Code	Text
10	1		maintenance method
		A	only switching (operation, control executed, no other measures)
		B	only inspection
		C	cleaning, flushing, draining, ventilation, decontamination
		D	supplement, fill up
		E	change
		F	adjust, readjust, calibrate, recalibrate
		G	restaurating repair
		H	exchanging repair
		J	changing, modification
		K	software works
		Z	other maintenance method

18.11 Event characteristic key 11 “Measures against recurrence”

Key	Group	Code	Text
11	1		measures against recurrence
		A00	no measures (only repair of failure/damage)
		A10	measures were started during a former similar event
		A20	measurements in preparation
		B00	change in production/construction
		B10	development
		B20	planning/construction
		B30	production
		B40	check/quality assurance department (change of check list)
		B50	transport/storage
		B60	assembling
		B70	commencement of operation
		C00	preventive maintenance
		C10	change of frequency and contents of checks and inspections
		C20	change of maintenance
		C30	change of supervision
		C40	change of transport and storage
		D00	check of similar equipment

Key	Group	Code	Text
11	1	E00	change/modification of plant
		E10	change/modification – other types
		E11	component
		E12	equipment
		E13	aggregate
		E14	unit/system/plant
		E20	change/modification – other materials
		E30	change/modification – other construction
		E40	change/modification – other dimensioning
		E50	change of operation (not E10 to E40)
		E51	supervision
		E52	control
		E53	regulation (also gradients/parameters)
		E54	protection
		E55	operation
		E56	auxiliary substances/ lubri- cants/fuels
		F00	change of organization
		F10	training of employees
		F20	continuation organization
		F21	personnel
		F22	responsibility
		F23	structure
		F30	documentation
		F40	implement quality management measures
		F41	inspection plans
		F42	quality management system
		Z00	other measures

Event characteristic key 12 “Urgency of measures”

Key	Group	Code	Text
12	1		urgency of starting activities
		A	start of activities at once
		B	start of activities within 3 days
		C	works with fixed date
		D	works with free planable date
		E	works must be done during next outage
		F	works must be done during next revision
	2		personal engagement
		1	optimized personal engagement concerning minimal duration of measures
		2	personnel activities during normal working hours

Advice: For using this key it is necessary to adjust the data's with the input of registration systems of maintenance.

19 Use of the technical assessment of energy conversion plants for the electricity market and grid safety

The grid operator needs data from the power plant operators for its processes to ensure system security.

The 'undispatchability' is for him important in addition to the data related to the use of the unavailability. Figure 33 shows the grid operators/electricity market point of view. For this purpose, the power plant operator can use the analytics described in this issue for availability and unavailability.

Providing data to the grid operator to determine the system's security, according to its dispatchability definition (from the power plant operator's point of view is this technical availability) enables the grid operator to meet its requirements for system management of the energy system.

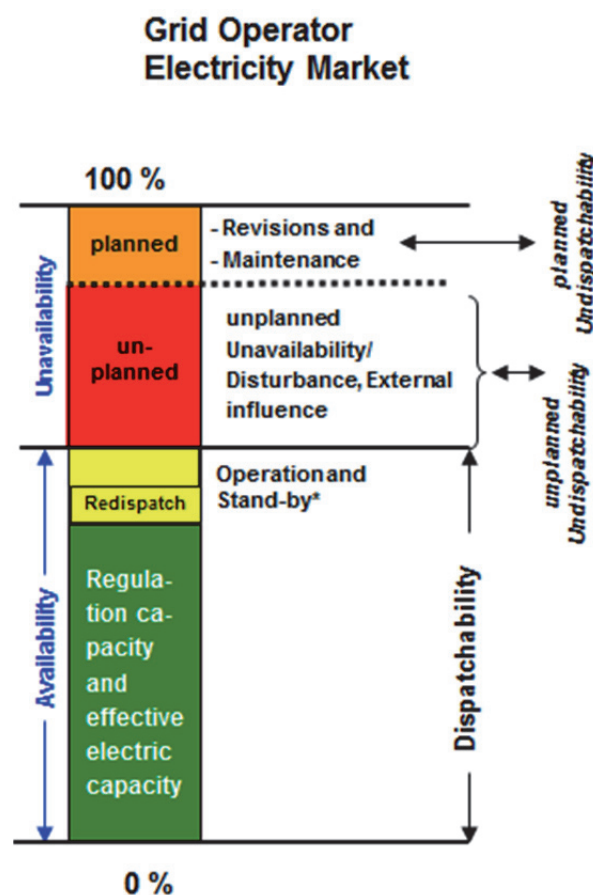


Figure 33: Analysis levels unavailability, availability dispatchability (reference net) / BDEW.

In the data delivery of the power plant operator to the grid operator, it should be noted that a planned undispachability/unavailability means all incidents at a power plant (revision, repair) in the future. Unplanned undispachability/unavailability is an incident for the network operator that has already entered the power plant.

Furthermore, as described above, the performance terms are defined differently by the grid operator from his perspective. This fact is illustrated in Figure 34, Figure 35 and Figure 36.

20 Examples of use

20.1 Example 1: “Unplanned not available load reduction”

No. of event:	00000000142
Unit:	KW A, Block P
KKS designation:	P OCAA 20
Start of event:	30.07.2007 10:49
End of event:	30.07.2007 20:32

EMS:

Key		Group		Characteristic	
No.	Text	No.	Text	Code	Text
01	Type of event	1	Type of event	A2	damage
02	Operational status before beginning of event	1	Operating status	B4	Full load
04	Impact on unit	1	Time frame	C	Ordered of shut down
		2	Main effect	2	Load limitations
06	Cause	1	Origin	F1	In function
07	Failure mechanism	1	Type of damage	E0	Fatigue
09	Detection of outage	1	Mode of detection	C2	Malfunction information
		2	Expression of outage	CF	Anomaly of performance.

Not available electrical capacity: 180 MW

Description:

Failure of condensate pump, because declutch of spindle in condensate regulation valve (protective interlocking).

20.2 Example 2: “Blackout”

No. of event:	00000000086
Unit:	KW B, Block A
KKS designation:	A 0BAT 01
Start of event:	02.06.2007 03:17
End of event:	02.06.2007 18:09

EMS:

Key		Group		Characteristic	
No.	Text	No.	No.	Text	No.
01	Type of event	1	Type of event	A2	Damage
02	Operational status before beginning of event	1	Operating status	B4	Full load
04	Impact on unit	1	Time frame	A	Automatic scram
		2	Main effect	4	Shutdown
06	Cause	1	Origin	D1	Montage
07	Failure mechanism	1	Type of damage	V0	Prematured deterioration
09	Detection of outage	1	Mode of detection	C3	Protection activated
		2	Expression of outage	CE	Electrical anomaly

Not available electrical capacity: 840 MW

Description:

Failure in insulation bushing of generator transformer.

20.3 Example 3: “Unplanned not available block unavailability”

No. of event:	00000000820
Unit:	KW C, Block C, Dampfkessel 2
KKS designation:	C 2HAH
Start of event:	07.09.2007 06:14
End of event:	08.09.2007 15:00

EMS:

Key		Group		Characteristic	
No.	Text	No.	Text	No.	Text
01	Type of event	1	Type of event	A2	Damage
02	Operational status before beginning of event	1	Operating status	B4	Full load
04	Impact on unit	1	Time frame	C	Manual shutdown
		2	Main effect	4	Shutdown
06	Cause	1	Origin	D1	Assembling
07	Failure mechanism	1	Type of damage	V0	Prematured deterioration
09	Detection of outage	1	Mode of detection	D0	Inspection
		2	Expression of outage	A01	Noise

Not available electrical capacity: 250 MW

Description:

Damage of boiler, high pressure overheater 2-outlet, welded seam-pore.

20.4 Example 4: “Blackout after faulty operation”

No. of event:	00000000321
Unit:	KW C, Block A, Dampfkessel 2
KKS designation:	A 2H
Start of event:	06.04.2007 10:52
End of event:	06.04.2007 11:18

EMS:

Key		Group		Characteristic	
No.	Text	No.	Text	No.	Text
01	Type of event	1	Type of event	A1	Malfunction without damage
02	Operational status before beginning of event	1	Operating status	B4	Full load
04	Impact on unit	1	Time frame	A	Autom. Scram
		2	Main effect	4	Shutdown
06	Cause	1	Origin	F0	Operation
07	Failure mechanism	1	Type of damage	W0	No damage
09	Detection of outage	1	Mode of detection	D0	Observation
		2	Expression of outage	CE	Electrical anomaly

Not available electrical capacity: 250 MW

Description:

Failure in operating because of mixing miniature circuit breakers while switching off of a control voltage.

20.5 Example 5: “BDEW”

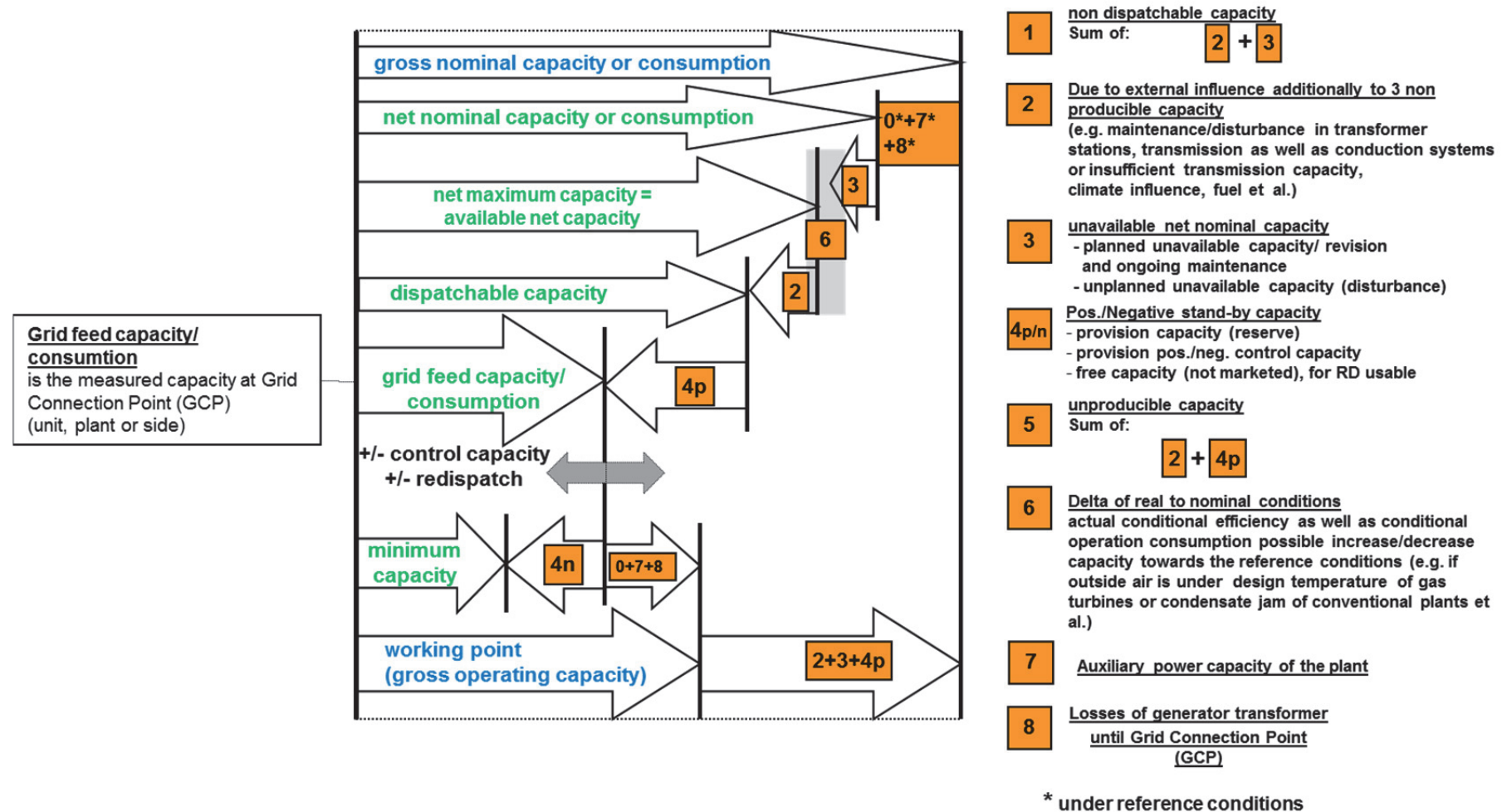


Figure 34: BDEW.

20.6 Example 6: “Capacity terms of technical resource / BDEW”

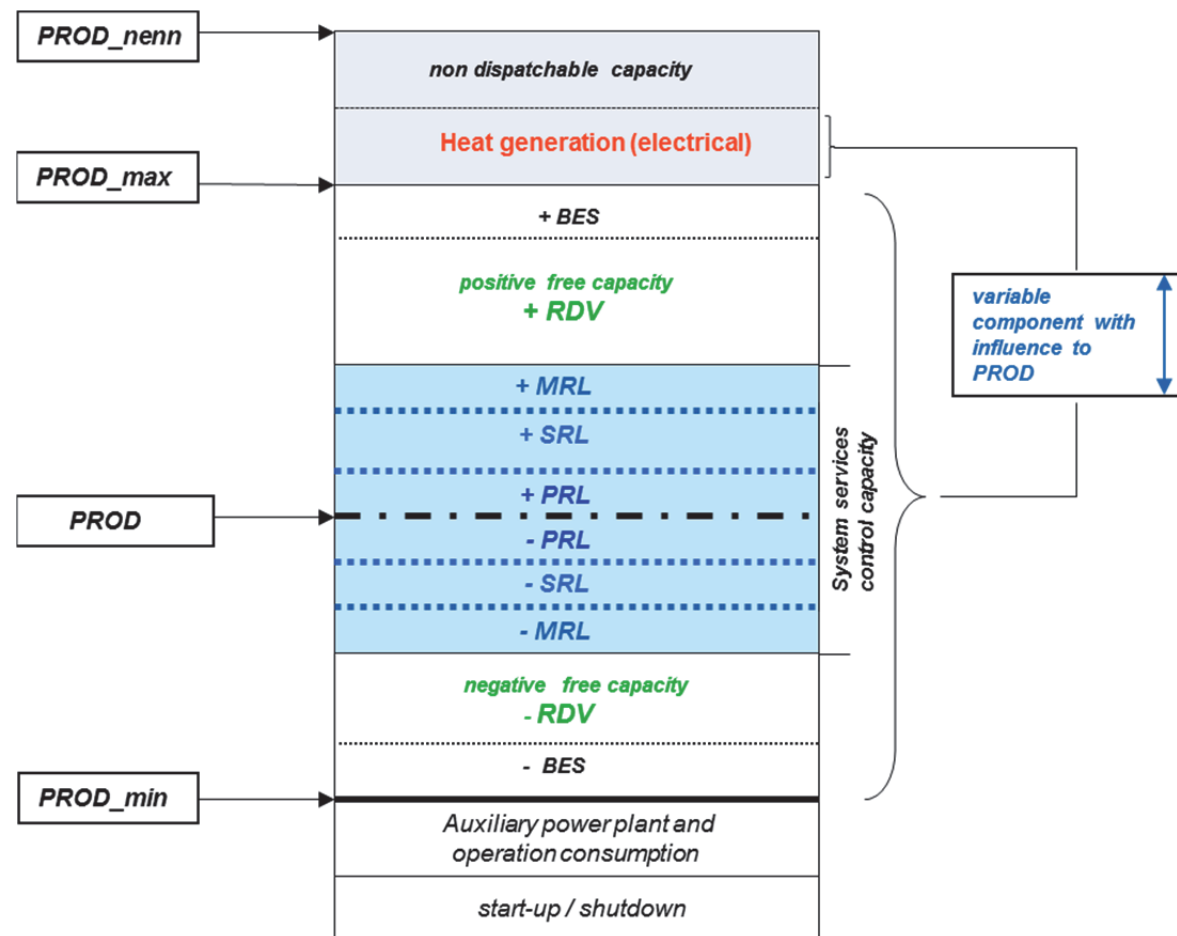


Figure 35: Overview on the relation of capacity values of a technical resource (generator/pump) obtained on the grid connection point.

20.7 Example 7: “Capacity terms Power Plant Object / PPO of hydro pumped storage power plant / BDEW”

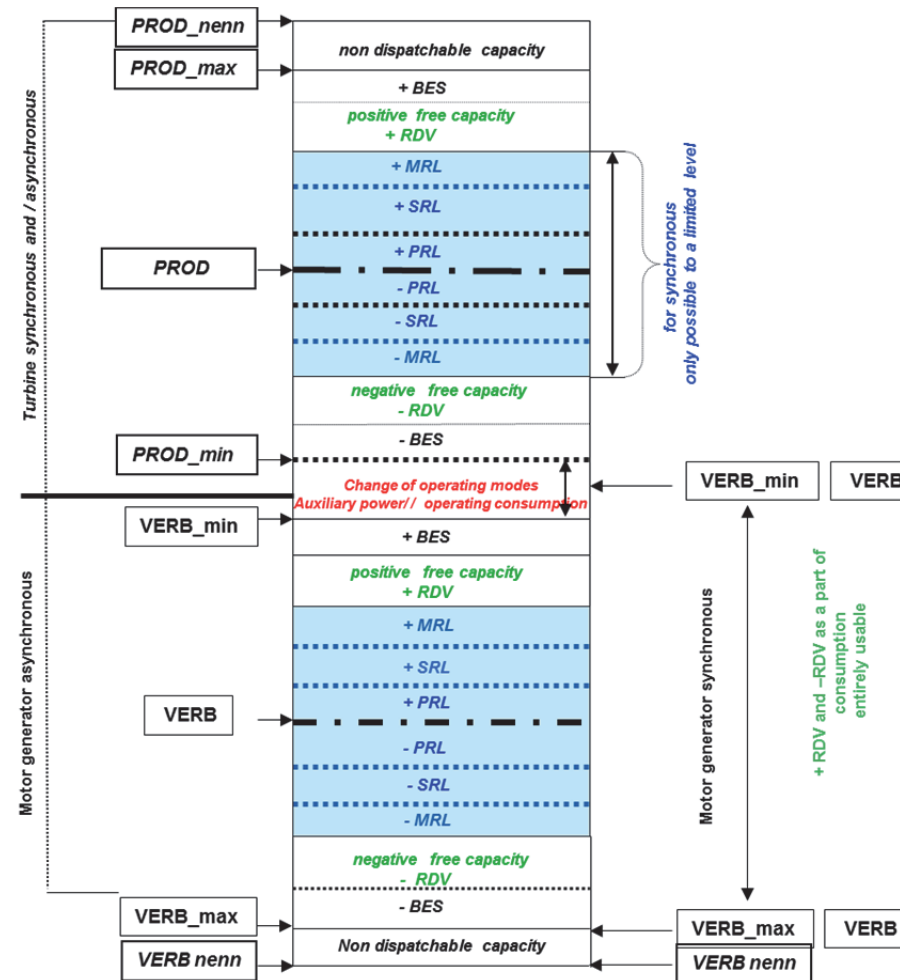


Figure 36: Capacity terms Power Plant Object / PPO of hydro pumped storage power plant / BdeW.

List of abbreviations

CHP	Combined heat and power generation
CO ₂	Carbon dioxide
UA	Unavailability
EEX	European Energy Exchange
BImSchV	Federal Immission Control Ordinance
WANO	World Association of Nuclear Operators
EMS	Event-Characteristics-System
KKS	Power Plant Classification System
RDS-PP	Reference Designation System for Power Plants
KISSY	Power Plant Information System
GuD	Gas and Steam
SMS	Damage-Characterisation-System
GRS	Company for plant and reactor safety (Gesellschaft für Anlagen- und Reaktorsicherheit)
VDEW	Association of the Electricity Industry

List of Figures and Tables

Figure 1:	Analysis level unavailability, availability, dispatchability (reference level net).	18
Figure 2:	Operating diagram and performance indicators.	20
Figure 3:	Classification of unavailability.	22
Figure 4:	Hierarchy of definitions (survey).....	40
Figure 5:	Diagram of time-related terms.....	42
Figure 6:	Example for the determination of the nominal capacity due to the correlation between operating capacity and cooling water inlet temperature.....	52
Figure 7:	Capacity Terms' of energy conversion plants.	53
Figure 8:	Terms for energy- and heat operated plants.	54
Figure 9:	Capacity terms of hydro pumped storage power plant.	55
Figure 10:	Interconnection point in the data exchange between Operator, Grid Operator.	56
Figure 11:	Diagram of energy-related definitions.	57
Figure 12:	Factual delimitation of power plant systems.....	63
Figure 13:	Example for the determination of the unavailability with the simultaneous presence of a planned (e. g. repeated testing) and an unplanned partial unavailability (e. g. leakage).	65
Figure 14:	Example for the determination of the unavailability with the simultaneous presence of a planned unavailability (e.g. revision) and an unplanned event (e. g. turbine emergency trip).....	65
Figure 15:	Example for the determination of the unavailability with the simultaneous presence of an unplanned unavailability (e. g. turbine emergency trip) and an external influence (e.g. stretch-out-operation with nuclear power plants)	66
Figure 16:	Example for the determination of the unavailability with the simultaneous presence of an unplanned partial unavailability (e. g. feed water pump failure), an external influence (e. g. cooling water temperature beyond design) and a stand-by (e. g. lack of load). ..	66
Figure 17:	Extension of a planned unavailability due to a damage.	69
Figure 18:	Co-Generation plant (CHP) with an extraction condensing turbine, case a.	73
Figure 19:	Co-generation plant (CHP) with an extraction condensing turbine, case b.	74
Figure 20:	Co-generation plant (CHP) with an extraction condensing turbine, case c.....	75
Figure 21:	Advancing of a planned unavailability on the occasion of a damage.	81
Figure 22:	Example of frequency distribution [Eurelectric].	87
Figure 23:	Example of a Pareto chart.....	88
Figure 24:	Information flow for determination and revision of data.....	91

Figure 25:	Example for a possible examination depth of the unavailability analysis.	92
Figure 26:	Unavailable event “incipient crack at evaporator pipe”.....	98
Figure 27:	Unavailability over several capacity levels	99
Figure 28:	Failure of a draft fan and of the generator during capacity operation.	99
Figure 29:	Possibilities of evaluation.	101
Figure 30:	Screen ‘Select type of plant/unit’	104
Figure 31:	Example of yearly operating and availability data of a power plant.	104
Figure 32:	Example of unavailability incidents.....	105
Figure 33:	Analysis levels unavailability, availability dispatchability (reference net) / BDEW.	134
Figure 34:	BdEW.....	140
Figure 35:	Overview on the relation of capacity values of a technical resource (generator/pump) obtained on the grid connection point.	141
Figure 36:	Capacity terms Power Plant Object / PPO of hydro pumped storage power plant / BdEW.	142
Table 1:	Rules for the recording of event data	95
Table 2:	Encoding of event data	97
Table 3:	Key overview.....	109

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List of keywords

Availability		CHP unit.....	63, 73
definition.....	18, 20	Combined Heat and Power Generation . see	
energy	20	CHP	
market-assessed.....	25	Comparison of units	88
overview	41	Data recording.....	83
time	20	begin.....	44
Balancing energy	34	Definitions	
Basic parameters	39	availability.....	20, 24
Calculation of average values.....	83	capacity-related	47
Capacity		dispatchability.....	29
auxiliary power	51	energy-related	58
available	42, 50	failure rate	36
available not dispatchable	42	hierarchy.....	41
available not in operation	42	overview	39
available unproducible	51	reliability	27
CHP unit.....	77	time-related	43
definitions.....	47	unavailability.....	22
diagram conversion plants.....	54	utilization	33
diagram energy/heat.....	55	Dispatchability	27, 30, 31
diagram hydro	56	overview	41
dispatchable.....	50	Energy	
equivalent electrical	77	availability.....	25, 78, 85, 87
external influence..... see capacity, available		available	42, 59
not dispatchable		available not generated.....	42, 60
external influences	70	available unproducible	42, 60
fluctuations.....	68	balancing	34
generated.....	50	dispatchable	59
gross	50	excess	68
net	51	failure rate	36
nominal	42, 77	generated	59
nominal capacity	see Nominal capacity	nominal.....	42
restrictions.....	70	nominal energy.....	see Nominal energy
schedule.....	51	not postponable.....	42, 61
stand-by	51	peak-times.....	59
unavailable.....	42, 52	planned.....	42, 61

postponable	42, 61	KISSY see Power Plant Information System	
reliability	27	Mothballing	71
schedule	59	Nominal	
stand-by	60	capacity	48
unavailable	42	energy	59
unplanned	42, 61	Operating	
unavailable	60	capacity	42
utilization	34, 78, 85, 87	energy	42
Event characteristic key	109, 138	operation	41
External influence		stretch-out/ stretch-in	67, 71, 80
climate	72	time	42, 85
definition	70	Pareto-Diagram	88
dispatcher	22	Perzentile-Diagram	88
fuel	71	Point of transfer	57
grid related restrictions	72	Power Plant Information System	
hierarchy	65	data collection	104
other matters	73	evaluation	106
shortage of personnel	72	Profit margin	68
External influence energy	see Energy, available unproducible	Reference period	44
External influence time	see Time, not dispatchable	Regulations	63
Failure rate	22, 36	Reliability	
Grid connection point	57	unplanned	27, 29
Hierarchy	65	Retrofitting measures	70
Indicators		Rules	63
availability	18, 24	Schedule	
CHP	38	capacity	51
CO ₂	38	compliance	30
diagram	21	power plant	68
failure rate	36, 37	Special Regulations	
other	38	flue gas cleaning	80
overview	19, 39	missing operating permit	81
reliability	27	nuclear power plants	80
start-up rate	79	Stand-by	41, 65
UAGS	32	Start-up reliability	22, 28
utilization	33	Successful start-up rate	79
		Supply reliability	
		market-assessed	28, 68

Terms		Unavailability	
energy	58	advancing of planned	82
hierarchy	41, 42	analysis	90
Time		classification	22, 23
availability	24, 85, 87	energy	26
available	42, 44	evaluation	101
available not dispatchable	45	extension	69
available time not in operation	45	external influence	70
begin date	44	falling below	69
definitions	43	hierarchy	65
during peak-times	44	not postponable	23
end date	44	overview	41
failure rate	36	planned	23, 65
nominal	42	postponable	23
not dispatchable	42	recording	93 , 95
not postponable	42, 46	time	26
operating	42, 45	unplanned	23, 65
peak-times	44	Undispatchability	see Unavailability
planned	46	Utilization	
postponable	42, 46	calculation	22
reference period	see Reference period	definition	33
reliability	27	duration	85
stand-by	45	energy	20
.....	42, 46	market-assessed	35
unplanned	46	Variable costs	68
utilization	33, 85, 87	VGB Guideline 140	90

