VGB POWERTECH

VGB-Standard
Annex to VGB-S-002 Series

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VGB-S-002-33-2016-08-EN

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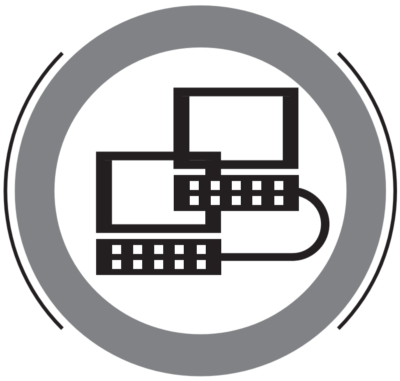

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Treatment of proposing amendments

Amendments can be sent to the e-mail address vgb.standard@vgb.org. The subject line should contain the exact specification of the relevant document in order to clearly assign the e-mail content to the appropriate VGB-Standard.

Table of Revision

VGB-Standard	Date of Revision	Chapter	Description
VGB-S-002-Annex	October 2015		Original

Preface

The inclusion of new definitions and the development of current needs fulfilling indicators in the VGB bodies was always based on extensive discussions between technical representatives of member companies and on illustration of the issues discussed supported by diagrams and examples. These have so far been left out of count when publishing the final agreed definitions and indicators. However, following publications, we often receive questions regarding the practical usage of the standards.

With the present supplemental booklet, the authors want to give the reader of the VGB-Standard 'Technical and Commercial Key Indicators for Power Plants' VGB-S-002-03-EN insight into these examples, and further explanations on practical applications. It is a collection of examples and explanations from the above definition and development phase, from daily practice in handling operational data of power generation facilities and for data maintenance and evaluation in the VGB Power Plant Information System KISSY.

The supplemental booklet is an open document. This means that we expect to release new versions, reflecting new and changed indicators, as well as further examples and explanations. The publication is always carried out as a freely available electronic document in PDF format in the download area of VGB PowerTech e.V.

The VGB Performance Indicators committee welcomes criticism, suggestions and proposals for further improvement. Please feel free to contact us through (KISSY@vgb.org).

Contents

Input and Output Forms

Data sheet of availability (monthly)

Electronic templates: https://www.vgb.org/en/kissy_templates.html

Data sheet for reporting to VGB Stand 10/2012	**Monthly Operating and Availability Data for Nuclear Power Plants**	Year: 2015 Month: 02

Nuclear power plant:	**KKW Essen**	**) Based on:
Gross nominal power [MW]:	(*) 1,430	g = gross values
net [MW]:	(*) 1,360	n = net values x
Nominal Time [h]	(*) 696	
Nominal Energy [MWh]	(*) 946,560	

Operating Data				**Dimension**	**Month**	**Year**
Energy generated	**gross**		(*)	MWh	968,969.40	2,001,211.80
	net		(*)	MWh	916,696.40	1,895,621.70
	thereof steam/traction power production			MWh	0.00	0.00
Energy utilization				%	96.85	96.79
Unavailable energy (***)				MWh	172.00	451.00
	planned (target)			MWh		
	planned (actual)		(*)	MWh	172.00	451.00
	Extensions of planned unavailabilities (1)			MWh		
	unplanned (total)			MWh	0.00	0.00
	postponable		(*)	MWh	0.00	0.00
	not postponable		(*)	MWh	0.00	0.00
Available but not producible energy (external influences) (2)				MWh	0.00	0.00
Energy availability				%	99.98	99.98
Dispatcher failure rate		unplanned		%	0.00	0.00
		not postponable		%	0.00	0.00
Energy failure rate		unplanned		%	0.00	0.00
		not postponable		%	0.00	0.00
Load dispatcher reliability		unplanned		%	100.00	100.00
		not postponable		%	100.00	100.00
Energy reliability		unplanned		%	100.00	100.00
		not postponable		%	100.00	100.00
Operating time			(*)	h	696.00	1,440.00
Time utilization				%	100.00	100.00
Unavailability time (***)				h	0.00	0.00
	planned		(*)	h	0.00	0.00
	unplanned		(*)	h	0.00	0.00
Time availability				%	100.00	100.00
Thermal generation				MWh_{th}	2,635,919.00	5,442,852.00
Electric peak load				MW	1,370.00	1,378.00

(***) Classification of unavailability (UA)

planned UA	Start and duration of UA have more than four weeks shall be determined before entry.
unplanned UA	The beginning of the UA isn' t or movable to four weeks.
postponable	The beginning of the UA is more than 12 hours moved to four weeks.
not postponable	The beginning of the UA isn' t or displaceable to 12 hours.

(1) Any exceedance of the target date of a planned unavailability, and unplanned extensions

(2) is only calculated if unavailability events have been reported

Remark Code:	
refuelling:	stretch out:
revision:	stretch in:
repair:	steam production:
traction power:	new nominal power:

Important Notes
(et al. stretch-out / stretch-in operation, refuelling, regulatory compliance, load-following operation, major modifications / changes, excellent operational events)

Created: 20.04.2016 11:11 Verified:

(*) mandatory fields calculated fields

Data sheet of annual availability for thermal power plants

Electronic templates: https://www.vgb.org/en/kissy_templates.html

Data sheet for reporting to VGB		Availabilty													VGB Status 10/2012
Utility:	**VGB PowerTech e.V.**			**Power Plant:**	**PowerTech**						**Time range: 2015**				
for fossil fired units and gas turbines															
	1	2	3	4	5	6	7	8	9	10		11	12	13	14
				Energy Utilization, Energy Availability											
							Unavailable Energy (***)								
	Block/ Unit No.	**Nominal Power** (*)	**Nominal Time** (*)	**Nominal Energy** (*)	**Energy Generated** (*)	Energy Utilization	planned Target	planned **Actual** (*)	**unplanned post-ponable** (*)	**unplanned not post-ponable** (*)	unplanned total (columns 9+10)	total (columns 8+9+10)	Extensions of planned unavaila-bilities (1)	Energy Availability	Available but not producible energy (external influences) (2)
		MW	h	GWh	GWh	%	GWh	GWh	GWh	GWh	GWh	GWh	GWh	%	GWh
(**)		P_N	t_N	$W_N = P_N * t_N$	W_B	$n_W = \frac{W_B}{W_N}$	$W_{nv\ p}$	$W_{nv\ p}$	$W_{nv\ ud}$	$W_{nv\ un}$	$W_{nv\ u}$	W_{nv}		$k_W = \frac{W_N - W_{nv}}{W_N}$	W_{ns}
n	A	1,000	4,380	4,380.0	1,752.0	40.0	0.0	0	0	0	0	0.0	0.0	100.0	0.0

(***) Classification of unavailability (UA)

planned UA	Start and duration of UA have more than four weeks shall be determined before entry.
unplanned UA	The beginning of the UA isn' t or movable to four weeks.
postponable	The beginning of the UA is more than 12 hours moved to four weeks.
not postponable	The beginning of the UA isn' t or displaceable to 12 hours.

(1) Any exceedance of the target date of a planned unavailability, and unplanned extensions

(2) Available not producable energy based on influences outside the plant

**) Based on: g = gross values, n = net values

(*) mandatory fields

calculated fields

Data sheet for reporting to VGB	Availabilty																VGB Status 10/2012
Utility: VGB PowerTech e.V.				Power Plant: PowerTech										Time range 2015			
for fossil fired units and gas turbines												for power plants/gas turbines	only for gas tubines				
1	16	17	18	19	20	21	22					23	23	24	25		
	Time Utilization, Time Availability												Start Reliability				
Block/ Unit No.	Operating Time (*)	Time utilization	Unavailability Time (***) planned (*)	unplanned (*)	total (*)	Time Availability	During the reporting perid used fuel Part of generation (*)					Number of Starts	Number of Starts successful	not successful	Start Reliability	Number of Unplanned Automatic Grid Separations	Unplanned Automatic Grid Separation UAGS7
	h	%	h	h	h	%	%								%		
	t_B	$n_t = \frac{t_B}{t_N}$	$t_{nv\ p}$	$t_{nv\ u}$	$t_{nv} = t_{nv\ p} + t_{nv\ u}$	$k_t = \frac{t_N - t_{nv}}{t_N}$	hard coal	lignite	oil	gas	refuse derived fuel	a	s_e	s_n	$z = \frac{s_e}{s_e + s_n}$	P0	$= \frac{P0 * 7000}{t_B}$
A	4,380	100.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0	10	0	0	0.0	0	0.0

(***) Classification of unavailability (UA)

planned UA	Start and duration of UA have more than four weeks shall be determined before entry.
unplanned UA	The beginning of the UA isn' t or movable to four weeks.
postponable	The beginning of the UA is more than 12 hours moved to four weeks.
not postponable	The beginning of the UA isn' t or displaceable to 12 hours.

Note to 'For Plants/Gas turbines' (column 23 to 25): enter data only if 'successful' as well as 'unsuccessful' start-ups have been recorded.

(*) mandatory fields
calculated fields

Data sheet for reporting to VGB				**Availabilty**					VGB Status 10/2012
Utility:	**VGB PowerTech e.V.**			**Power Plant:**	**PowerTech**			**Time range 2015**	
for fossil fired units and gas turbines									
1	27	28	29	30	31	32	33	34	26
Block/ Unit No.	Failure Rate				Reliability				Comment
	Dispatcher failure rate		Energy failure rate		Load dispatcher reliability		Energy reliability		
	unplanned total	unplanned not postponable	unplanned total	unplanned not postponable	unplanned total	unplanned not postponable	unplanned total	unplanned not postponable	
	%	%	%	%	%	%	%	%	
	$p_{lu} = \frac{W_{nv\,u}}{W_B + W_{nv\,u} + W_{ns}}$	$p_{lun} = \frac{W_{nv\,un}}{W_B + W_{nv\,un} + W_{ns}}$	$p_{w\,u} = \frac{W_{nv\,u}}{W_B + W_{nv\,u}}$	$p_{w\,un} = \frac{W_{nv\,un}}{W_B + W_{nv\,un}}$	$p_{v\,u} = \frac{W_B}{W_B + W_{nv\,u} + W_{ns}}$	$p_{v\,un} = \frac{W_B}{W_B + W_{nv\,un} + W_{ns}}$	$w_{v\,u} = \frac{W_B}{W_B + W_{nv\,u}}$	$w_{V\,un} = \frac{W_B}{W_B + W_{nv\,un}}$	
A	0.0	0.0	0.0	0.0	100.0	100.0	100.0	100.0	

(*) mandatory fields
calculated fields

Data sheet of annual availability of hydro power plants

Electronic templates: https://www.vgb.org/en/kissy_templates.html

Data sheet for reporting to VGB						Availabilty								VGB Status 07/2012	
Utility:	VGB PowerTech e.V.					Power Plant: Essen						Time range: 2015			
for Hydro Power Plants															
	1	2		3	6	7	8	9	10	11	12	13	14	15	16
					Operating Time, Number of Changes of Operating Type										
	Machine Set No.	Nominal Capacity		Nominal Time	Operating Time					Number of Changes of Operating Type					Number of Unplanned Automatic Grid Separations
		Turbine (*)	Pump	(*)	Turbine (*)	Pump	Phase Shifter	Hydraul. Short Circuit	Total	Turbine	Pump	Phase Shifter	Hydraul. Short Circuit	Total	
		MW	MW	h	h	h	h	h	h						
(**)		$P_{N\ Tu}$	$P_{N\ Pu}$	t_N	$t_{B\ Tu}$	$t_{B\ Pu}$	$t_{B\ Ph}$	$t_{B\ hy}$	t_B	a_{Tu}	a_{Pu}	a_{Ph}	a_{hy}	a	P_0
	A	265	290	8,760	2,494.0	2,610.0	38.0	0.0	5142.0	711	396	156	0	1,263	0
	B	265	290	8,760	1,966.0	1,697.0	92.0	0.0	3755.0	895	368	484	0	1,747	0
	C	265	290	8,760	1,836.0	1,481.0	82.0	0.0	3399.0	816	319	402	0	1,537	0
	D	265	290	8,760	2,194.0	3,991.0	30.0	0.0	6215.0	463	353	172	0	988	0

**) Based on: g = gross values
n = net values

(*) mandatory fields
calculated fields

Data sheet for reporting to VGB					Availabilty											VGB Status 07/2012	
Utility:	**VGB PowerTech e.V.**					**Power Plant:**	**Essen**						**Time range: 2015**				
for Hydro Power Plants																	
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Machine Set No.	**Time Utilization, Time Availability**																
	Time Utilization			Unavailability Time (***) Turbine/Generator					Pump					Available but not producible hours (External Influences)	Time Availability		
	Turbine	Pump	Total	**planned** (*)	unplan-ned	**unplanned postponable** (*)	**unplanned not postponable** (*)	Total	planned	unplan-ned	unplanned postponabl e	unplanned not postponabl e	Total		Turbine	Pump	Total
	%	%	%	h	h	h	h	h	h	h	h	h	h	h	%	%	%
	$n_{tTu}=\frac{t_{BTu}}{t_N}$	$n_{tPu}=\frac{t_{BPu}}{t_N}$	$n_t=\frac{t_B}{t_N}$	$t_{nv\ p\ Tu}$	$t_{nv\ u\ Tu}$	$t_{nv\ ud\ Tu}$	$t_{nv\ un\ Tu}$	$_{Tu}=t_{nv\ p\ Tu}+t_{nv\ u}$	$t_{nv\ p\ Pu}$	$t_{nv\ u\ Pu}$	$t_{nv\ ud\ Pu}$	$t_{nv\ un\ Pu}$	$_{Pu}=t_{nv\ p\ Pu}+t_{nv\ u}$	$W_{ns\ h}$	$k_{tTu}=\frac{t_N-t_{nvTu}}{t_N}$	$k_{tPu}=\frac{t_N-t_{nvPu}}{t_N}$	$k_t=\frac{t_N-t_{nv}}{t_N}$
A	28.5	29.8	58.7	744.0	13.0	7.0	6.0	757.0	745.0	34.0	12.0	22.0	779.0	1.0	91.4	91.1	91.2
B	22.4	19.4	42.9	743.0	26.0	8.0	18.0	769.0	743.0	26.0	8.0	18.0	769.0	0.0	91.2	91.2	91.2
C	21.0	16.9	38.8	1,194.0	1.0	0.0	1.0	1,195.0	1,192.0	5.0	4.0	1.0	1,197.0	3.0	86.4	86.3	86.3
D	25.0	45.6	70.9	1,142.0	28.0	4.0	24.0	1,170.0	1,142.0	28.0	4.0	24.0	1,170.0	1.0	86.6	86.6	86.6

(***) Classification of unavailability (UA)

planned UA	Start and duration of UA have more than four weeks shall be determined before entry.
unplanned UA	The beginning of the UA isn't or movable to four weeks.
postponable	The beginning of the UA is more than 12 hours moved to four weeks.
not postponable	The beginning of the UA isn't or displaceable to 12 hours.

(*) mandatory fields
calculated fields

Data sheet for reporting to VGB	Availabilty	VGB Status 07/2012
Utility: VGB PowerTech e.V.	**Power Plant:** Essen	**Time range: 2014**

for Hydro Power Plants

	34
Machine Set No.	Remarks
A	
B	
C	
D	

(*) mandatory fields
calculated fields

Example for input of ‘Unavailability incidents of fossil-fired units’

Electronic templates: https://www.vgb.org/en/kissy_templates.html

(*) mandatory fields calculated fields

Data sheet for reporting to VGB	Unavailability Incidents			VGB Status 10/2012
Utility: VGB PowerTech e. V.	Power Plant: Essen	Unit No.: 2	Nominal Power: 200	**Time range 2015**

Unavailability incidents (total and partial failures of units/gas turbines)

gross/net	1	2	3	4	5			6	7	8	9
	Event No.	**Duration of Unavailability**		**Energy Unavail-ability**	**Reference Designation System (KKS Function)**			**Event Characteristics Key**			Brief Description
		Start (TT/MM/JJJJ; hh:mm)	**End** (TT/MM/JJJJ; hh:mm)	MWh	F 1	F 2	F 3	**Time Frame** EMS 4/1	**Type of Incident** EMS 1	**Main Impact** EMS 4/2	(Additionally to the encryption: short description of the event and naming of the affected component.)
(*)		(*)	(*)	(*)	(*)			(*)	(*)	(*)	
n	2015001	12.01.2015 13:24	12.01.2015 20:00	1,320	H	A	C	A	A1	4	Disturbance: With load admission occurred fire from "difference amount feed water about Eco " (loss by frost effect)
n	2015002	12.01.2015 20:00	14.01.2015 08:08	7,227	E	T	A	D	A2	4	During the shutdown failure of the trough chains claimant's ETA 20 because of winding-damaging of the impulse engine on account of a strain. Engine was exchanged.
n	2015003	01.02.2015 23:40	02.02.2015 15:35	795	H	F	C	C	A2	2	Max. 275 MW because plant operated with four mills. Mill 3 in repair, mill 6 unusual by "short circuit release" (engine was changed afterwards)
n	2015004	25.02.2015 18:31	26.02.2015 12:25	3,580	H	A	D	C	A2	4	Pipe scribing in the evaporator, + 27.0 m of corner mill 2, by tearing off a cam of the membrane wall guidance as a result of stretch impediment. By repair welds removes.
n	2015005	26.02.2015 12:25	26.02.2015 20:23	1,593	M	A	J	D	A2	4	Disturbance at the starting-up operation: Damaged magnet valves of the Elmopumpen-aerial emitters led to aerial burglary and thereby to unenough vacuum.
n	2015006	02.08.2015 00:00	12.08.2015 00:00	12,000				C	D2	2	Outside impact: Cooling water temperature to high
n	2015007	20.12.2015 16:20	22.12.2015 15:00	8,074	X	A	A	C	A2	2	Damage at the driving turbine TKSP, regulation beam twisted
n	2015008	23.12.2015 21:45	24.12.2015 05:30	388	P	A	C	C	A2	2	Repairing of the central cooling water pump

Example for input 'Unavailability incidents of nuclear power plants'

Electronic templates: https://www.vgb.org/en/kissy_templates.html

(*) mandatory fields calculated fields

Data sheet for reporting to VGB	Unavailability					VGB Status 10/2012
Utility: VGB PowerTech e. V.	Power Plant: Essen		Unit No.: 3	Nominal Capacity: 1000		**Time range: 2015**

Unavailability incidents (total and partial failures of units/gas turbines)

gross/net (*)	1 Event No.	2 Duration of Unavailability Start (TT/MM/JJJJ; hh:mm) (*)	3 End (TT/MM/JJJJ; hh:mm) (*)	4 Energy Unavail-ability MWh (*)	5 Reference Designation System (KKS Function) F 1 (*)	 F 2	 F 3	6 Event Characteristics Key Time Frame EMS 4/1 (*)	7 Type of Incident EMS 1 (*)	8 Main Impact EMS 4/2 (*)	9 Brief Description (Additionally to the encryption: short description of the event and naming of the affected component.)
n	2015009	12.01.2015 13:24	12.01.2015 20:00	2,112	J	D	A	J	Z0	2	control rod shut down process change or control rod pattern change
n	2015010	12.01.2015 20:00	14.01.2015 08:08	11,403	M	A	Y	J	B1	2	Scramtest, time measurement of closing of the fresh steam isolation valves, turbine check, test run food water pump C and removal of a poetry leakage in the locking steam rule valve 35V6301B.
n	2015011	07.05.2015 12:00	01.06.2015 23:00	611,000	J			K	B7	4	Refuelling and revisions
n	2015012	10.03.2015 10:14	13.03.2015 15:45	1,030	L	C	Y	C	A2	2	Disturbance in the main condensate-expiry rule valve
n	2015013	09.04.2015 03:00	09.04.2015 05:45	107	M	A	W	H	A2	2	Removal of a steam leakage in an armature in the locking steam system
n	2015014	02.10.2015 03:50	02.10.2015 05:00	500	J	R		A	A1	2	Adaptation of the reactor limitations following the nuclear power density gradient in the reactor kernel
n	2015015	27.05.2015 00:00	28.05.2015 05:00	29,000	P			C	B7	4	Repair of condenser leak
n	2015016	22.12.2015 22:30	22.12.2015 23:45	250	L	B		H	A2	2	Repairs on the armature RF24S103

Example for input ‘Unavailability incidents and temporarily overlapping incidents’

Electronic templates: https://www.vgb.org/en/kissy_templates.html

(*) mandatory fields calculated fields

Data sheet for reporting to VGB	Unavailability Incidents			VGB Status 10/2012
Utility: VGB PowerTech e. V.	Power Plant: Essen	Unit No.: 1	Nominal capacity: 250	**Time range: 2015**

Unavailability Incidents (total and partial failures of units/gas turbines)

		1	2	3	4	5			6	7	8	9
	gross/net (*)	Event No.	**Duration of Unavailability** **Start** (TT/MM/JJJJ; hh:mm) (*)	**End** (TT/MM/JJJJ; hh:mm) (*)	**Energy Unavail-ability** MWh (*)	**Reference Designation System (KKS Function)** F 1 (*)	F 2	F 3	**Event Characteristics Key** **Time Frame** EMS 4/1 (*)	**Type of Incident** EMS 1 (*)	**Main Impact** EMS 4/2 (*)	Brief Description (Additionally to the encryption: short description of the event and naming of the affected component.)
Figure 26	n	2015001	25.02.2015 !8:31	26.02.2015 !2:25	4,358	H	A	D	C	A2	4	Tube leakage boiler + 27 meter corner mill 2, caused by a ripped off cam of the membrane wall conduct due to a plane strain constraint. Fixed by repair welding.
Figure 27	n	2015002	06.05.2015 13:12	06.05.2015 23:48	1,250	H	L	D	C	A2	2	Reset because of density of the economizer
	n	2015003	06.05.2015 23:48	07.05.2015 07:51	1,750	H	L	D	C	A2	4	Units shutdown, economizer sheet metals de-tached from mounting support, repair of mounting supports and renewal of destructed sheet metals; unit at full load
Figure 28	n	2015004	16.05.2015 19:30	17.05.2015 13:12	2,138	H	L	B	C	A2	2	Failure of draft fan
	n	2015005	17.05.2015 13:12	18.05.2015 17:51	6,900	M	K	Y	A	A1	4	Disturbance in the excitation of the generator; voltage failure of the excitation supply; error de-tection cause cannot be detected.

Relevant EMS coding for reporting to VGB

Reporting to VGB	VGB event-characteristic-key-system for the unavailable event recording (only relevant EMS codes)	Status VGB 10/2015

EMS 4/1 time limits *

A	automatic load shedding/emergency trip
B	manual load shedding/emergency trip
C	arranged shutdown within 12 hours
D	restart resp. re-commissioning not possible (as far as not point E, K, L). Due to technical failures the start-up activity cannot be initialized.
E	exceeding of the planned event time according to point J or K because of unplanned measures (damages, disturbances...)
F	start-up delay. An initialized start-up activity cannot be led to the grid switching in the dictated time.
G	start-up extension. After the grid switching, an increase of capacity is not possible corresponding to the start-up curve/the operating manual
H	can be postponed more than 12 hours
J	fixed more than 4 weeks before
K	annual shutdown program
L	exceeding the planned event time according to point J or K by extension of the planned period
M	without effect (only valid in connection with plant components)
A-G:	unplanned not postponable
H:	unplanned postponable
J, K, L:	planned

* valid for capacity restriction and shutdown of the plant

EMS 1 type of event *

A1	disturbance without damage
A2	damage
B1	control/test of condition
B2	lubrication
B3	maintenance
B4	inspection
B5	preventive repair
B6	keeping clean
B7	revision
B8	fuel element change
C0	reconstruction/extension
D2	outside influence without damage
D21	fuel
D22	mothballing of plants
D23	climate
D24	grid restriction
D241	Redispatch
D25	staff shortage
D26	others
E0	tests/functional trials/functional test
F0	official test/measure
G0	lack of reactivity
Z0	other type of event

EMS 4/2 main effect

2	power limitation
4	shutdown

Indicators and definitions

Market-rated utility reliability

$$r_m = 1 - \frac{\Sigma(|W_{Bi} - W_{Fpi}| \cdot DB_i)}{\Sigma(W_{Fpi} \cdot DB_{ii})}$$

r_m:	market – rated utility reliability
WB_i:	energy generated
W_{Fpi}:	scheduled generation
$DB_i = EEX - DB_{ii}$:	profit contribution of a power plant
DB_{ii}:	specific profit contribution of a power plant

Definition

The market-rated utility reliability is the quotient of the difference between generated energy and scheduled generation weighted by the specific profit contribution and the scheduled generation weighted by the specific profit contribution, in each case based on the time period. The calculation of the input data is carried out in the same way as price trend.

Utilization

The market-rated utility reliability is a measure of the economic utilisability of a power plant in the Whole-sale market. It assesses the economic benefits of the deployment beyond the technical utilisability.

$$r_m = 1 - \frac{\Sigma(|W_{Bi} - W_{Fpi}| \cdot (EEX - DB_{ii}))}{\Sigma(W_{Fpi} \cdot DB_{ii})}$$

$$\begin{aligned} r_m = \; & 1 - ((240.46\,MWh - 600\,MWh) \cdot (19.79\,€/MWh - 18.43\,€/MWh) \\ & + (0.045 + 0{,}128 + 0 + \ldots + 0.572 + 0.582 + \ldots) \\ & + (240.46\,MWh - 600\,MWh) \cdot (20.11\,€/MWh - 18.43\,€/MWh) = 0{,}918 \approx 92\% \end{aligned}$$

* specific profit contribuion is at least the fuel cos t

Example

Power Plant	Hard Coal
Market-related availability [T€]	-7
P_N nominal capacity [MW_n]	600
Scheduled generation [MW_n]	600

Date	Time	EEX	specific profit contribu-tion	Energy generat-ed	Market-related availability	
		[€/MWh]	[€/MWh]	[MWh_n]	[T€/h]	[$T€_{kum}$]
01/01/2015	0:00	19.79	18.43	240.46	-0.49	-0.49
01/01/2015	1:00	18.46	18.43	240.46	-0.01	-0.50
01/01/2015	2:00	17.04	18.43	240.46	0.00	-0.50
01/01/2015	3:00	14.47	18.43	240.46	0.00	-0.50
01/01/2015	4:00	9.90	18.43	240.46	0.00	-0.50
01/01/2015	5:00	7.71	18.43	240.46	0.00	-0.50
01/01/2015	6:00	0.81	18.43	240.46	0.00	-0.50
01/01/2015	7:00	0.57	18.43	240.46	0.00	-0.50
01/01/2015	8:00	0.18	18.43	599.14	0.00	-0.50
01/01/2015	9:00	5.34	18.43	607.02	0.00	-0.50
01/01/2015	10:00	8.87	18.43	607.02	0.00	-0.50
01/01/2015	11:00	12.67	18.43	607.02	0.00	-0.50
01/01/2015	12:00	14.52	18.43	607.02	0.00	-0.50
01/01/2015	13:00	14.50	18.43	607.02	0.00	-0.50
01/01/2015	14:00	11.34	18.43	607.02	0.00	-0.50
01/01/2015	15:00	13.59	18.43	607.02	0.00	-0.50
01/01/2015	16:00	18.58	18.43	607.02	0.00	-0.50
01/01/2015	17:00	25.60	18.43	607.02	0.05	-0.45
01/01/2015	18:00	25.99	18.43	607.02	0.05	-0.40
01/01/2015	19:00	25.84	18.43	607.02	0.05	-0.34
01/01/2015	20:00	24.05	18.43	240.46	-2.02	-2.36
01/01/2015	21:00	22.09	18.43	240.46	-1.32	-3.68
01/01/2015	22:00	26.34	18.43	240.46	-2.84	-6.52
01/01/2015	23:00	20.11	18.43	240.46	-0.60	-7.13

Time availability factor during peak times

$$k_{t\ Pe} = t_{v\ Pe} / t_{N\ Pe} = (t_{N\ Pe} - t_{nv\ Pe}) / t_{N\ Pe}$$

$k_{t\ Pe}$:	Time availability factor during peak times
$t_{v\ Pe}$:	Availability time during peak times
$t_{N\ Pe}$:	Number of peak hours in nominal time
$t_{nv\ Pe}$:	Unavailability time during peak times

Definition

The time availability during peak times is the quotient of availability time during peak times and the number of peak hours in nominal time.
The availability time during peak times is the difference between the number of peak hours in nominal time and the unavailability time during peak times.

Utilization

The time availability in peak times is a measurement for the temporal utilisability of a power plant in peak times. It is mainly used for power plants that are designated for mid- and peak-load operation.
The time availability in peak times is independent of the capacity available in a particular case. Where required, further differentiation can be achieved by utilizing planned and unplanned unavailability times.

Example

Hard coal power plant with P_N = 150 MW
Month November with 22 peak-days = 264 peak-hours

Reduction of capacity:
P = 120 MW from Fr 05.11. 12:00 until 18:00 h

Boiler failure:
Fr 05.11. 18:00 until Mo 08.11. 16:00 h

Reduction of capacity:
110 MW from Tu 16.11. 06:00 until 14:00 h

$$k_{t\ Pe} = t_{v\ Pe} / t_{N\ Pe} = (t_{N\ Pe} - t_{nv\ Pe}) / t_{N\ Pe}$$

$$k_{t\ Pe} = (264\,h - 10h)/264\,h = 0.9621$$

Peak-times T_{NPe}

The peak hours within nominal time cover all power exchange market typical peak-times (e.g. in Germany: Monday to Friday all hours from 08:00 until 20:00 h; holidays that fall on these days count as normal business days).

Insofar as peak-time-related indicators are to be determined, the time, capacity, and energy values of the events in energy conversion plants must not be considered over the entire nominal time in all subsequent definitions, but only during the peak hours within the nominal time.

The number of peak hours can also be calculated online, e.g.: http://www.prognoseforum.de/elektrizitaet/monatsstunden.htm

Example: yearly peak hours 2015

T_{NPe} = | 08 – 20 | h/d * 261 d = 3,132 h

Energy availability factor during peak times

$$k_{W\ Pe} = W_{v\ Pe} / W_{N\ Pe} = \left(W_{N\ Pe} - W_{nv\ Pe}\right) / P_N\ *\ t_{NPe}$$

$k_{W\ Pe}$: energy availability factor during peak times
$W_{v\ Pe}$: available energy during peak times
$W_{N\ Pe}$: nominal energy within peak times
$W_{n\ Pe}$: unavailable energy during peak times
$t_{N\ Pe}$: peak hours within nominal time

(can be related to gross or net.)

Definition
The energy availability factor during peak times is the quotient of available energy during peak times and the nominal energy during peak times.
The available energy during peaktimes is the difference between the nominal energy and the unavailable energy during peak times. The nominal energy is the product of nominal capacity and peak hours in nominal time.

Utilization
The energy availability in peak times is a measurement for the energy that a plant can produce in peak times in view of its technical and operational condition. It is used especially for power plants that are designated for mid- and peak-load operation mainly.
The energy availability in peak times includes in contrast to the time availability in peak times also partial unavailabilities and, where required for further differentiation purposes, can be distinguished between planned and unplanned unavailability times, too.

Example
Hard-coal fired unit with P_N = 150 MW
Month November with 22 peak-days = 264 peak-hours

Capacity reduction:
P = 120 MW from Fr 05.11. 12:00 h until 18:00 h

Boiler failure: Fr 05.11. 18:00 h until Mo 08.11. 16 h

Capacity reduction:
110 MW from Tu 16.11. 06:00 h until 14:00 h

$$k_{W\ Pe} = W_{v\ Pe} / W_{N\ Pe} = \left(W_{N\ Pe} - W_{nv\ Pe}\right) / P_N\ *\ t_{NPe}$$
$$k_{W\ Pe} = 150\ MW * 264\ h - \left(30\ MW * 6\ h + 150\ MW * 10\ h + 40\ MW * 8\ h\right) / 150\ MW * 264\ h$$
$$k_{W\ Pe} = 0.9495$$

Dispatching (energy) failure rate

$$p_l = W_{nv\ u(n)} / \left(W_{nv\ u(n)} + W_{ns} + W_B\right) * 100\,\%$$

p_l: dispatching (energy) failure rate
$W_{nv\ u(n)}$: unplanned (not postponable) unavailability energy
W_{ns}: external influence energy
W_B: generated energy operating time

Definition
The dispatching (energy) failure rate – unplanned (total) is the quotient of the unplanned (not postponable) unavailability energy and the sum of the unplanned (not postponable) unavailability energy, the external influence energy, and the generated energy operating time.

Utilization
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.

Example
Coal fired unit February 2015
0.07 % = 230 MWh / (230 MWh + 0 MWh + 320,209 MWh) * 100 %
Calculation per unit, per power class, per power station

Coal fired unit December 2015
12.2 % = 44,137 MWh / (44,137 MWh + 274 MWh + 318,208 MWh) * 100 %
Calculation per unit, per power class, per power station

Dispatch reliability

$$p_v = W_B \ / \ \left(W_B + W_{nv\ u(n)} + W_{ns}\right) * 100\,\%$$

p_V: dispatch reliability
W_B: generated energy operating time
$W_{nv\ u(n)}$: (not postponable) unplanned unavailability energy
W_{ns}: external influence energy

Definition
The dispatch reliability is the quotient of generated energy operating time and the sum of generated energy operating time, (not-)postponable unplanned unavailability energy and external influence energy.

Utilization
The dispatch reliability is a measure of a plant's dependability outside planned unavailabilities.

The indicator can also be used for peak-load plants.

Example
Coal fired unit December 2015
87.75 % = 318,208 MWh / (318,208 MWh + 44,137 MWh + 274 MWh) * 100 %
Calculation per unit, per power class, per power station

Energy reliability

$$W_v = W_B \ / \ (W_B + W_{nv\ u(n)}) * 100\,\%$$

W_V:	Energy reliability
W_B:	generated energy operating time
$W_{nv\ u(n)}$:	(not postponable) unplanned unavailability energy

<u>Definition</u>
Energy reliability is the ratio of generated energy operating time and the sum of generated energy and unplanned (not postponable) unavailability energy.

<u>Utilization</u>
Reliability is a synonym for the dependability of a plant as regards unplanned (not postponable) events.

<u>Example</u>
Coal fired unit February 2015
95.53 % =320,209 MWh / (320,209 MWh + 14,998 MWh) * 100 %
Calculation per unit, per power class, per power station

Time reliability

$$w_t = t_B / \left(t_B + t_{nv\ u(n)}\right) * 100\,\%$$

w_t: time reliability
t_B: operating time
$t_{nv\ u(n)}$: unplanned (not postponable) unavailability time

Definition
Time reliability is the quotient of operating time and the sum of operating time and unplanned (not postponable) unavailability time.

Utilization
Reliability is a synonym for the dependability of a plant as regards unplanned (not postponable) events.

Example
Coal fired unit December 2015
99.17 % = 737.8 h / (737.8 h + 6.2 h) * 100 %

Schedule compliance

$$f_{FP} = W_B / W_{FP} * 100\,\%$$

f_{FP}: schedule compliance per time unit
W_B: generated energy operating time
W_{FP}: scheduled energy requirement

Definition
Schedule compliance is the quotient of generated energy and scheduled energy requirement to be met by a production plant within a given time period.

Utilization
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.

Example
Coal fired unit February 2015
92.5 % = 1,780 GWh / 1,924 GWh * 100 %

Schedule capacity

P_{FP}

The 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.

The schedule energy $\mathbf{W_{Fp}}$ results as a product from schedule capacity with the corresponding time frame.

<u>Example</u>

Coal fired unit with P_N = 670 MW

P_N in MW	h	P_{FP} in MW
670	1	320
670	2	320
670	3	320
670	4	320
670	5	640
670	6	640
670	7	640
670	8	640
670	9 … 23	640
670	24	640

Schedule deviation

Absolute schedule deviation

$$\Delta P_a = \sum_{i}^{n-1} \left| P_{FP_t} - P_{B_t} \right| / n \, [MW / x \, min]$$

ΔP_a:	absolute schedule deviation
P_{FPt}:	schedule capacity (netted out with balancing capacity)
P_{Bt}:	operating capacity (grid supply)

The absolute schedule deviation is a measure for the ability of a unit to follow the schedule.

Specific schedule deviation

$$f_{Vn} = \left(\sum \frac{\left| W_{FP} - W_B \right|}{W_{FP}} \right) * 100\,\%$$

Example: 350 MW hard coal-fired unit

Schedule	measurement	schedule deviation
MW	MW	MW
185	179	6
185	177	8
185	174	11
	…	
190	186	4
202	195	7
	288	5,257
		5,257 / 288 = 18.25 MW/5min

24 h correspond to 288 5-minutes values

The energy conversion facility follows the schedule demand within 24 h with an average deviation of 18.25 MW.

Here is stated that all results which differ from the schedule deviation are a violation of the timetable. Every company should establish an independent tolerance for their acceptable deviation (such as measurement errors/accuracy).

The schedule deviation is an addition to the schedule compliance. With this indicator the absolute respectively specific deviation from the schedule per time unit is determined.

It is recommended to refer to a time unit of 15 minutes.

CHP indicator

$$n_{KWK} = W_{ne\ KWK} / W_{N\ ne} * 100\,\%$$

n_{KWK}: CHP indicator
$W_{ne\ KWK}$: generated CHP net energy
$W_{N\ ne}$: net nominal energy

Definition
The CHP indicator is the quotient of generated CHP net energy and net nominal energy.

Utilization
Rating of a plant concerning its CHP net energy related to the net nominal energy.

Example
Coal fired unit February 2015
1.44 % = (24.646 GWh / 1,715 GWh) * 100 %

Greenhouse gas indicator

$$e_{CO2} = \frac{M_B \cdot H_u \cdot e_f \cdot e_{ox}}{W_{B\ ne}}$$

e_{CO2}:	greenhouse gas emission indicator [t $_{CO2}$ / MWh]
M_B:	fuel provided [t / a]
H_u:	lower heating value [MJ / kg]
e_f:	emission factor [t_{CO2} / TJ]
e_{ox}:	oxidization factor [-]
$W_{B\ ne}$	net generated energy [MWh]

Definition

The greenhouse gas indicator of a power generation unit is the quotient of the amount of CO_2-emission and the net generated energy.

Utilization

The greenhouse gas indicator displays the CO_2- emission in t/MWh for the generation of electricity and heat.

Example lignite fired power station

M_B:	6,566,000.0	t p.a.
H_u:	8.786	MJ/kg
e_f:	113	t CO_2/TJ
e_{ox}:	0.99	
W_B:	6,671,675	MWh
e_{CO2}:	0.97	t/MWh

Market-rated availability

$$k_{Wm} = \frac{\sum_{i=1..N} \left(W_{N,i} - W_{nv,i} \right) \cdot DB +_i}{\sum_{i=1...N} W_{N,i} \cdot DB +_i}$$

k_{Wm}: market-rated availability
W_{Ni}: nominal energy
W_{nvi}: unavailable energy
DB: profit margin*
EEX: power exchange price (e.g. peak, base; per h)

*) DB = fuel costs (e.g. BAFA) + CO_2 (e.g. EEX-EUA)

Example: (simplified consideration without ramps)

- 500 MW hard coal-unit: Mo-Fr 8-20 h full load; Th from 14:00 to 18:00 h reserve; Fr from 16:00 h network works
- consideration for peak (13. cw 2015)
- sum of marginal costs: 40 €/MWh
- EEX (in €/MWh): Mo 50.1; Tu 55.4; We 48.6; Th 55.6; Fr 51.6

hourly consideration necessary!

$$k_{Wm} = \frac{500\,MW \cdot 10h}{500\,MW \cdot 0h} \cdot \frac{\overline{EEX}}{40€/MWh} \qquad \text{Mo – We}$$

$$k_{Wm} = \frac{500MW \cdot 6h + 500MW \cdot 4h}{500MW \cdot 10h} \cdot \frac{\overline{EEX}}{40€/MWh} \qquad \text{Th}$$

$$k_{Wm} = \frac{500MW \cdot 10h - 500MW \cdot 4h}{500MW \cdot 10h} \cdot \frac{\overline{EEX}}{40€/MWh} \qquad \text{Fr}$$

Mo: $k_{Wm} = 1.25$
Tu: $k_{Wm} = 1.39$
We: $k_{Wm} = 1.22$
Th: $k_{Wm} = 1.39$
Fr: $k_{Wm} = 0.77$

Market-rated availability – Comparison

$$k_k = \frac{W_k}{W_N} \cdot \frac{EEX - \sum GK}{EEX} = \frac{W_{Bne} + W_R - W_{ng}}{W_N} \cdot \frac{EEX - \sum GK}{EEX} \quad \text{für} \quad (EEX - \sum GK) \geq 0$$

$$k_k = 0 \quad \text{für} \quad (EEX - \sum GK) < 0$$

k_k:	market-rated availability
W_k:	market-rated energy
W_{Bne}:	net generated energy
W_R:	stand-by energy
W_{ng}:	not dispatchable energy (external influence)
GK:	marginal cost*
EEX:	power exchange-price (e.g. peak, base; per h)

*) GK = fuel cost (e.g. BAFA) + CO_2(e.g. EEX-EUA)

$$k_K = \frac{\sum_{i=1..N} (W_{N,i} - W_{nv,i}) \cdot DB_i}{\sum_{i=1...N} W_{N,i} \cdot DB_i}$$

k_K	[%]	commercial availability
$W_{N,i}$	[MWh]	nominal energy per timeframe i
$W_{nv,i}$	[MWh]	‘unavailable energy (UA-energy)’ per time frame i
I	[1]	continuous index over the time frames 1 to N of the considered time period the time pattern is given by the time pattern of the power exchange prices, which is currently 1 hour
N	[1]	number of time frames in the considered time period
DB_i	[€/MWh]	marginal income in the time frame i with DBi = 0 for EEXi < GKi = EEXi – GKi for EEXi ≥ GKi
EEX_i	[€/MWh]	power exchange-price of the spot market, e.g. EEX-power exchange, in the time frame i
GK_i	[€/MWh]	actual costs in the time frame i

Availability of Combined Cycle Gas-Turbine (CCGT)

$$k_{GuD} = \frac{\left(\sum\limits_{i=1...x} W_{NGuD,i} + W_{Näqu}\right) - \sum\limits_{i=1...x} W_{nVGuD,i}}{\sum\limits_{i=1...x} W_{NGuD,i} - W_{Näqu}}$$

$$= \frac{\left(\sum\limits_{i=1...y} W_{N,GTi} + \left(W_{N,DT} + W_{Näqu}\right)\right) - \left(\sum\limits_{i=1...y} W_{nV,GTi} + \left(W_{nV,DT} + W_{nVäqu}\right)\right)}{\left(\sum\limits_{i=1...y} W_{N,GTi} + \left(W_{N,DT} + W_{Näqu}\right)\right)}$$

k_{GuD}:	availability of a CCGT
DT:	steam turbine
GT:	gas turbine
W_{GuD}:	energy of a CCGT
W_{nv}:	unavailable energy
$W_{GT,i}$:	energy share of the gas turbine(s) in the combined cycle process
W_{DT}:	energy share of the steam turbine(s) in the combined cycle process
$W_{N,i}$:	nominal energy share
$W_{äqu}$:	equivalent electric energy belonging to heat extraction

Example: CCGT with unfired heat recovery boiler

$$k_{GuD} = \frac{\left(W_{N,GT1} + W_{N,GT2} + \left(W_{N,DT} + W_{Näqu}\right)\right) - \left(W_{nV,GT1} + W_{nV,GT2} + \left(W_{nV,DT} + W_{nVäqu}\right)\right)}{W_{N,GT1} + W_{N,GT2} + \left(W_{N,DT} + W_{Näqu}\right)}$$

(GT- stand alone operation allowed, given period of 8 h)
Nominal capacities: P_N(GuD) = 540 MW, P_N(GT1) = 190 MW, P_N(GT2) = 190 MW, P_N(DT) = 190 MW; $P_{Näqu}$ = -30 MW; $P_{nVäqu}$ = -110 MW *)

- case 1: GT1 full load, GT2 full load, DT full load

$$k_{GuD} = \frac{(190\,MW + 190\,MW + (190\,MW - 30\,MW)) * 8h - ((0\,MW + 0\,MW + (0\,MW + 0\,MW)) * 8h)}{(190\,MW + 190\,MW + (190\,MW - 30\,MW)) * 8h} = 100\%$$

- case 2: GT1 in repair, GT2 full load t, DT fully available

$$k_{GuD} = \frac{(190MW + 190MW + (190MW - 30MW)) * 8h - ((190MW + 0\,MW + (0\,MW + 110MW)) * 8h)}{(190MW + 190MW + (190MW - 30MW)) * 8h} = 44.4\%$$

- case 3: GT1 full load, GT2 full load, DT in repair

$$k_{GuD} = \frac{(190MW + 190MW + (190MW - 30MW)) * 8h - ((0\,MW + 0\,MW + (190MW + 0\,MW)) * 8h)}{(190MW + 190MW + (190MW - 30MW)) * 8h} = 64.8\%$$

- case 4: GT1 in repair, GT2 in repair, DT available
  k_{GuD} = 0, because heat recovery boiler without auxiliary firing

*) outage DT = 0.5 (P_N(DT) + $P_{Näqu}$

Availability of combined (e.g. gas-coal) power plants

$$k_{Kombi} = \frac{\sum_{i=1...x} W_{N_{Kombi,i}} - \sum_{i=1...x} W_{nV_{Kombi,i}}}{\sum_{i=1...x} W_{N_{Kombi,i}}}$$

$$= \frac{\left(W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr.}}\right) - \left(\left(W_{nV_{Kohle}} - W_{Stütz}\right) + W_{nV_{GT}} + W_{nV_{Kombi,korr.}}\right)}{W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr.}}}$$

k_{kombi}:	availability of a combined gas-coal power plant process
$W_{Kombi,\,i}$:	energy share in the combined process
$W_{N,\,i}$:	nominal energy share (Kohle = Coal)
W_{nV}:	unavailable energy
$W_{Stütz}$:	compensated energy by back up firing (e.g. outage of a mill)
W_{korr}:	correction for the overall process (e.g.: $P_{Kombi} = P_{DT} + P_{GT} \pm x^*$)

*) extra capacity by utilization of gas turbines waste heat for preheating when an increased maximum throughput of the steam turbine is available; minor capacity due to steam taking for other processes

Example: hard coal-fired power station

$$K_{Kombi} = \frac{\left(W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr.}}\right) - \left(\left(W_{nV_{Kohle}} - W_{Stütz}\right) + W_{nV_{GT}} + W_{nV_{Kombi,korr.}}\right)}{W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr.}}}$$

(GT-stand-alone operation allowed, given period of 8 h)
Nominal capacities (equivalent capacity 1 mill: 75 MW):
Coal: P_N = 600 MW, $P_{N(Kombi)}$ = 588 MW; $P_{N(GT)}$ = 112 MW):
→ $P_{N,\,korr.}$ = - 12 MW

- Case 1: coal-fired unit full load, GT-reserve

$$k_{Kombi} = \frac{(600MW + 112MW - 12MW) * 8h - (0\,MW + 0\,MW + 0\,MW + 0\,MW)}{(600MW + 112MW - 12MW) * 8h} = 100\,\%$$

- Case 2: coal-fired unit full load, compensation 1 mill by gas, GT-full load

$$k_{Kombi} = \frac{(600MW + 112MW - 12MW) * 8h - (75MW - 75MW + 0\,MW + 0\,MW) * 8h}{(600MW + 112MW - 12MW) * 8h} = 100\,\%$$

- Case 3: GT in repair, coal-fired unit full load

$$k_{Kombi} = \frac{(600MW + 112MW - 12MW) * 8h - (0\,MW - 0\,MW + 112MW - 12MW) * 8h}{(600MW + 112MW - 12MW) * 8h} = 85.7\%$$

– Case 4: coal-fired unit full load, outage 2 mills (1 compensated), GT full load

$$k_{Kombi} = \frac{(600MW + 112MW - 12MW) * 8h - (150MW - 75MW + 0MW + 0MW) * 8h}{(600MW + 112MW - 12MW) * 8h} = 89.3\%$$

Availability of power plants with VGT (topping gas turbine)

$$k_{VGT} = \frac{\sum_{i=1...x} W_{NVGT,i} - \sum_{i=1...x} W_{nVVGT,i}}{\sum_{i=1...x} W_{NVGT,i}}$$

$$= \frac{(W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}) - (W_{nVVGT,Kohle} + W_{nVVGT,GT} + W_{nVVGT,korr.})}{W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}}$$

k_{VGT}: availability of a power plant with topping gas turbine
W_{VGT}: energy of a power plant with topping gas turbine
W_{Bne}: net generated energy
W_R: stand-by energy
W_{ng}: not dispatchable energy (external influence)
$W_{VGT,}$: energy share in the combined process
$W_{N,i}$: nominal energy share
$W_{korr.}$: correction for the overall process
(e.g.: $P = P_{Kombi} + P_{GT} \pm x$)

<u>Example:</u> power plant with topping gas turbine

$$k_{VGT} = \frac{(W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}) - (W_{nVVGT,Kohle} + W_{nVVGT,GT} + W_{nVVGT,korr.})}{W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}}$$

(GT-stand-alone operation allowed, considered time period in each case 8 h)
Nominal capacities: P_N(coal) = 600 MW, P_N(VGT) = 200 MW, $P_{N,korr.}$ = 80 MW

– <u>Case 1:</u> VGT full load, coal-fired unit full load
k_{VGT} = 100 %

– <u>Case 2:</u> VGT reserve, coal-fired unit full load
k_{VGT} = 100 %

– <u>Case 3:</u> VGT in repair, coal-fired unit full load

$$k_{VGT} = \frac{(600MW + 200MW + 80MW) * 8h - (0MW + 200MW + 80MW) * 8h}{(600MW + 200MW + 80MW) * 8h} = 68.2\%$$

– <u>Case 4:</u> VGT full load, coal fired unit boiler failure

$$k_{VGT} = \frac{(600\,MW + 200\,MW + 80\,MW) * 8h - (600\,MW + 0\,MW + 80\,MW) * 8h}{(600\,MW + 200\,MW + 80\,MW) * 8h} = 22.7\%$$

Calculation methods

Calculation of the indicator “energy availability”

The indicator “energy availability” specifies how much electrical energy a power plant could have generated, taking into account technical performance limitations, in relation to a continuous full load operation. It is a theoretical value that does not consider the real operation. The indicator is defined as

$$k_w = \frac{W_N - \sum W_{nv}}{W_N} = 1 - \frac{\sum W_{nv}}{W_N}$$

Note 1: The indicator “time availability” is a special case of “energy availability”. Time availability only considers outages with nominal power, but no partial load outages. Thus, the energy availability indicator must always be less or equal to the time availability.

Note 2: The indicator “dispatchability” is identical to the “energy availability” principle. However, dispatchability also takes into account a capacity reduction due to external influences. The term “UA-energy” (W_{nv}) plus “external-influence” (W_{ns}) is summarized as “not dispatchable energy quantity”. Thus, the indicator dispatchability must always be smaller or equal to the energy availability.

Special cases:

1) Increase of nominal capacity in the considered time period

For the calculation of the energy quantities (W_N or W_{nv}), the considered time period is subdivided into the time segments in which the different nominal capacities apply. The nominal energy or UA-energy is calculated as the sum over the respective energy quantities of the individual time ranges. For the nominal energy (denominator) the formula is shown as the sum of the nominal energy in the time sections (determination of the UA-energy is done analogous):

$$W_N = \sum W_{N,i} = \sum P_{N,i} \cdot t_{N,i}$$

with $i =$ time sections with different nominal capacity

2) Times before or after the operating phase (commercial operation) or during cold reserve

In principle, it is not useful to collect indicators over periods in which a power plant has not yet been commissioned or has already been decommissioned. However, there are cases where such a calculation is appropriate. For example, such a case may occur when aggregating indicators across several plants.

The principle does not change the calculation of the indicator. It is correct to hide these periods. The units can be faded out in different ways for the modeling of data processing routines. Conceivable for this modeling is the hiding of time sections or the adjustment of the capacity. The indicator does not change as a result taking these special periods into consideration. For these periods the corresponding energy quantities, as a product of time and capacity, are included in the calculation in both cases with 0 MW. Due to this they have no effect. In the case of a possible communication, the nominal capacity remaining unchanged must be strictly observed. This is evident, e.g. for network security calculations, or is the basic possibility to participate at the electricity market.

A percentage specification always contains a statement in combination with the reference quantity. As long as the reference value is always constant and thus contains only limited information during comparisons, the specification of the reference value can be omitted.

In principle, the multiplication of energy availability with the nominal energy results into the available energy during the reporting period. This quantity can be interpreted as mean available capacity over the entire viewing period or as a nominal capacity with an average percentage availability time.

If the reporting time also covers periods outside the operating phase, the energy as well as the energy availability remains constant, even if the time period is further increased. It is obvious to calculate the average capacity by dividing the energy by the period of observation. The average available capacity is reduced by considering times outside the operating phase

3) Aggregation of the indicator over several plants

The formula for calculating energy availability over the energy quantities can be applied not only to one plant but also to the aggregation of several plants. The corresponding energy quantities of all plants are taken into account in the terms nominal energy or sum of all UA-energy.

The calculation of the aggregated energy availability of several plants must be weighted when using the fully calculated energy availability of the individual plants. The weighting is carried out with the average nominal capacity of the plants. The principle is a weighting with the respective nominal energy. However, the viewing period is identical so that the viewing time shortens away and the average nominal capacity remains.

In the following, the return to the weighting of the indicators for the individual plant (index i) with its average nominal capacity is derived from the general formula. For the sake of simplicity, the UA-energy of the individual plants is already summarized as $W_{nv,\,i}$ and not as a sum over the individual incidents.

$$\bar{k}_w = \frac{W_N - W_{nv}}{W_N} = \frac{\sum W_{N,i} - \sum W_{nv,i}}{\sum W_{N,i}} = \frac{1}{\sum W_{N,i}} \cdot \left(\frac{\sum W_{N,i} - \sum W_{nv,i}}{1} \right) = \frac{1}{\sum W_{N,i}} \cdot \sum \left(\frac{W_{N,i} - W_{nv,i}}{1} \right)$$

$$= \frac{1}{\sum W_{N,i}} \cdot \sum \left(\left(\frac{W_{N,i} - W_{nv,i}}{W_{N,i}} \right) \cdot W_{N,i} \right) = \sum \left(\frac{1}{\sum W_{N,i}} \cdot \left(k_{w,i} \cdot W_{N,i} \right) \right) = \sum \left(\frac{W_{N,i}}{\sum W_{N,i}} \cdot k_{w,i} \right)$$

$$= \sum \left(\frac{\bar{P}_{N,i} \cdot t_N}{\sum \bar{P}_{N,i} \cdot t_N} \cdot k_{w,i} \right) = \sum \left(\frac{\bar{P}_{N,i}}{\sum \bar{P}_{N,i}} \cdot k_{w,i} \right) \quad \text{with } k_{w,i} = \frac{W_{N,i} - W_{nv,i}}{W_{N,i}} \quad \text{and } \bar{P}_{N,i} = \frac{W_{N,i}}{t_N}$$

In case nominal capacity changes over the period of observation, the average nominal capacity of the plant shall be used. The viewing time t_N is the same for all plants which characteristic values should be aggregated.

$$\bar{k}_w = \sum \left(\frac{\bar{P}_{N,i}}{\sum \bar{P}_{N,i}} \cdot k_{w,i} \right)$$

Examples for the calculation of the indicator "time availability"

In the examples below, simple numerical values were used, which are only very limited realistic. The focus should be on the procedures and calculations and the calculations are easier reproducible.

In the first example, a plant is considered in which a capacity increase occurs during the viewing period. If for the example two plants should be aggregated, the nominal capacity curve of the first example was split into two separate capacity curves of "two" plants: One plant is continuously in operation, including a small increase in capacity. The second plant is put into operation during the period of observation. The aggregation of both plants must yield the known result of the first example. For independent testing, the capacity characteristics of the first example can also be decomposed differently to simulate several other plants.

Example 1a: Increase of nominal capacity during operation period

Observation period: 200 days

Nominal capacity $P_{N,1}$ = 200 MW for 0 days < t ≤ 150 days

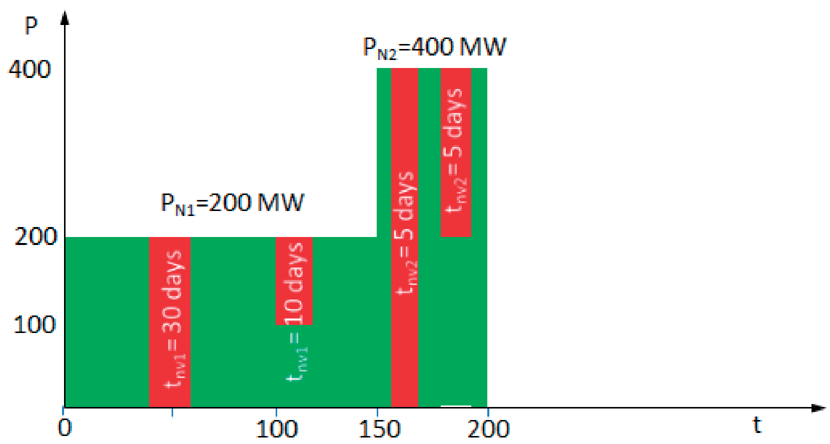
$P_{N,2}$ = 400 MW for 150 days < t ≤ 200 days

Outage duration $t_{nv,1}$ = 30 days P_{nv} = 200 MW in the period 0 days< t ≤ 150 days

$t_{nv,1}$ = 10 days P_{nv} = 100 MW in the period 0 days< t ≤ 150 days

$t_{nv,2}$ = 5 days P_{nv} = 400 MW in the period 150 days< t ≤ 200 days

$t_{nv,2}$ = 5 days P_{nv} = 200 MW in the period 150 days< t ≤ 200 days



$$k_w = \frac{W_N - \sum W_{nv}}{W_N}$$

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\ \text{MW} \cdot 3{,}600\ \text{h} + 400\ \text{MW} \cdot 1{,}200\ \text{h} = 1{,}200{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\text{MW} \cdot 720\ \text{h} + 100\text{MW} \cdot 240\text{h} + 400\text{MW} \cdot 120\text{h} + 200\text{MW} \cdot 120\text{h}$$
$$= 240{,}000\ \text{MWh}$$

$$k_w = \frac{1{,}200{,}000\ \text{MWh} - 240{,}000\ \text{MWh}}{1{,}200{,}000\ \text{MWh}} = 80.00\ \%$$

Average nominal capacity: $\overline{P}_N = 250\ \text{MW} = \frac{200\text{MW} \cdot 3{,}600\text{h} + 400\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$

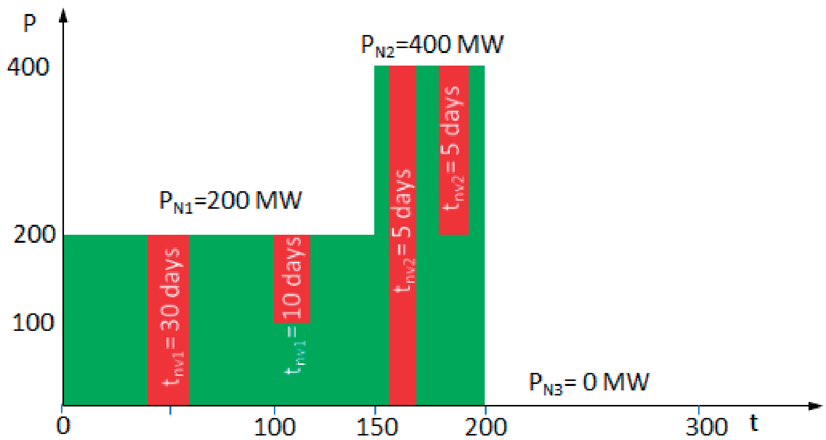
Average time-available capacity: $P = \overline{P}_N \cdot k_w = 200\ \text{MW} = 250\ \text{MW} \cdot 80.00\ \%$

Example 1b: Increase of nominal capacity and viewing period beyond decommissioning

Observation period: 300 days

Nominal capacity	$P_{N,1}$ = 200 MW	for	0 days < t ≤ 150 days	
	$P_{N,2}$ = 400 MW	for	150 days < t ≤ 200 days	
	$P_{N,3}$ = 0 MW	for	200 days < t	

Outage duration	$t_{nv,1}$ = 30 days	P_{nv} = 200 MW in the period	0 days < t ≤ 150 days
	$t_{nv,1}$ = 10 days	P_{nv} = 100 MW in the period	0 days < t ≤ 150 days
	$t_{nv,2}$ = 5 days	P_{nv} = 400 MW in the period	150 days < t ≤ 200 days
	$t_{nv,2}$ = 5 days	P_{nv} = 200 MW in the period	150 days < t ≤ 200 days
	$t_{nv,3}$ = 0 days	P_{nv} = 0 MW in the period	200 days < t



$$k_w = \frac{W_N - \sum W_{nv}}{W_N}$$

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\text{MW} \cdot 3{,}600\text{h} + 400\text{MW} \cdot 1{,}200\text{h} + 0\ \text{MW} \cdot 2{,}400\text{h} = 1{,}200{,}000\text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\ \text{MW} \cdot 720\ \text{h} + 100\ \text{MW} \cdot 240\ \text{h} + 400\ \text{MW} \cdot 120\ \text{h} + 200\ \text{MW} \cdot 120\ \text{h}$$
$$= 240{,}000\ \text{MWh}$$

$$k_w = \frac{1{,}200{,}000\ \text{MWh} - 240{,}000\ \text{MWh}}{1{,}200{,}000\ \text{MWh}} = 80.00\ \%$$

Average nominal capacity:

$$\overline{P}_N = 166.67\ \text{MW} = \frac{200\text{MW} \cdot 3{,}600\text{h} + 400\text{MW} \cdot 1{,}200\text{h} + 0\text{MW} \cdot 2{,}400\text{h}}{3{,}600\text{h} + 1{,}200\text{h} + 2{,}400\text{h}}$$

Average time-available capacity: $P = \overline{P}_N \cdot k_w = 133.33\ \text{MW} = 166.67\ \text{MW} \cdot 80.00\ \%$

Aggregation of 2 plants

Observation period: 200 days

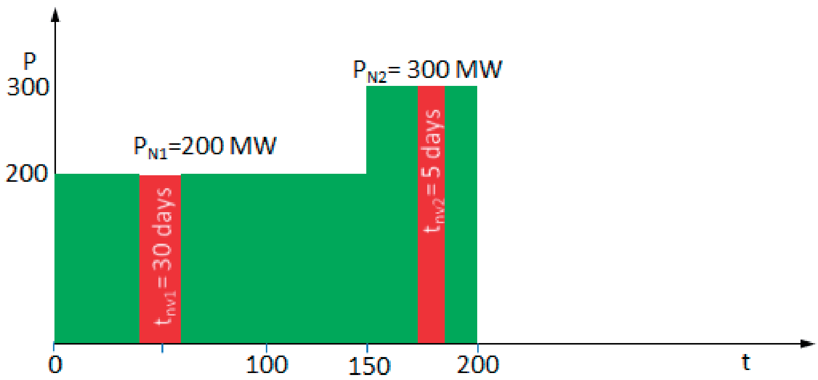
Plant 1 (with increase of nominal capacity)

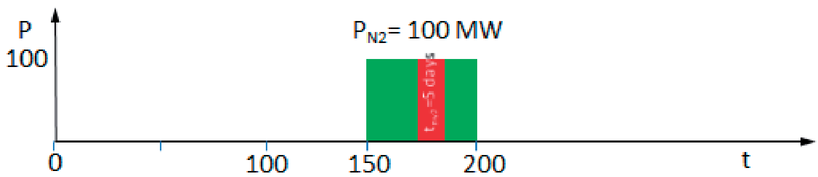
Nominal capacity	$P_{N,1}$ = 200 MW	for	0 days < t ≤ 150 days
	$P_{N,1}$ = 300 MW	for	150 days < t ≤ 200 days

Outage duration	$t_{nv,1a}$ = 30 days	P_{nv} = 200 MW in the period	0 days < t ≤ 150 days
	$t_{nv,1b}$ = 10 days	P_{nv} = 100 MW in the period	0 days < t ≤ 150 days
	$t_{nv,2a}$ = 5 days	P_{nv} = 300 MW in the period	150 days < t ≤ 200 days
	$t_{nv,2b}$ = 5 days	P_{nv} = 150 MW in the period	150 days < t ≤ 200 days

Plant 2 (Commissioning)

Nominal capacity	$P_{N,2}$ = 0 MW	for	0 days < t ≤ 150 days
	$P_{N,2}$ = 100 MW	for	150 days < t ≤ 200 days
Outage duration	$t_{nv,2a}$ = 5 days	P_{nv} = 100 MW in the period	150 days < t ≤ 200 days
	$t_{nv,2b}$ = 5 days	P_{nv} = 50 MW in the period	150 days < t ≤ 200 days





$$k_t = \frac{t_N - \sum t_{nv}}{t_N} = \frac{W_N - \sum W_{nv}}{W_N}$$

Plant 1

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\ \text{MW} \cdot 3{,}600\,\text{h} + 300\ \text{MW} \cdot 1{,}200\,\text{h} = 1{,}080{,}000\text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\ \text{MW} \cdot 720\ \text{h} + 100\ \text{MW} \cdot 240\ \text{h} + 300\ \text{MW} \cdot 120\ \text{h} + 150\ \text{MW} \cdot 120\ \text{h}$$
$$= 222{,}000\ \text{MWh}$$

$$k_w = \frac{1{,}080{,}000\ \text{MWh} - 222{,}000\ \text{MWh}}{1{,}080{,}000\ \text{MWh}} = 79.44\ \%$$

Average nominal capacity: $\overline{P}_N = 225.00\ \text{MW} = \dfrac{200\text{MW} \cdot 3{,}600\text{h} + 300\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$

Average time-available capacity: $P = \overline{P}_N \cdot k_w = 178.74\ \text{MW} = 225.00\ \text{MW} \cdot 79.44\ \%$

Plant 2

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 0\ \text{MW} \cdot 3{,}600\,\text{h} + 100\ \text{MW} \cdot 1{,}200\,\text{h} = 120{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 100\ \text{MW} \cdot 120\,\text{h} + 50\ \text{MW} \cdot 120\,\text{h} = 18{,}000\,\text{MWh}$$

$$k_w = \frac{120{,}000\ \text{MWh} - 18{,}000\ \text{MWh}}{120{,}000\ \text{MWh}} = 85.00\ \%$$

Average nominal capacity: $\overline{P}_N = 25.00\ \text{MW} = \dfrac{0\text{MW} \cdot 3{,}600\text{h} + 100\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$

Average time-available capacity: $P = \overline{P}_N \cdot k_w = 21.25\ \text{MW} = 25.00\ \text{MW} \cdot 85.00\ \%$

Aggregated indicator time availability for both plants

Capacity weighting of the individual unit indicators with the average nominal capacities:

$$\overline{k}_w = \sum\left(\frac{\overline{P}_{N,i}}{\sum \overline{P}_{N,i}} \cdot k_{w,i}\right)$$

$$\overline{k}_t = \frac{225\text{ MW}}{225\text{ MW} + 25\text{ MW}} \cdot 0.7944 + \frac{25\text{ MW}}{225\text{ MW} + 25\text{ MW}} \cdot 0.85 = 80.00\ \%$$

Average capacity of both plants: = 250 MW

$$\overline{P}_N = 250\text{ MW} = 225\text{MW} + 25\text{MW}$$

$$= \frac{200\text{MW} \cdot 3{,}600\text{h} + 300\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}} + \frac{0\text{MW} \cdot 3{,}600\text{h} + 100\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$$

Average time-available capacity:

$$P = \overline{P}_N \cdot \overline{k}_w = 200\text{ MW} = 250\text{ MW} \cdot 80.00\ \%$$

Conclusion

The energy availability of a plant is calculated according to the definition from the nominal energy and the technically caused unavailable energy.

If the nominal capacity changes during the observation period in a plant, the calculation formula must be used with energy quantities. In the case of the energy quantities, the observation period is subdivided into the time sections with different nominal capacity values and the corresponding energy quantities are calculated. Times before commissioning or after decommissioning should be ignored. For computing routines it is equivalent to set the nominal capacity to zero during these times.

According to the current VGB rules for the indicator generation, plants in cold reserve are no longer included in the statistics. These times are either not taken into account in the calculation or the nominal capacity is set to zero as described above.

The aggregation of energy availability for several plants is possible:

If the final calculated indicators are used, the aggregation must be carried out via a capacity weighting. The weighting is based on the nominal capacity of the individual plants, which is normally constant. If the nominal capacity of a single system changes during the period of observation, the average nominal capacity thereof must be used.

Alternatively, the basic formula can be used with energy quantities. Then the energy quantities of all plants which are of interest should be summed up and entered.

Note

The aggregation of the energy availability over several plants takes place using existing basic data for energy quantities as follows:

$$\bar{k}_w = \frac{\sum W_N - \sum_{\text{plant i}} \sum_{\text{incident. k}} W_{nv,i,k}}{\sum W_N} = 1 - \frac{\sum W_{nv}}{\sum W_N} = 1 - \frac{\sum_{\text{plant i}} \sum_{\text{incident.k}} P_{nv,i,k} \cdot t_{nv,\,i,\,k}}{\sum_{\text{plant i}} W_{N,i}}$$

with i = plant i

i, k = plant i, incident k

The aggregation of the energy availability over several plants is carried out capacity weighted with the use of the finally calculated indicators for the individual plants:

$$\bar{k}_w = \sum \left(\frac{\bar{P}_{N,i}}{\sum \bar{P}_{N,i}} \cdot k_{w,i} \right)$$

The average nominal capacity for each plant must be used as nominal capacity over the period of observation. Usually this is constant. Changes could be capacity increases, or times before commissioning, or after decommissioning, or during cold reserve.

Calculation of the "time availability" indicator

The "time availability" indicator is a special case of the "energy availability" parameter. Only events are considered where the complete capacity, this is the nominal capacity, is not available. In addition, the "energy availability" indicator also takes into account the outages where partial capacities are not available.

Deduction of time availability is a special case of energy availability:

Starting from the definition of energy availability, the formula for time availability is deduced by transforming the energy into nominal capacity and duration:

$$k_t = \frac{W_N - \sum W_{nv}}{W_N} = \frac{P_N \cdot t_N - \sum P_N \cdot t_{nv}}{P_N \cdot t_N} = \frac{P_N \cdot t_N - P_N \cdot \sum t_{nv}}{P_N \cdot t_N} = \frac{P_N \cdot \left(t_N - \sum t_{nv}\right)}{P_N \cdot t_N} = \frac{t_N - \sum t_{nv}}{t_N}$$

With outage capacity always $P_{nv} = P_N$ and $W_N = P_N \cdot t_N$

Note:

For both indicators "time" and "work availability" the same denominator is used for this transformation. Differences result in the counter. In the case of energy availability, the unavailable energy (UA-energy) is always greater or equal to the UA-energy in terms of time availability due to additional partial outages are considered. Thus the "energy availability" indicator must always be less than or equal to the "time availability" indicator.

Special cases:

1) Increase of nominal capacity during the observation period

For the calculation of the working quantities (W_N or W_{nv}), the observation time is subdivided into time segments in which the different nominal capacities apply; the nominal energy or the energy which is calculated as the sum over the respective energy quantities of the individual time ranges. For the nominal energy (denominator) the formula is shown as the sum of the nominal energy in the time sections (determination of the energy of the UA-energy is analogous):

$$W_N = \sum W_{N,i} = \sum P_{N,i} \cdot t_{N,i}$$

with $i =$ time sec tions with differing no min al capacity

2) Times before or after the operating phase (commercial operation) or during cold reserve

In principle, it is not useful to collect indicators over periods in which an installation has not yet been commissioned or has already been decommissioned. However, there are cases where such a calculation is appropriate. Such a case may occur when aggregating indicators across several plants.

The principle does not change the calculation of the indicator. It is correct to hide these periods. The units can be faded-out in different ways for the modeling of data processing routines. Conceivable for this modeling is the hiding of time sections or the adjustment of the capacity. The indicator does not change as a result of the consideration of these special periods because the corresponding working quantities as a product of time and performance are included in the calculation for these periods in both cases with 0 MWh and therefore have no effect. In the case of a possible communication, the constant remaining nominal capacity must be strictly observed. This is evident e.g. for grid security requirements or for the basic possibility to participate at the electricity market.

A percentage specification always contains a statement in combination with the reference value. As long as the reference value is always constant, thus contains only limited information for comparisons; the reference value cannot be specified. In principle, the multiplication of time availability with the nominal energy results in the available energy in the reporting period. This indicator can be interpreted as mean available capacity over the entire observation period or as a nominal capacity with an average percentage availability time.

If the report time also covers periods outside the operating phase, the energy as well as the time availability indicator remains constant, even if the time span is further increased. It is obvious to calculate the mean capacity by dividing the energy by the observation period. The average available capacity is reduced by considering times outside the operating phase.

3) Aggregation of the indicator over several plants

The formula for calculating the time availability over the energy quantities cannot only be applied to one plant, it is also valid for the aggregation of several plants. The corresponding energy quantities of all plants are taken into account in the terms “nominal energy” or “sum of all UA-energies”.

For the aggregated calculation of the time availability of several plants, a capacity weighting of all individual plants has to take place when using the formula, which contains only time data. In the following, this is derived for two systems (index i), starting from the calculation formula with energy quantities. For the sake of simplicity, not only the sum of the UA-times is shown with “$t_{nv,\,i}$” but also the entire UA-time of a system i. Finally, the time availability of the individual systems $k_{t,\,i}$ is shown with a factor which contains the capacity weight.

$$k_t = \frac{W_N - \sum W_{nv}}{W_N} = \frac{W_{N,1} + W_{N,2} - W_{nv,1} - W_{nv,2}}{W_{N,1} + W_{N,2}} = \frac{W_{N,1} - W_{nv,1} + W_{N,2} - W_{nv,2}}{W_{N,1} + W_{N,2}} =$$

$$= \frac{\left(P_{N,1} \cdot t_N - P_N \cdot t_{nv,1}\right) + \left(P_{N,2} \cdot t_N - P_N \cdot t_{nv,2}\right)}{\left(P_{N,1} \cdot t_N + P_{N,2} \cdot t_N\right)} = \frac{P_{N,1}}{P_{N,1} + P_{N,2}} \cdot \frac{t_N - t_{nv,1}}{t_N} + \frac{P_{N,2}}{P_{N,1} + P_{N,2}} \cdot \frac{t_N - t_{nv,2}}{t_N} =$$

$$= \frac{P_{N,1}}{P_{N,1} + P_{N,2}} \cdot k_{t,1} + \frac{P_{N,2}}{P_{N,1} + P_{N,2}} \cdot k_{t,2}$$

In this example, the nominal capacity during the period of observation is constant.

In case the nominal capacity changes during the observation period, the average nominal capacity of the plant shall be used:

$$\overline{k}_t = \sum \left(\frac{\overline{P}_{N,i}}{\sum \overline{P}_{N,i}} \cdot k_{t,i} \right)$$

Examples for the calculation of the “time availability” indicator

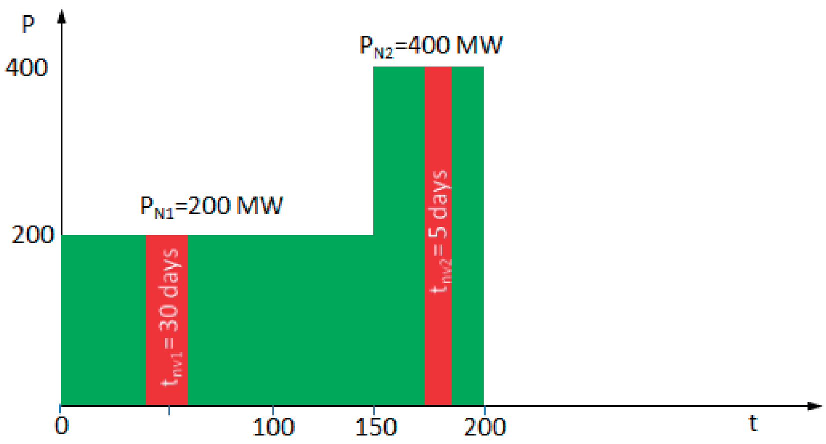
In the examples below, simple numerical values were used, which are only very limited realistic. The procedures and calculations are in focus and the calculations are easier reproducible.

In the first example, a plant is considered in which a nominal capacity increase occurs during the viewing period. If for example two plants should be aggregated, the nominal capacity curve of the first example was split into two separate capacity curves describing “two” plants: One plant is continuously in operation, including a small increase in capacity. The second plant is put into operation during the period of observation. The aggregation of both plants must yield the known result of the first example. For independent testing, the capacity characteristics of the first example can also be decomposed differently to simulate several other plants.

Example 1a: Increase of nominal capacity during operation:

Observation period: 200 days

Nominal capacity	$P_{N,1}$ = 200 MW	for	0 days < t ≤ 150 days
	$P_{N,2}$ = 400 MW	for	150 days < t ≤ 200 days
Outage duration	$t_{nv,1}$ = 30 days	in the period	0 days < t ≤ 150 days
	$t_{nv,2}$ = 5 days	in the period	150 days < t ≤ 200 days



$$k_t = \frac{t_N - \sum t_{nv}}{t_N} = \frac{W_N - \sum W_{nv}}{W_N}$$

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\ \text{MW} \cdot 3{,}600\ \text{h} + 400\ \text{MW} \cdot 1{,}200\ \text{h} = 1{,}200{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\ \text{MW} \cdot 720\ \text{h} + 400\ \text{MW} \cdot 120\ \text{h} = 192{,}000\ \text{MWh}$$

$$k_t = \frac{1{,}200{,}000\ \text{MWh} - 192{,}000\ \text{MWh}}{1{,}200{,}000\ \text{MWh}} = 84.00\ \%$$

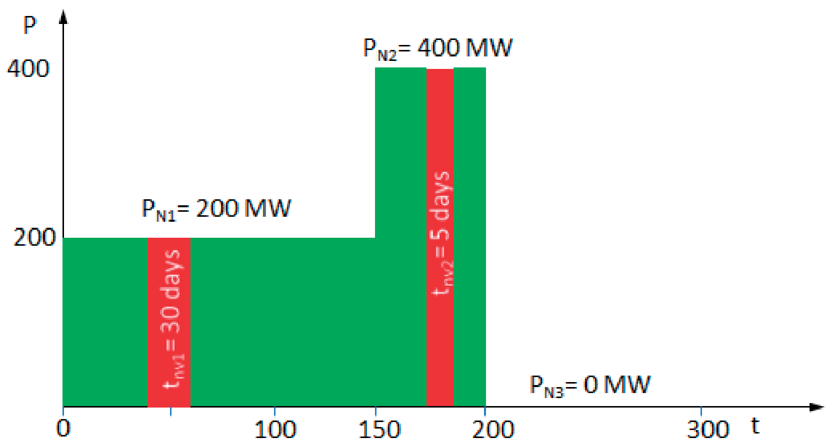
Average nominal capacity: $\overline{P}_N = 250\ \text{MW} = \frac{200\ \text{MW} \cdot 3{,}600\ \text{h} + 400\ \text{MW} \cdot 1{,}200\ \text{h}}{3{,}600\ \text{h} + 1{,}200\ \text{h}}$

Average time-available capacity: $P = \overline{P}_N \cdot k_t = 210\ \text{MW} = 250\ \text{MW} \cdot 84.00\ \%$

Example 1b: Increase of nominal capacity and viewing period beyond decommissioning

Observation period: 300 days

Nominal capacity	$P_{N,1}$ = 200 MW	for		0 days < t ≤ 150 days
	$P_{N,2}$ = 400 MW	for		150 days < t ≤ 200 days
	$P_{N,3}$ = 0 MW	for		200 days < t
Outage duration	$t_{nv,1}$ = 30 days	in the period		0 days < t ≤ 150 days
	$t_{nv,2}$ = 5 days	in the period		150 days < t ≤ 200 days
	$t_{nv,3}$ = 0 days	in the period		200 days < t



$$k_t = \frac{t_N - \sum t_{nv}}{t_N} = \frac{W_N - \sum W_{nv}}{W_N}$$

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\ \text{MW} \cdot 3{,}600\text{h} + 400\ \text{MW} \cdot 1{,}200\text{h} + 0\ \text{MW} \cdot 2{,}400\ \text{h} = 1{,}200{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\ \text{MW} \cdot 720\ \text{h} + 400\ \text{MW} \cdot 120\ \text{h} + 0\ \text{MW} \cdot 0\ \text{d} = 192{,}000\ \text{MWh}$$

$$k_t = \frac{1{,}200{,}000\ \text{MWh} - 192{,}000\ \text{MWh}}{1{,}200{,}000\ \text{MWh}} = 84.00\ \%$$

Average nominal capacity:

$$\overline{P}_N = 166.67\ \text{MW} = \frac{200\text{MW} \cdot 3{,}600\text{h} + 400\text{MW} \cdot 1{,}200\text{h} + 0\text{MW} \cdot 2{,}400\text{h}}{3{,}600\text{h} + 1{,}200\text{h} + 2{,}400\text{h}}$$

Average time-available capacity: $P = \overline{P}_N \cdot k_t = 140.00\ \text{MW} = 166.67\ \text{MW} \cdot 84.00\ \%$

Aggregation of 2 plants

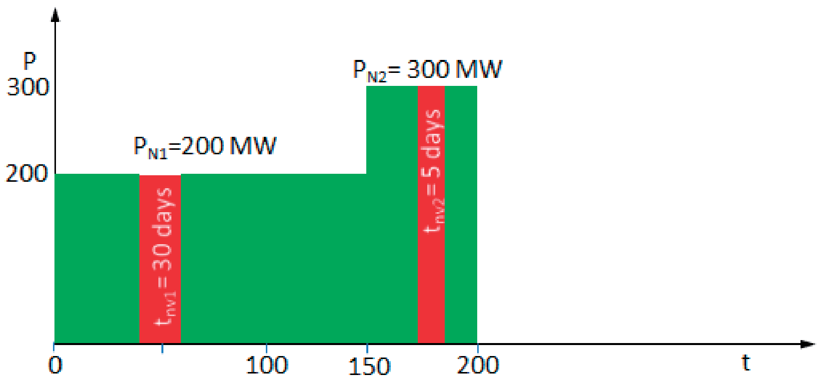
Observation period: 200 days

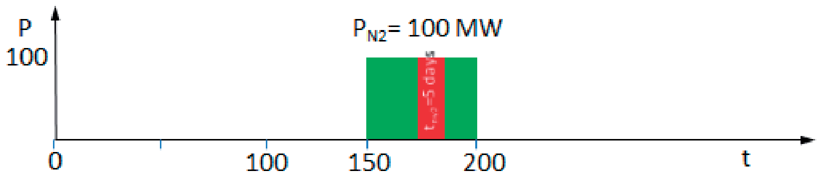
plant 1 (with increase of nominal capacity)

Nominal capacity	$P_{N,1}$ = 200 MW	for	0 days < t ≤ 150 days
	$P_{N,1}$ = 300 MW	for	150 days < t ≤ 200 days
Outage duration	$t_{nv,1a}$ = 30 days	in the period	0 days < t ≤ 150 days
	$t_{nv,1b}$ = 5 days	in the period	150 days < t ≤ 200 days

plant 2 (commissioning)

Nominal capacity	$P_{N,2}$ = 0 MW	for	0 days < t ≤ 150 days
	$P_{N,2}$ = 100 MW	for	150 days < t ≤ 200 days
Outage duration	$t_{nv,2}$ = 5 days	in the period	150 days < t ≤ 200 days





$$k_t = \frac{t_N - \sum t_{nv}}{t_N} = \frac{W_N - \sum W_{nv}}{W_N}$$

Plant 1

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 200\ \text{MW} \cdot 3{,}600\ \text{h} + 300\ \text{MW} \cdot 1{,}200\ \text{h} = 1{,}080{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 200\ \text{MW} \cdot 720\ \text{h} + 300\ \text{MW} \cdot 120\ \text{h} = 180{,}000\ \text{MWh}$$

$$k_t = \frac{1{,}080{,}000\ \text{MWh} - 180{,}000\ \text{MWh}}{1{,}080{,}000\ \text{MWh}} = 83.33\ \%$$

Average nominal capacity: $\overline{P}_N = 225.00\ \text{MW} = \frac{200\text{MW} \cdot 3{,}600\text{h} + 300\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$

Average time-available capacity: $P = \overline{P}_N \cdot k_t = 187.50\ \text{MW} = 225.00\ \text{MW} \cdot 83.33\ \%$

Plant 2

$$W_N = \sum P_{N,i} \cdot t_{N,i} = 0\ \text{MW} \cdot 3{,}600\ \text{h} + 100\ \text{MW} \cdot 1{,}200\ \text{h} = 120{,}000\ \text{MWh}$$

$$W_{nv} = \sum P_{N,i} \cdot t_{nv,i} = 100\ \text{MW} \cdot 120\ \text{h} = 12{,}000\ \text{MWh}$$

$$k_t = \frac{120{,}000\ \text{MWh} - 12{,}000\ \text{MWh}}{120{,}000\ \text{MWh}} = 90.00\ \%$$

Average nominal capacity: $\overline{P}_N = 25.00\ \text{MW} = \frac{0\text{MW} \cdot 3{,}600\text{h} + 100\text{MW} \cdot 1{,}200\text{h}}{3{,}600\text{h} + 1{,}200\text{h}}$

Average time-available capacity: $P = \overline{P}_N \cdot k_t = 22.50\ \text{MW} = 25.00\ \text{MW} \cdot 90.00\ \%$

Aggregated indicator time availability for both systems

Capacity weighting of the individual plant characteristics with the average nominal capacity:

$$\bar{k}_t = \sum \left(\frac{\bar{P}_{N,i}}{\sum \bar{P}_{N,i}} \cdot k_{t,i} \right)$$

$$\bar{k}_t = \frac{225 \text{ MW}}{225 \text{ MW} + 25 \text{ MW}} \cdot 0.833 + \frac{25 \text{ MW}}{225 \text{ MW} + 25 \text{ MW}} \cdot 0.9 = 84.00 \ \%$$

Average power from both systems: = 250 MW

$$\bar{P}_N = 250 \text{ MW} = 225\text{MW} + 25\text{MW}$$

$$= \frac{200 \text{ MW} \cdot 3{,}600 \text{ h} + 300 \text{ MW} \cdot 1{,}200 \text{ h}}{3{,}600 \text{ h} + 1{,}200 \text{ h}} + \frac{0 \text{ MW} \cdot 3{,}600 \text{ h} + 100 \text{ MW} \cdot 1{,}200 \text{ h}}{3{,}600 \text{ h} + 1{,}200 \text{ h}}$$

Average time-available capacity:

$$P = \bar{P}_N \cdot \bar{k}_t = 210 \text{ MW} = 250 \text{ MW} \cdot 84.00 \ \%$$

Conclusion

The “time availability” indicator is a special case of the “energy availability” indicator, which takes only 100% outages into account. Using the exact calculation formula for energy quantities, the nominal capacity is eliminated if it is constant. The formula remains only with time related input data.

If the nominal capacity changes during the observation period in a plant, the calculation formula must be used with energy quantities. In this case the observation period is subdivided into the time sections with different nominal capacity values and the respective energy quantities are calculated. Times before commissioning or after decommissioning would be ignored. For computing routines it is equivalent to set the nominal capacity to zero during these times.

According to the current VGB rules for the indicator generation, plants in cold reserve are no longer included in the statistics. These times are either not taken into account in the calculation or the nominal capacity is set to zero as described above.

The aggregation of time availability for several plants is possible:

If the final calculated indicators are used, the aggregation must be carried out via a capacity weighting. The weighting is based on the nominal capacity of the individual plants, which is normally constant. If the nominal capacity of a single system changes during the period of observation, the average nominal capacity thereof must be used.

Alternatively, the basic formula can be used with energy quantities. Then the energy quantities of all plants to be aggregated must be summed up and entered.

Note

The aggregation of the time availability over several plants takes place using the following basic data for energy quantities:

$$\bar{k}_t = \frac{\sum W_N - \sum_{\text{plant i}} \sum_{\text{incident k}} W_{nv,i,k}}{\sum W_N} = 1 - \frac{\sum W_{nv}}{\sum W_N} = 1 - \frac{\sum_{\text{plant i}} \sum_{\text{incident k}} P_{N,i} \cdot t_{nv,i,k}}{\sum_{\text{plant i}} W_{N,i}}$$

with i = plant i

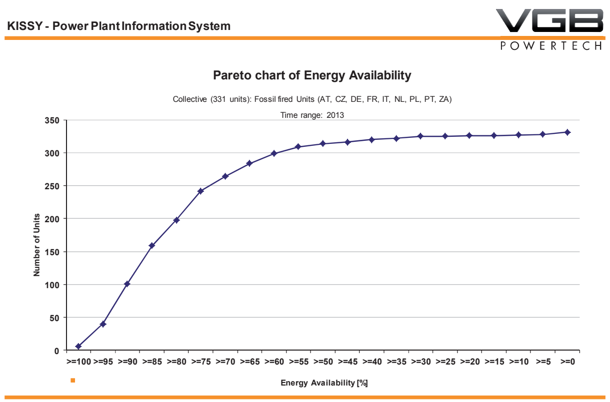
i, k = plant i, incident k

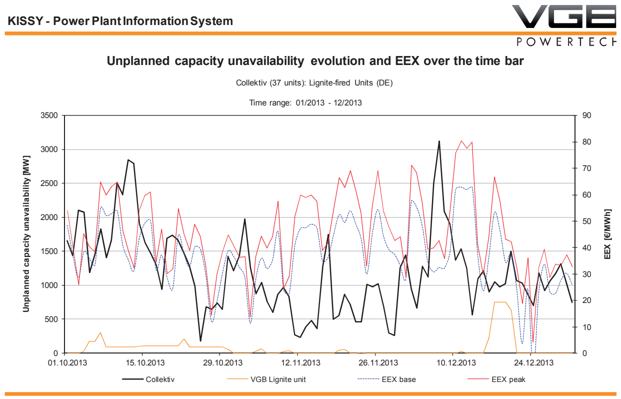
The aggregation of the time availability over several plants is carried out by capacity-weighted indicators for the individual plants:

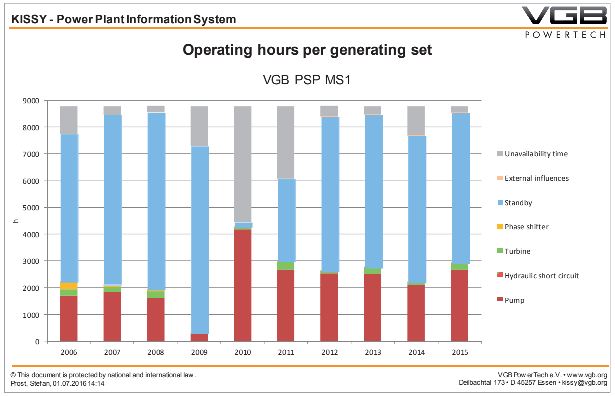
$$\bar{k}_t = \sum \left(\frac{\bar{P}_{N,i}}{\sum \bar{P}_{N,i}} \cdot k_{t,i} \right)$$

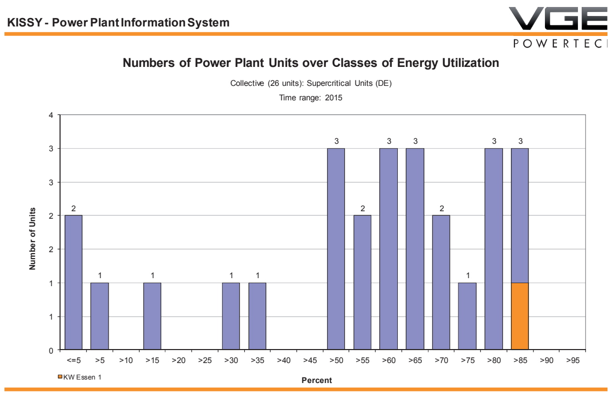
The average nominal capacity for each system must be used as the nominal capacity during the observation period. Usually this is constant. Changes could be capacity increases, or times before commissioning, or after decommissioning, or during cold reserve.

Examples of evaluation

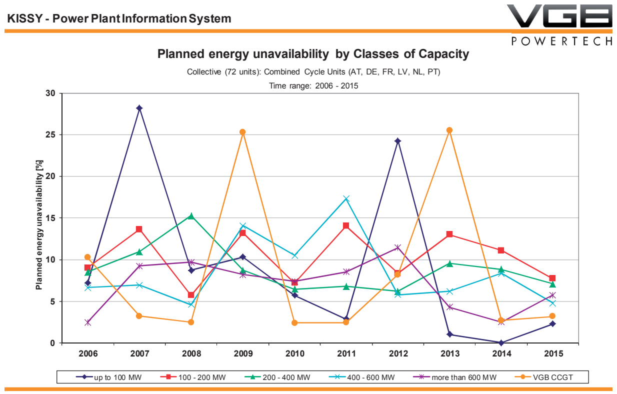


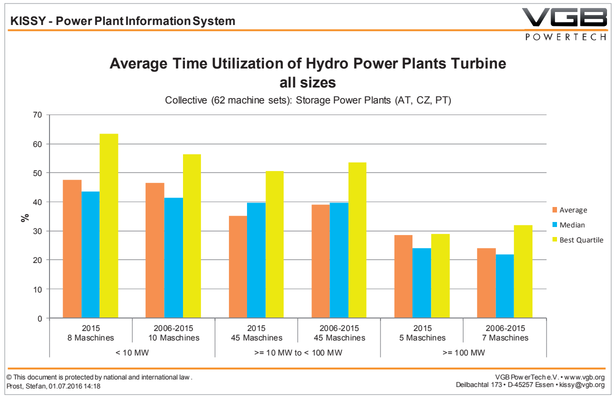






Opportunities which reports can be generated from KISSY





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