VGB-Standard
Annex to VGB-S-002 Series

Edition 2016

VGB-S-002-33-2016-08-EN
VGB-Standard
Annex to VGB-S-002 Series

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

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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

<table>
<thead>
<tr>
<th>VGB-Standard</th>
<th>Date of Revision</th>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGB-S-002-Annex</td>
<td>October 2015</td>
<td></td>
<td>Original</td>
</tr>
</tbody>
</table>


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).
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## Input and Output Forms

### Data sheet of availability (monthly)


<table>
<thead>
<tr>
<th>Data sheet for reporting to VGB</th>
<th>Monthly Operating and Availability Data for Nuclear Power Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand 10/2012</td>
<td></td>
</tr>
</tbody>
</table>

**KKW Essen**

**Gross nominal power [MW]:**

| (*) 1,430                      |

**Net [MW]:**

| (*) 1,390                      |

**Nominal Time [h]:**

| (*) 696                       |

**Nominal Energy [MWh]:**

| (*) 946,560                   |

### Operating Data

<table>
<thead>
<tr>
<th>Energy generated</th>
<th>Dimension</th>
<th>Month</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>gross</td>
<td>MWh</td>
<td>968,969.40</td>
<td>2,001,211.80</td>
</tr>
<tr>
<td>net</td>
<td>MWh</td>
<td>916,696.40</td>
<td>1,899,621.70</td>
</tr>
<tr>
<td>thereof steam/traction power production</td>
<td>MWh</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Energy utilization

<table>
<thead>
<tr>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>96.85</td>
</tr>
</tbody>
</table>

### Unavailable energy (***)

<table>
<thead>
<tr>
<th>planned (target)</th>
<th>MWh</th>
<th>172.00</th>
<th>451.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>planned (actual)</td>
<td>MWh</td>
<td>172.00</td>
<td>451.00</td>
</tr>
</tbody>
</table>

### Extensions of planned unavailabilities (1)

<table>
<thead>
<tr>
<th>unplanned (total)</th>
<th>MWh</th>
<th>0.00</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>postponable (*)</td>
<td>MWh</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>not postponable (*)</td>
<td>MWh</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Available but not producible energy (external influences) (2)

| MWh | 0.00 | 0.00 |

### Energy availability

<table>
<thead>
<tr>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.98</td>
</tr>
</tbody>
</table>

### Dispatcher failure rate

<table>
<thead>
<tr>
<th>unplanned</th>
<th>%</th>
<th>0.00</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>not postponable</td>
<td>%</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Energy failure rate

<table>
<thead>
<tr>
<th>unplanned</th>
<th>%</th>
<th>0.00</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>not postponable</td>
<td>%</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Load dispatcher reliability

<table>
<thead>
<tr>
<th>unplanned</th>
<th>%</th>
<th>100.00</th>
<th>100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>not postponable</td>
<td>%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Energy reliability

<table>
<thead>
<tr>
<th>unplanned</th>
<th>%</th>
<th>100.00</th>
<th>100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>not postponable</td>
<td>%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Operating time

| (*) h | 696.00 | 1,440.00 |

### Time utilization

| % | 100.00 | 100.00 |

### Unavailability time (***)

| (*) h | 0.00 | 0.00 |

### Time availability

| % | 100.00 | 100.00 |

### Thermal generation

| MWh | 2,635,919.00 | 5,442,852.00 |

### Electric peak load

| MW  | 1,370.00 | 1,378.00 |

### Remark Code:

- **Refuelling:***
- **Stretch out:***
- **Repair:***
- **Steam production:***
- **Traction power:***
- **New nominal power:***

### Important Notes

(1) 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 movable to 12 hours.

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

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

### Created: 20.04.2016 11:11

(*) mandatory fields
Data sheet of annual availability for thermal power plants


<table>
<thead>
<tr>
<th>Block/Unit No.</th>
<th>Nominal Power</th>
<th>Nominal Time</th>
<th>Energy Utilization</th>
<th>Energy Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) MW</td>
<td>h</td>
<td>GWh</td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GWh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(**)</th>
<th>Total</th>
<th>Planned</th>
<th>Unplanned</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_n</td>
<td>t_n</td>
<td>W_n - P_n * t_n</td>
<td>W_n</td>
<td>W_n - P_n * t_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
<td>W_n</td>
</tr>
<tr>
<td>n</td>
<td>A</td>
<td>1,000</td>
<td>4,380</td>
<td>4,380.0</td>
<td>1,752.0</td>
<td>40.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

(1) Any exceedance of the target date of a planned unavailability, and unplanned extensions
(2) Available not producible energy based on influences outside the plant

(1) Any exceedance of the target date of a planned unavailability, and unplanned extensions
(2) Available not producible energy based on influences outside the plant

(*1) Based on: g = gross values
(1) required during the planning and duration of the planning.
(1) mandatory fields
(1) calculated fields

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 producible energy based on influences outside the plant
**Data sheet for reporting to VGB**

<table>
<thead>
<tr>
<th>Block/Unit No.</th>
<th>Operating Time</th>
<th>Unavailability Time (**)</th>
<th>During the reporting period used fuel</th>
<th>Part of generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Utilization</td>
<td>Planned</td>
<td>Unplanned</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>Ns</td>
<td>%</td>
<td>Nt</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>t0</td>
<td>t0 - t0</td>
<td>t0</td>
<td>t0 - t0</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>4,380</td>
<td>100.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

(***) Classification of unavailability (UA)

- **planned UA**: The beginning of the UA is more than four weeks.
- **unplanned UA**: The beginning of the UA isn’t or movable to four weeks.
- **postponable UA**: The beginning of the UA is more than 12 hours moved to four weeks.
- **not postponable UA**: 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

(**) 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 UA**: The beginning of the UA is more than 12 hours moved to four weeks.
- **not postponable UA**: The beginning of the UA isn’t or displaceable to 12 hours.

(* ) calculated fields

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
#### Availability

**Data sheet for reporting to VGB**

<table>
<thead>
<tr>
<th>Utility: VGB PowerTech e.V.</th>
<th>Power Plant: PowerTech</th>
<th>Time range 2015</th>
</tr>
</thead>
</table>

for fossil fired units and gas turbines

<table>
<thead>
<tr>
<th>Block/Unit No.</th>
<th>Failure Rate</th>
<th>Reliability</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dispatcher failure rate</td>
<td>Energy failure rate</td>
<td>Load dispatcher reliability</td>
</tr>
<tr>
<td></td>
<td>unplanned total</td>
<td>unplanned not postponable</td>
<td>unplanned total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(*) mandatory fields
(calculated fields)
Data sheet of annual availability of hydro power plants


<table>
<thead>
<tr>
<th>Machine Set No.</th>
<th>Nominal Capacity</th>
<th>Nominal Time</th>
<th>Operating Time</th>
<th>Number of Changes of Operating Type</th>
<th>Total</th>
<th>Turbine</th>
<th>Pump</th>
<th>Phase Shifter</th>
<th>Hydraul. Short Circuit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Turbine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(*) (**)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(*) (**)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>265</td>
<td>290</td>
<td>8,760</td>
<td>2,494.0</td>
<td>2,610.0</td>
<td>38.0</td>
<td>0.0</td>
<td>5142.0</td>
<td>711</td>
<td>396</td>
</tr>
<tr>
<td>B</td>
<td>265</td>
<td>290</td>
<td>8,760</td>
<td>1,966.0</td>
<td>1,697.0</td>
<td>92.0</td>
<td>0.0</td>
<td>3755.0</td>
<td>895</td>
<td>368</td>
</tr>
<tr>
<td>C</td>
<td>265</td>
<td>290</td>
<td>8,760</td>
<td>1,836.0</td>
<td>1,481.0</td>
<td>82.0</td>
<td>0.0</td>
<td>3399.0</td>
<td>816</td>
<td>319</td>
</tr>
<tr>
<td>D</td>
<td>265</td>
<td>290</td>
<td>8,760</td>
<td>2,194.0</td>
<td>3,991.0</td>
<td>30.0</td>
<td>0.0</td>
<td>6215.0</td>
<td>463</td>
<td>353</td>
</tr>
</tbody>
</table>

***) Based on:

- g = gross values
- n = net values

(**) mandatory fields

calculated fields
### Availability

**Data sheet for reporting to VGB**

<table>
<thead>
<tr>
<th>Utility: VGB PowerTech e.V.</th>
<th>Power Plant: Essen</th>
<th>Time range: 2015</th>
</tr>
</thead>
</table>

#### Time Utilization, Time Availability

<table>
<thead>
<tr>
<th>Machine Set No.</th>
<th>Time Utilization</th>
<th>Turbine/Generator-Unavailability Time (**)</th>
<th>Unavailability Time (**)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Turbine</td>
<td>Pump</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>A</td>
<td>28.5</td>
<td>29.8</td>
<td>58.7</td>
</tr>
<tr>
<td>B</td>
<td>22.4</td>
<td>19.4</td>
<td>42.9</td>
</tr>
<tr>
<td>C</td>
<td>21.0</td>
<td>16.9</td>
<td>38.8</td>
</tr>
<tr>
<td>D</td>
<td>25.0</td>
<td>45.6</td>
<td>70.9</td>
</tr>
</tbody>
</table>

#### Calculation

- \( t_{tu} \) = \( t_{pu} \) - \( t_{tu} \)
- \( t_{pu} \) = \( t_{pu} \) - \( t_{tu} \)
- \( t_{pu} \) = \( t_{pu} \) - \( t_{tu} \)
- \( W_{pu} \) = \( \frac{t_{pu}}{t_{pu}} \)

**Notes:**

- (*) mandatory fields
- calculated fields

**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 movable to four weeks.
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- **not postponable:** The beginning of the UA isn’t displaceable to 12 hours.
### Availability

**Data sheet for reporting to VGB**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Set No.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

- **(*) mandatory fields**
- **(*) calculated fields**
Example for input of ‘Unavailability incidents of fossil-fired units’


(*) mandatory fields
(*) calculated fields

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Start Time (TT/MM/YYYY; hh:mm)</th>
<th>End Time (TT/MM/YYYY; hh:mm)</th>
<th>Duration of Unavailability</th>
<th>Energy Unavailability</th>
<th>Reference Designation System (KKS Function)</th>
<th>Event Characteristics</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>n 2015001</td>
<td>12.01.2015 13:24</td>
<td>12.01.2015 20:00</td>
<td>1,320</td>
<td>H</td>
<td>A</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
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<td>14.01.2015 08:08</td>
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<td>795</td>
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<td>n 2015006</td>
<td>02.08.2015 00:00</td>
<td>12.08.2015 00:00</td>
<td>12,000</td>
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<tr>
<td>n 2015007</td>
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<td>22.12.2015 15:00</td>
<td>8,074</td>
<td>X</td>
<td>A</td>
<td>A</td>
<td>C</td>
</tr>
</tbody>
</table>

Disturbance: With load admission occurred fire from "difference amount feed water about Eco " (loss by frost effect)

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.

Max. 275 MW because plant operated with four mills. Mill 3 in repair, mill 6 unusual by "short circuit release* (engine was changed afterwards)

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.

Disturbance at the starting-up operation: Damaged magnet valves of the Elmopumpen-aerial emitters led to aerial burglary and thereby to unenough vacuum.

Outside impact: Cooling water temperature to high

Damage at the driving turbine TKSP, regulation beam twisted

Repairing of the central cooling water pump
Example for input ‘Unavailability incidents of nuclear power plants’


(*) mandatory fields

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Duration of Unavailability</th>
<th>Energy Unavailability MWh</th>
<th>Reference Designation System (KKS Function)</th>
<th>Time Frame</th>
<th>Type of Incident</th>
<th>Main Impact</th>
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<tbody>
<tr>
<td></td>
<td>Event Characteristics Key</td>
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<td></td>
<td>Brief Description</td>
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<td>n 2015009</td>
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<td>2,112</td>
<td>J D A</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>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.</td>
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<td>J</td>
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<td>Refuelling and revisions</td>
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<td>n 2015011</td>
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<td>J K B7</td>
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<td>10.03.2015 10:14 to 13.03.2015 15:45</td>
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<td>L C Y</td>
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<td>n 2015013</td>
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<td>M A W</td>
<td>H</td>
<td>A2</td>
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<td>n 2015014</td>
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<td>n 2015015</td>
<td>27.05.2015 00:00 to 28.05.2015 05:00</td>
<td>29,000</td>
<td>P C B7</td>
<td>4</td>
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</table>
### Unavailability Incidents

**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)**

<table>
<thead>
<tr>
<th>Event No.</th>
<th>Duration of Unavailability</th>
<th>Energy Unavailability</th>
<th>Reference Designation System (KKS Function)</th>
<th>Event Characteristics Key</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015002</td>
<td>n 06.05.2015 13:12 06.05.2015 23:48</td>
<td>1,250 MWh</td>
<td>H L D</td>
<td>C A2</td>
<td>2 Reset because of density of the economizer</td>
</tr>
<tr>
<td>2015003</td>
<td>n 06.05.2015 23:48 07.05.2015 07:51</td>
<td>1,750 MWh</td>
<td>H L D</td>
<td>C A2</td>
<td>4 Units shutdown, economizer sheet metals detached from mounting support, repair of mounting supports and renewal of destructed sheet metals; unit at full load</td>
</tr>
<tr>
<td>2015004</td>
<td>n 16.05.2015 19:30 17.05.2015 13:12</td>
<td>2,138 MWh</td>
<td>H L B</td>
<td>C A2</td>
<td>2 Failure of draft fan</td>
</tr>
<tr>
<td>2015005</td>
<td>n 17.05.2015 13:12 18.05.2015 17:51</td>
<td>6,900 MWh</td>
<td>M K Y</td>
<td>A A1</td>
<td>4 Disturbance in the excitation of the generator; voltage failure of the excitation supply; error detection cause cannot be detected.</td>
</tr>
</tbody>
</table>
### Relevant EMS coding for reporting to VGB

<table>
<thead>
<tr>
<th>Reporting to VGB</th>
<th>VGB event-characteristic-key-system for the unavailable event recording (only relevant EMS codes)</th>
<th>Status VGB 10/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>**EMS 4/1 time limits *</td>
<td>**EMS 1 type of event *</td>
<td></td>
</tr>
<tr>
<td>A automatic load shedding/emergency trip</td>
<td>A1 disturbance without damage</td>
<td></td>
</tr>
<tr>
<td>B manual load shedding/emergency trip</td>
<td>A2 damage</td>
<td></td>
</tr>
<tr>
<td>C arranged shutdown within 12 hours</td>
<td>B1 control/test of condition</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>B2 lubrication</td>
<td></td>
</tr>
<tr>
<td>E exceeding of the planned event time according to point J or K because of unplanned measures (damages, disturbances...)</td>
<td>B3 maintenance</td>
<td></td>
</tr>
<tr>
<td>F start-up delay. An initialized start-up activity cannot be led to the grid switching in the dictated time.</td>
<td>B4 inspection</td>
<td></td>
</tr>
<tr>
<td>G start-up extension. After the grid switching, an increase of capacity is not possible corresponding to the start-up curve/the operating manual</td>
<td>B5 preventive repair</td>
<td></td>
</tr>
<tr>
<td>H can be postponed more than 12 hours</td>
<td>B6 keeping clean</td>
<td></td>
</tr>
<tr>
<td>J fixed more than 4 weeks before</td>
<td>B7 revision</td>
<td></td>
</tr>
<tr>
<td>K annual shutdown program</td>
<td>B8 fuel element change</td>
<td></td>
</tr>
<tr>
<td>L exceeding the planned event time according to point J or K by extension of the planned period</td>
<td>C0 reconstruction/extension</td>
<td></td>
</tr>
<tr>
<td>M without effect (only valid in connection with plant components)</td>
<td>D2 outside influence without damage</td>
<td></td>
</tr>
<tr>
<td>A-G: unplanned not postponable</td>
<td>D21 fuel</td>
<td></td>
</tr>
<tr>
<td>H: unplanned postponable</td>
<td>D22 mothballing of plants</td>
<td></td>
</tr>
<tr>
<td>J, K, L: planned</td>
<td>D23 climate</td>
<td></td>
</tr>
<tr>
<td>* valid for capacity restriction and shutdown of the plant</td>
<td>D24 grid restriction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D241 Redispatch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D25 staff shortage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D26 others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E0 tests/functional trials/functional test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F0 official test/measure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G0 lack of reactivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Z0 other type of event</td>
<td></td>
</tr>
</tbody>
</table>

**EMS 4/2 main effect**

2 power limitation
4 shutdown
Indicators and definitions

Market-rated utility reliability

\[ r_m = 1 - \frac{\sum (|W_{Bi} - W_{Fpi}| \cdot DB_i)}{\sum (W_{Fpi} \cdot DB_i)} \]

- \( r_m \): market – rated utility reliability
- \( W_{Bi} \): 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 Wholesale market. It assesses the economic benefits of the deployment beyond the technical utilisability.

\[ r_m = 1 - \frac{\sum (|W_{Bi} - W_{Fpi}| \cdot (EEX - DB_{ii}))}{\sum (W_{Fpi} \cdot DB_{ii})} \]

\( \tau = \frac{1}{\text{price trend}} \)

Example

<table>
<thead>
<tr>
<th></th>
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<td>18.43</td>
<td>240.46</td>
</tr>
<tr>
<td>01/01/2015</td>
<td>23:00</td>
<td>20.11</td>
<td>18.43</td>
<td>240.46</td>
</tr>
</tbody>
</table>
Time availability factor during peak times

\[ k_{t Pe} = \frac{t_{v Pe}}{t_{N Pe}} = \frac{(t_{N Pe} - t_{nv Pe})}{t_{N Pe}} \]

- \( k_{t Pe} \): 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 \( P_N = 150 \text{ MW} \)

Month November with 22 peak-days = 264 peak-hours

Reduction of capacity:
\( P = 120 \text{ MW from Fr 05.11. 12:00 until 18:00 h} \)

Boiler failure:
\( \text{Fr 05.11. 18:00 until Mo 08.11. 16:00 h} \)

Reduction of capacity:
\( 110 \text{ MW from Tu 16.11. 06:00 until 14:00 h} \)

\[
k_{t Pe} = \frac{t_{v Pe}}{t_{N Pe}} = \frac{(t_{N Pe} - t_{nv Pe})}{t_{N Pe}}
\]

\[
k_{t Pe} = \frac{(264 \text{ h} -10\text{ h})}{264 \text{ h}} = 0.9621
\]
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

\[ T_{NPe} = |08 - 20| h/d * 261 \text{ d} = 3,132 \text{ h} \]
Energy availability factor during peak times

\[ k_{W, Pe} = \frac{W_{v, Pe}}{W_{N, Pe}} = \left( \frac{W_{N, Pe} - W_{uv, Pe}}{P_N} \right) / t_{N, Pe} \]

- \( k_{W, Pe} \): energy availability factor during peak times
- \( W_{v, Pe} \): available energy during peak times
- \( W_{N, Pe} \): nominal energy within peak times
- \( W_{uv, Pe} \): 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 peak times 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 \( P_N = 150 \text{ MW} \)
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

\[ k_{W, Pe} = \frac{W_{v, Pe}}{W_{N, Pe}} = \left( \frac{W_{N, Pe} - W_{uv, Pe}}{P_N} \right) / t_{N, Pe} \]

\[ k_{W, Pe} = 150 \text{ MW} \times 264 \text{ h} - (30 \text{ MW} \times 6 \text{ h} + 150 \text{ MW} \times 10 \text{ h} + 40 \text{ MW} \times 8 \text{ h}) / 150 \text{ MW} \times 264 \text{ h} \]

\[ k_{W, Pe} = 0.9495 \]
Dispatching (energy) failure rate

\[ p_i = \frac{W_{nv\ u(n)}}{W_{nv\ u(n)} + W_{ns} + W_B} \times 100\% \]

- \( p_i \): 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 unpredictable energy outside planned unavailabilities and outside available energy. Therefore it is an early-warning indicator in a risk-management system.

**Example**
Coal fired unit February 2015
0.07 % = \( \frac{230 \text{ MWh}}{230 \text{ MWh} + 0 \text{ MWh} + 320,209 \text{ MWh}} \) \times 100 %
Calculation per unit, per power class, per power station

Coal fired unit December 2015
12.2 % = \( \frac{44,137 \text{ MWh}}{44,137 \text{ MWh} + 274 \text{ MWh} + 318,208 \text{ MWh}} \) \times 100 %
Calculation per unit, per power class, per power station
Dispatch reliability

\[ p_v = \frac{W_B}{(W_B + W_{nv\, u(n)} + W_{ns})} \times 100\% \]

- \( p_v \): 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 \% = \( \frac{318,208 \text{ MWh}}{318,208 \text{ MWh} + 44,137 \text{ MWh} + 274 \text{ MWh}} \times 100\% \)
Calculated per unit, per power class, per power station
Energy reliability

\[ W_v = \frac{W_B}{W_B + W_{nv u(n)}} \times 100\% \]

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

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

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

**Example**
Coal fired unit February 2015
95.53 % = \( \frac{320,209 \text{ MWh}}{320,209 \text{ MWh} + 14,998 \text{ MWh}} \times 100\% \)
Calculation per unit, per power class, per power station
Time reliability

\[ w_t = \frac{t_B}{t_B + t_{nv\,u(n)}} \times 100\% \]

- \( w_t \): 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

\[ f_{FP} = \frac{W_B}{W_{FP}} \times 100\% \]

- \( f_{FP} \): 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 \times 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 $W_{FP}$ results as a product from schedule capacity with the corresponding time frame.

Example

Coal fired unit with $P_N = 670$ MW

<table>
<thead>
<tr>
<th>$P_N$ in MW</th>
<th>$h$</th>
<th>$P_{FP}$ in MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>670</td>
<td>1</td>
<td>320</td>
</tr>
<tr>
<td>670</td>
<td>2</td>
<td>320</td>
</tr>
<tr>
<td>670</td>
<td>3</td>
<td>320</td>
</tr>
<tr>
<td>670</td>
<td>4</td>
<td>320</td>
</tr>
<tr>
<td>670</td>
<td>5</td>
<td>640</td>
</tr>
<tr>
<td>670</td>
<td>6</td>
<td>640</td>
</tr>
<tr>
<td>670</td>
<td>7</td>
<td>640</td>
</tr>
<tr>
<td>670</td>
<td>8</td>
<td>640</td>
</tr>
<tr>
<td>670</td>
<td>9 ... 23</td>
<td>640</td>
</tr>
<tr>
<td>670</td>
<td>24</td>
<td>640</td>
</tr>
</tbody>
</table>
Schedule deviation

Absolute schedule deviation

$$\Delta P_a = \sum_{i=1}^{n-1} |P_{FP_i} - P_{B_i}| / n \text{[MW / x min]}$$

- $\Delta P_a$: absolute schedule deviation
- $P_{FP_i}$: schedule capacity (netted out with balancing capacity)
- $P_{B_i}$: operating capacity (grid supply)

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

Specific schedule deviation

$$f_{vn} = \left( \sum \frac{|W_{FP} - W_{B}|}{W_{FP}} \right) \times 100\%$$

Example: 350 MW hard coal-fired unit

<table>
<thead>
<tr>
<th>Schedule</th>
<th>measurement</th>
<th>schedule deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>MW</td>
<td>MW</td>
</tr>
<tr>
<td>185</td>
<td>179</td>
<td>6</td>
</tr>
<tr>
<td>185</td>
<td>177</td>
<td>8</td>
</tr>
<tr>
<td>185</td>
<td>174</td>
<td>11</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>186</td>
<td>4</td>
</tr>
<tr>
<td>202</td>
<td>195</td>
<td>7</td>
</tr>
<tr>
<td>288</td>
<td>5,257</td>
<td>5,257 / 288 = 18.25 MW/5min</td>
</tr>
</tbody>
</table>

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**

\[ n_{KWK} = \frac{W_{ne \ KWK}}{W_{N \ ne}} \times 100\% \]

- \( n_{KWK} \): 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

\[ \text{e}_{\text{CO2}} = \frac{M_B \cdot H_u \cdot e_f \cdot e_{\text{ox}}}{W_{\text{B net}}} \]

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

Definition
The greenhouse gas indicator of a power generation unit is the quotient of the amount of CO2-emission and the net generated energy.

Utilization
The greenhouse gas indicator displays the CO2-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 \text{CO2}/TJ
- \( e_{\text{ox}} \): 0.99

- \( W_{\text{B}} \): 6,671,675 MWh
- \( \text{e}_{\text{CO2}} \): 0.97 t/MWh
Market-rated availability

\[ k_{Wm} = \frac{\sum_{i=1}^{N} (W_{Ni} - W_{nvi}) \cdot DB + i}{\sum_{i=1}^{N} W_{Ni} \cdot DB + i} \]

\( k_{Wm} \): 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 re-serve; 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

\( k_{Wm} = \frac{500\text{MW} \cdot 10\text{h}}{500\text{MW} \cdot 0\text{h}} \cdot \frac{40\text{€}}{\text{MWh}} \) Mo – We

\( k_{Wm} = \frac{500\text{MW} \cdot 6\text{h} + 500\text{MW} \cdot 4\text{h} \cdot \frac{\text{EEX}}{40\text{€}}}{500\text{MW} \cdot 10\text{h}} \) Th

\( k_{Wm} = \frac{500\text{MW} \cdot 10\text{h} - 500\text{MW} \cdot 4\text{h} \cdot \frac{\text{EEX}}{40\text{€}}}{500\text{MW} \cdot 10\text{h}} \) 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

\[ k_k = \frac{W_k}{W_{N}} \cdot \frac{EEX - \sum GK}{EEX} = \frac{W_{Bne} + W_{R} \cdot W_{ng}}{W_{N}} \cdot \frac{EEX - \sum GK}{EEX} \quad \text{für} \quad (EEX - \sum GK) \geq 0 \]
\[ k_k = 0 \quad \text{für} \quad (EEX - \sum GK) < 0 \]

- \( k_k \): 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)

\( \ast \) \( GK = \text{fuel cost (e.g. BAFA) + CO}_2(\text{e.g. EEX-EUA}) \)

\[ k_k = \frac{\sum_{i=1}^{N} (W_{N,i} - W_{nv,i}) \cdot DB_i}{\sum_{i=1}^{N} W_{N,i} \cdot DB_i} \]

- \( k_K \) [%] 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
- \( N \) [1] number of time frames in the considered time period
- \( DB_i \) [€/MWh] marginal income in the time frame i with
  \[ DB_i = 0 \quad \text{for} \quad EEX_i < GK_i \]
  \[ = EEX_i - GK_i \quad \text{for} \quad EEX_i \geq GK_i \]
- \( EEX_i \) [€/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)

\[
k_{\text{GuD}} = \left( \sum_{i=1}^{x} W_{\text{NGuD},i} + W_{\text{Naqu}} \right) - \left( \sum_{i=1}^{x} W_{\text{rNGuD},i} \right) - W_{\text{Naqu}}
\]

\[
= \left( \sum_{i=1}^{x} W_{\text{N,GT},1} + \left( W_{\text{N,DT}} + W_{\text{Naqu}} \right) \right) - \left( \sum_{i=1}^{x} W_{\text{rN,GT},1} + \left( W_{\text{rN,DT}} + W_{\text{rNaqu}} \right) \right)
\]

\[
= \left( \sum_{i=1}^{x} W_{\text{N,GT},1} + \left( W_{\text{N,DT}} + W_{\text{Naqu}} \right) \right) - \left( \sum_{i=1}^{x} W_{\text{N,GT},1} + \left( W_{\text{N,DT}} + W_{\text{Naqu}} \right) \right)
\]

\[
k_{\text{GuD}}: \text{availability of a CCGT}
\]

DT: steam turbine

GT: gas turbine

W_{\text{GuD}}: energy of a CCGT

W_{\text{r}}: unavailable energy

W_{\text{GT},i}: energy share of the gas turbine(s) in the combined cycle process

W_{\text{DT}}: energy share of the steam turbine(s) in the combined cycle process

W_{\text{N},i}: nominal energy share

W_{\text{äqu}}: equivalent electric energy belonging to heat extraction

Example: CCGT with unfired heat recovery boiler

\[
k_{\text{GuD}} = \frac{\left( W_{\text{N,GT},1} + W_{\text{N,GT},2} + \left( W_{\text{N,DT}} + W_{\text{Naqu}} \right) \right) - \left( W_{\text{rN,GT},1} + W_{\text{rN,GT},2} + \left( W_{\text{rN,DT}} + W_{\text{rNaqu}} \right) \right)}{W_{\text{N,GT},1} + W_{\text{N,GT},2} + \left( W_{\text{N,DT}} + W_{\text{Naqu}} \right)}
\]

(GT- stand alone operation allowed, given period of 8 h)

Nominal capacities: P_{\text{N}(\text{GuD})} = 540 MW, P_{\text{N}(\text{GT1})} = 190 MW, P_{\text{N}(\text{GT2})} = 190 MW, P_{\text{N}(\text{DT})} = 190 MW; P_{\text{Naqu}} = -30 MW; P_{\text{rNaqu}} = -110 MW

- case 1: GT1 full load, GT2 full load, DT full load
  \[
k_{\text{GuD}} = \frac{\left( 190 MW + 190 MW + (190 MW - 30 MW) \right) * 8h - \left( (0 MW + 0 MW + 0 MW + 0 MW) \right) * 8h}{(190 MW + 190 MW + (190 MW - 30 MW)) * 8h} = 100\%
  \]

- case 2: GT1 in repair, GT2 full load, DT fully available
  \[
k_{\text{GuD}} = \frac{\left( 190 MW + 190 MW + (190 MW - 30 MW) \right) * 8h - \left( (190 MW + 0 MW + (0 MW + 110 MW)) \right) * 8h}{(190 MW + 190 MW + (190 MW - 30 MW)) * 8h} = 44.4\%
  \]

- case 3: GT1 full load, GT2 full load, DT in repair
  \[
k_{\text{GuD}} = \frac{\left( 190 MW + 190 MW + (190 MW - 30 MW) \right) * 8h - \left( (0 MW + 0 MW + (190 MW + 0 MW)) \right) * 8h}{(190 MW + 190 MW + (190 MW - 30 MW)) * 8h} = 64.8\%
  \]

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

*) outage DT = 0.5 (P_{\text{N}(\text{DT})} + P_{\text{Naqu}})
Availability of combined (e.g. gas-coal) power plants

\[
k_{kombi} = \frac{\sum_{i=1}^{x} W_{N_{Kombi},i} - \sum_{i=1}^{x} W_{nV_{Kombi},i}}{\sum_{i=1}^{x} W_{N_{Kombi},i}}
= \frac{(W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr}}) - ((W_{nV_{Kohle}} - W_{Stütz}) + W_{nV_{GT}} + W_{nV_{Kombi,korr}})}{W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr}}}.
\]

- \( k_{kombi} \): 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

\[
k_{Kombi} = \frac{(W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr}}) - ((W_{nV_{Kohle}} - W_{Stütz}) + W_{nV_{GT}} + W_{nV_{Kombi,korr}})}{W_{N_{Kohle}} + W_{N_{GT}} + W_{N_{Kombi,korr}}}.
\]

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

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

\[
k_{kombi} = \frac{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h - (0\text{ MW} + 0\text{ MW} + 0\text{ MW} + 0\text{ MW})}{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h} = 100 \%
\]

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

\[
k_{kombi} = \frac{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h - (75\text{ MW} - 75\text{ MW} + 0\text{ MW} + 0\text{ MW}) \times 8h}{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h} = 100 \%
\]

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

\[
k_{kombi} = \frac{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h - (0\text{ MW} - 0\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h}{(600\text{ MW} + 112\text{ MW} - 12\text{ MW}) \times 8h} = 85.7 \%
\]
Case 4: coal-fired unit full load, outage 2 mills (1 compensated), GT full load

\[ k_{\text{Kombi}} = \frac{(600\text{MW}+112\text{MW}-12\text{MW})^8h - (150\text{MW}-75\text{MW}+0\text{MW}+0\text{MW})^8h}{(600\text{MW}+112\text{MW}-12\text{MW})^8h} = 89.3\% \]
Availability of power plants with VGT (topping gas turbine)

\[ k_{VGT} = \frac{\sum_{i=1}^{n} W_{NVGT,i} - \sum_{i=1}^{n} W_{nNVGT,i}}{\sum_{i=1}^{n} W_{NVGT,i}} \]

\[ = \frac{(W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}) - (W_{nNVGT,Kohle} + W_{nNVGT,GT} + W_{nNVGT,korr.})}{W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}} \]

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

Example: power plant with topping gas turbine

\[ k_{VGT} = \frac{(W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}) - (W_{nNVGT,Kohle} + W_{nNVGT,GT} + W_{nNVGT,korr.})}{W_{NVGT,Kohle} + W_{NVGT,GT} + W_{NVGT,korr.}} \]

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

- **Case 1:** VGT full load, coal-fired unit full load
  \[ k_{VGT} = 100 \% \]

- **Case 2:** VGT reserve, coal-fired unit full load
  \[ k_{VGT} = 100 \% \]

- **Case 3:** VGT in repair, coal-fired unit full load
  \[ k_{VGT} = \frac{(600 \text{ MW} + 200 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h} - (0 \text{ MW} + 200 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h}}{(600 \text{ MW} + 200 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h}} = 68.2\% \]

- **Case 4:** VGT full load, coal fired unit boiler failure
  \[ k_{VGT} = \frac{(600 \text{ MW} + 200 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h} - (600 \text{ MW} + 0 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h}}{(600 \text{ MW} + 200 \text{ MW} + 80 \text{ MW}) \times 8 \text{ h}} = 22.7\% \]
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):

\[
W_N = \sum W_{nj} = \sum P_{nj} \cdot t_{nj}
\]

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.

\[
\bar{k}_w = \frac{W_N - W_{nv}}{W_N} = \frac{\sum W_{Ni} - \sum W_{nvj}}{\sum W_{Ni}} = \frac{1}{\sum W_{Ni}} \left( \sum \frac{W_{Ni} - W_{nvj}}{1} \right) = \frac{1}{\sum W_{Ni}} \sum \left( \frac{W_{Ni} - W_{nvj}}{1} \right)
\]

\[
= \frac{1}{\sum W_{Ni}} \sum \left( \frac{W_{Ni} - W_{nvj}}{W_{Ni}} \cdot W_{Ni} \right) = \sum \left( \frac{1}{\sum W_{Ni}} \cdot (k_{wj} \cdot W_{nj}) \right) = \sum \left( \frac{W_{Ni} - W_{nvj}}{\sum W_{Ni}} \cdot k_{wj} \right)
\]

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.

\[
\bar{k}_w = \sum \left( \frac{\bar{P}_{ni} \cdot t_N}{\sum \bar{P}_{ni} \cdot t_N} \cdot k_{wj} \right)
\]
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

\[ P_{N,1} = 200 \text{ MW for } 0 \text{ days} < t \leq 150 \text{ days} \]
\[ P_{N,2} = 400 \text{ MW for } 150 \text{ days} < t \leq 200 \text{ days} \]

Outage duration

\[ t_{nv,1} = 30 \text{ days} \]  \( P_{nv} = 200 \text{ MW in the period } 0 \text{ days} < t \leq 150 \text{ days} \)
\[ t_{nv,1} = 10 \text{ days} \]  \( P_{nv} = 100 \text{ MW in the period } 0 \text{ days} < t \leq 150 \text{ days} \)
\[ t_{nv,2} = 5 \text{ days} \]  \( P_{nv} = 400 \text{ MW in the period } 150 \text{ days} < t \leq 200 \text{ days} \)
\[ t_{nv,2} = 5 \text{ days} \]  \( P_{nv} = 200 \text{ MW in the period } 150 \text{ days} < t \leq 200 \text{ days} \)
\[ k_w = \frac{W_N - \sum W_{nv}}{W_N} \]

\[ W_N = \sum P_{Ni} \cdot t_{Ni} = 200 \text{ MW} \cdot 3,600 \text{ h} + 400 \text{ MW} \cdot 1,200 \text{ h} = 1,200,000 \text{ MWh} \]

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

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

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:

\( P_{N,1} = 200 \text{ MW} \) for \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( P_{N,2} = 400 \text{ MW} \) for \( 150 \text{ days} < t \leq 200 \text{ days} \)
\( P_{N,3} = 0 \text{ MW} \) for \( 200 \text{ days} < t \)

Outage duration:

\( t_{nv,1} = 30 \text{ days} \)
\( t_{nv,1} = 10 \text{ days} \)
\( t_{nv,2} = 5 \text{ days} \)
\( t_{nv,2} = 5 \text{ days} \)
\( t_{nv,3} = 0 \text{ days} \)

P = \overline{P}_N \cdot k_w = 200 \text{ MW} = 250 \text{ MW} \cdot 80.00 \%

\[ k_w = \frac{W_N - \sum W_{nv}}{W_N} \]

\[ W_N = \sum P_{Ni} \cdot t_{Ni} = 200 \text{ MW} \cdot 3,600 \text{ h} + 400 \text{ MW} \cdot 1,200 \text{ h} + 0 \text{ MW} \cdot 2,400 \text{ h} = 1,200,000 \text{ MWh} \]
\[ W_{nv} = \sum P_{ni} \cdot t_{nvj} = 200 \text{ MW} \cdot 720 \text{ h} + 100 \text{ MW} \cdot 240 \text{ h} + 400 \text{ MW} \cdot 120 \text{ h} + 200 \text{ MW} \cdot 120 \text{ h} = 240,000 \text{ MWh} \]

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

Average nominal capacity:
\[ \bar{P}_N = 166.67 \text{ MW} = \frac{200 \text{ MW} \cdot 3,600 \text{ h} + 400 \text{ MW} \cdot 1,200 \text{ h} + 0 \text{ MW} \cdot 2,400 \text{ h}}{3,600 \text{ h} + 1,200 \text{ h} + 2,400 \text{ h}} \]

Average time-available capacity: \[ P = \bar{P}_N \cdot k_w = 133.33 \text{ MW} = 166.67 \text{ MW} \cdot 80.00 \% \]
Aggregation of 2 plants
Observation period: 200 days

**Plant 1** (with increase of nominal capacity)
Nominal capacity \( P_{N,1} = 200 \text{ MW} \) for \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( P_{N,1} = 300 \text{ MW} \) for \( 150 \text{ days} < t \leq 200 \text{ days} \)

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

**Plant 2** (Commissioning)
Nominal capacity \( P_{N,2} = 0 \text{ MW} \) for \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( P_{N,2} = 100 \text{ MW} \) for \( 150 \text{ days} < t \leq 200 \text{ days} \)

Outage duration
\( t_{nv,2a} = 5 \text{ days} \) \( P_{nv} = 100 \text{ MW} \) in the period \( 150 \text{ days} < t \leq 200 \text{ days} \)
\( t_{nv,2b} = 5 \text{ days} \) \( P_{nv} = 50 \text{ MW} \) in the period \( 150 \text{ days} < t \leq 200 \text{ days} \)
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: \( \bar{P}_N = 225.00 \text{ MW} = \frac{200 \text{ MW} \cdot 3,600 \text{ h} + 300 \text{ MW} \cdot 1,200 \text{ h}}{3,600 \text{ h} + 1,200 \text{ h}} \)

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

Plant 2

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

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

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

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

Average time-available capacity: \( P = \bar{P}_N \cdot k_w = 21.25 \text{ MW} = 25.00 \text{ MW} \cdot 85.00 \% \)
Aggregated indicator time availability for both plants

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

\[
\bar{k}_w = \sum \left( \frac{P_{N,i}}{\sum P_{N,j}} \cdot k_{w,i} \right)
\]

\[
\bar{k}_t = \frac{225 \text{ MW}}{225 \text{ MW} + 25 \text{ MW}} \cdot 0.7944 + \frac{25 \text{ MW}}{225 \text{ MW} + 25 \text{ MW}} \cdot 0.85 = 80.00\%
\]

Average capacity of both plants: = 250 MW

\[
\bar{P}_N = 250 \text{ MW} = \frac{225 \text{ MW} + 25 \text{ MW}}{3}
\]

\[
\bar{P}_N = \frac{200 \text{ MW} \cdot 3,600\text{h} + 300 \text{ MW} \cdot 1,200\text{h}}{3,600\text{h} + 1,200\text{h}} + \frac{0 \text{ MW} \cdot 3,600\text{h} + 100 \text{ MW} \cdot 1,200\text{h}}{3,600\text{h} + 1,200\text{h}}
\]

Average time-available capacity:

\[
P = \bar{P}_N \cdot \bar{k}_w = 200 \text{ MW} = 250 \text{ MW} \cdot 80.00\%
\]
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:

\[
\bar{k}_w = \frac{\sum_{\text{plant } i} \sum_{\text{incident } k} W_{N_i} \cdot W_{n_{v_{i,k}}}}{\sum_{\text{plant } i} W_{N_i}} - 1 - \frac{\sum_{\text{plant } i} \sum_{\text{incident } k} P_{n_{v_{i,k}}} \cdot t_{n_{v_{i,k}}}}{\sum_{\text{plant } i} W_{N_{i,j}}} 
\]

with \( i = \text{plant } i \)
\( i, k = \text{plant } i, \text{incident } k \)

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:

\[
\bar{k}_w = \sum \left( \frac{P_{N_{i,j}}}{\sum P_{N_{i,j}}} \cdot \bar{k}_{w_{i,j}} \right)
\]

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:

\[
k_t = \frac{W_N - \sum W_{Nv}}{W_N} = \frac{P_N \cdot t_N - \sum P_N \cdot t_{Nv}}{P_N \cdot t_N} = \frac{P_N \cdot t_N - P_N \cdot \sum t_{Nv}}{P_N \cdot t_N} = \frac{P_N \cdot (t_N - \sum t_{Nv})}{P_N \cdot t_N} = \frac{t_N - \sum t_{Nv}}{t_N}
\]

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 \((W_N \text{ or } W_{Nv})\), 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):

\[
W_N = \sum W_{Nj} = \sum P_{NJ} \cdot t_{NJ}
\]

with \( i = \text{time sections with differing nominal capacity} \)
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 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 “tnv, i,” but also the entire UA-time of a system i.

Finally, the time availability of the individual systems $k_{Li}$ is shown with a factor which contains the capacity weight.
\[ k_t = \frac{W_N - \sum W_{rv}}{W_N} = \frac{W_{N,1} + W_{N,2} - W_{rv,1} - W_{rv,2}}{W_{N,1} + W_{N,2}} = \frac{W_{N,1} - W_{rv,1} + W_{N,2} - W_{rv,2}}{W_{N,1} + W_{N,2}} = \]

\[ = \left( P_{N1} \cdot t_N - P_{N} \cdot t_{nv1} \right) + \left( P_{N2} \cdot t_N - P_{N} \cdot t_{nv2} \right) \]

\[ = \left( P_{N1} \cdot t_N + P_{N2} \cdot t_N \right) \]

\[ = \frac{P_{N1}}{P_{N1} + P_{N2}} \cdot k_{t,1} + \frac{P_{N2}}{P_{N1} + P_{N2}} \cdot k_{t,2} \]

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:

\[ \bar{k}_t = \left( \frac{\sum P_{Nj}}{\sum P_{Nj}} \cdot k_{t,j} \right) \]
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

<table>
<thead>
<tr>
<th>Nominal capacity</th>
<th>P_{N,1} = 200 MW</th>
<th>for</th>
<th>0 days &lt; t ≤ 150 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{N,2}</td>
<td>400 MW</td>
<td>for</td>
<td>150 days &lt; t ≤ 200 days</td>
</tr>
</tbody>
</table>

| 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 |

![Diagram showing the nominal capacity and outage duration for the first example.](attachment:image.png)
\[ k_i = \frac{t_N - \sum t_{nv}}{t_N} = \frac{W_N - \sum W_{nv}}{W_N} \]

\[ W_N = \sum P_{Nj} \cdot t_{Nj} = 200 \text{ MW} \cdot 3,600 \text{ h} + 400 \text{ MW} \cdot 1,200 \text{ h} = 1,200,000 \text{ MWh} \]

\[ W_{nv} = \sum P_{Nj} \cdot t_{nv,j} = 200 \text{ MW} \cdot 720 \text{ h} + 400 \text{ MW} \cdot 120 \text{ h} = 192,000 \text{ MWh} \]

\[ k_i = \frac{1,200,000 \text{ MWh} - 192,000 \text{ MWh}}{1,200,000 \text{ MWh}} = 84.00 \% \]

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

Average time-available capacity: \( P = \bar{P}_N \cdot k_i = 210 \text{ MW} = 250 \text{ MW} \cdot 84.00 \% \)
Example 1b: Increase of nominal capacity and viewing period beyond decommissioning

Observation period: 300 days

Nominal capacity

\[ P_{N,1} = 200 \text{ MW} \text{ for } 0 \text{ days} < t \leq 150 \text{ days} \]
\[ P_{N,2} = 400 \text{ MW} \text{ for } 150 \text{ days} < t \leq 200 \text{ days} \]
\[ P_{N,3} = 0 \text{ MW} \text{ for } 200 \text{ days} < t \]

Outage duration

\[ t_{nv,1} = 30 \text{ days} \text{ in the period } 0 \text{ days} < t \leq 150 \text{ days} \]
\[ t_{nv,2} = 5 \text{ days} \text{ in the period } 150 \text{ days} < t \leq 200 \text{ days} \]
\[ t_{nv,3} = 0 \text{ days} \text{ in the period } 200 \text{ days} < t \]

\[ \sum_{i} t_{W} W_{N,i} = 200 \text{ MWh} \cdot 3,600 \text{h} + 400 \text{ MW} \cdot 1200 \text{h} + 0 \text{ MW} \cdot 2400 \text{h} = 1,200,000 \text{ MWh} \]
\[ \sum_{i} W_{nv,i} = 200 \text{ MWh} \cdot 720 \text{h} + 400 \text{ MW} \cdot 120 \text{h} + 0 \text{ MW} \cdot 0 \text{d} = 192,000 \text{ MWh} \]

\[ k_{t} = \frac{1,200,000 \text{ MWh} - 192,000 \text{ MWh}}{1,200,000 \text{ MWh}} = 84.00 \% \]

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 \( P_{N,1} = 200 \text{ MW} \) for \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( P_{N,1} = 300 \text{ MW} \) for \( 150 \text{ days} < t \leq 200 \text{ days} \)
Outage duration \( t_{nv,1a} = 30 \text{ days} \) in the period \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( t_{nv,1b} = 5 \text{ days} \) in the period \( 150 \text{ days} < t \leq 200 \text{ days} \)

**plant 2** (commissioning)
Nominal capacity \( P_{N,2} = 0 \text{ MW} \) for \( 0 \text{ days} < t \leq 150 \text{ days} \)
\( P_{N,2} = 100 \text{ MW} \) for \( 150 \text{ days} < t \leq 200 \text{ days} \)
Outage duration \( t_{nv,2} = 5 \text{ days} \) in the period \( 150 \text{ days} < t \leq 200 \text{ days} \)
Average nominal capacity: $\bar{P}_N = 225.00\text{ MW} = \frac{200\text{ MW} \cdot 3.600\text{ h} + 300\text{ MW} \cdot 1,200\text{ h}}{3,600\text{ h} + 1,200\text{ h}}$

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

**Plant 2**

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

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

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

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

Average time-available capacity: $P = \bar{P}_N \cdot k_t = 22.50\text{ MW} = 25.00\text{ MW} \cdot 90.00\%$
Aggregated indicator time availability for both systems

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

$$k_t = \sum \left( \frac{P_{Nj}}{\sum P_{Nj}} \cdot k_{tj} \right)$$

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

Average power from both systems: = 250 MW

$$P_N = 250 \text{ MW} = \frac{200 \text{ MW} \cdot 3,600 \text{ h} + 300 \text{ MW} \cdot 1,200 \text{ h}}{3,600 \text{ h} + 1,200 \text{ h}} + \frac{0 \text{ MW} \cdot 3,600 \text{ h} + 100 \text{ MW} \cdot 1,200 \text{ h}}{3,600 \text{ h} + 1,200 \text{ h}}$$

Average time-available capacity:

$$P = P_N \cdot k_t = 210 \text{ MW} = 250 \text{ MW} \cdot 84.00 \%$$
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:

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

with \( i = \text{plant } i \)
\( i, k = \text{plant } i, \text{incident } k \)

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

\[ \bar{k}_t = \sum \left( \frac{P_{N,i}}{\sum P_{N,i}} \cdot k_{i,t} \right) \]

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

Pareto chart of Energy Availability
Collective (331 units): Fossil fired Units (AT, CZ, DE, FR, IT, NL, PL, PT, ZA)
Time range: 2013
Energy Availability [%]

KISSY - Power Plant Information System

KISSY - Power Plant Information System

Unplanned capacity unavailability evolution and EEX over the time bar
Collective (72 units): Combined Cycle Units (AT, DE, FR, LV, NL, PT)
Time range: 2006 - 2015
Planned energy unavailability by Classes of Capacity
Collective (56 units): Gas Turbine Units (AT, DE, FR, LV, NL, PT)
Time range: 2006 - 2015

Operating hours per generating set
KISSY - Power Plant Information System

Average Time Utilization of Hydro Power Plants Turbine
Collective (62 machine sets): Storage Power Plants (AT, CZ, PT)
Time range: 2006-2015

Opportunities which reports can be generated from KISSY

Examples of evaluation