

# VGB-Standard

## Hydropower

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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.*

## List of amendments

<b>VGB-Standard</b>	<b>Amendment date</b>	<b>Chapter</b>	<b>Description</b>
1 <sup>st</sup> edition 2014, issued June 2014	June 2014		Original

## Introduction

Hydropower was used in the pre-industrial era to drive mills, sawmills and hammer mills and is a proven, reliable, highly efficient and flexible form of energy. Today, hydropower is used almost exclusively in Europe to generate electricity. With efficiency levels of above 90 %, it makes a sustainable contribution to reducing CO<sub>2</sub> emissions.

In order to do justice to its significance in terms of energy supplies, all previously released publications on the subject of hydropower have attempted to practically depict the complex links between technology/engineering, nature and official-legal standards. The hydropower industry includes, in the most general sense, all technical and economic disciplines involved in converting the potential and kinetic energy of water into electrical energy.

Since the appearance of the 6<sup>th</sup> edition of the hydropower booklet in 1992, editorial responsibility for the booklet has passed from the former VDEW to VGB PowerTech e.V. The new edition takes account of recent sustained changes in the energy industry sphere of hydropower.

Major changes in this sphere can be briefly covered by the key phrases "market liberalisation", "internationalisation of the energy market" and "energy transition", for example. Among other things, the resulting increasing number of official activities, as well as those by associations, requires a thorough knowledge of the content of terms used in an international environment.

This revised version of the VGB "Hydropower" standard from the previous VDEW series "Definitions of terms within the Energy Industry" is geared to this requirement and also takes account of the new electronic standard format for VGB publications.

What can readers expect from the 1<sup>st</sup> edition of the new VGB-Standard VGB-S-002-02-2014-06-EN?

- Basic definitions of hydropower-related terms (including hydrology)
- Definition of hydropower-specific time, output/capacity and energy terms
- Derivation of statistical and other plant parameters
- An overview of current European standards
- Definitions in additions to, extensions of and/or updates to the applicable DIN standards 4048 [2] and 19700 [6]
- The basic fundamentals of general statistics

The international editorial team is aware that many terms and/or groups of terms exceed the normal scope of the majority of hydropower operators. Therefore, the terms should be used by potential users as guidance for proposals and direction.

With comprehensive definitions as well as the elimination of synonymous definitions, this standard should create a common understanding regarding the provision of data for public investigations, analyses and acquisitions. Suggestions for improvements for future editions are welcomed and will be gratefully received by the offices of VGB PowerTech e. V.

Essen, June 2014

VGB PowerTech e.V.

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- 5<sup>th</sup> edition 1982 VDEW e.V., BGW e.V.
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- 7<sup>th</sup> edition 2014 VGB PowerTech e.V.

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## Alphabetical list of symbols/abbreviations

Symbol/Abbreviation	Definition	Chapter
$A_{HR}$	Standard operation	1.4.2.14
f	Freeboard	1.3.3.8
$h_{brutto}$	Gross head	1.7.3.1
$h_g$	Critical head	1.7.2.1
$h_K$	Power plant head	1.7.2.2
$h_{KA}$	Power plant installed head	1.7.2.3
$h_m$	Mean head	1.7.3.2
$h_{max}$	Maximum head	1.7.3.4
$h_{max\ theo}$	Maximum theoretical head	1.7.3.3
$h_{min}$	Minimum head	1.7.3.6
$h_{min\ theo}$	Minimum theoretical head	1.7.3.5
$h_N$	Nominal head	1.7.1.2
$h_{netto}$	Net head	1.7.1.1
$h_{p\ geo}$	Geodetic discharge head	1.7.3.8
$h_{p\ man}$	Manometric discharge head	1.7.3.10
$h_{pm}$	Mean discharge head	1.7.3.9
$H_{HQ}$	Maximum flood runoff	1.5.5
$H_Q$	Flood runoff	1.5.3
$H_{Qn}$	n-annual flood runoff	1.5.14
$h_U$	Bypass head	1.7.2.4
$h_V$	Head loss	1.7.1.3
$h_{z\ geo}$	Geodetic suction head	1.7.3.7
$I_B$	Operating content	1.3.2.3
$I_N$	Usable content	1.3.2.2
$I_{RO}$	Upper reserve volume content	1.3.2.5
$I_{RU}$	Lower reserve volume content	1.3.2.6
$I_S$	Hydropeaking volume content	1.3.2.4
$k_{PH}$	Capacity availability	5.3
$k_{PT}$	Technical capacity availability	5.4



Symbol/Abbreviation	Definition	Chapter
$k_t$	Time availability	5.1
$k_t$	Time availability of a generator (%)	5.11
$k_t$	Time availability of a power plant (%)	5.12
$k_{tn}$	Time unavailability	5.2
$k_W$	Energy availability	5.5
$k_{Wn}$	Energy unavailability	5.7
$k_{WT}$	Technical energy availability	5.6
$M_{HQ}$	Mean flood runoff	1.5.8
$M_{NQ}$	Mean low water runoff	1.5.9
$M_Q$	Mean water runoff	1.5.7
$N_{NQ}$	Lowest low water runoff	1.5.12
$n_P$	Capacity utilisation	5.9
$n_{PE}$	Capacity utilisation of bottleneck capacity	5.9.1
$n_{PH}$	Capacity utilisation of mean capacity	5.9.2
$N_Q$	Low water runoff	1.5.13
$n_t$	Time utilisation	5.8
$n_W$	Utilisation	5.10
$n_{WE}$	Energy utilisation	5.10.1
$n_{Wr}$	Standard utilisation	5.10.2
$P_A$	Installed capacity	3.1
$P_B$	Operating capacity	3.3
$P_b$	Claimable capacity	3.21
$P_{Bil}$	Consolidated output	3.4
$P_s$	Guaranteed capacity	3.6
$P_e$	Bottleneck capacity, maximum capacity	3.5
$P_m$	Mean capacity	3.10
$P_N$	Nominal capacity	3.12
$P_{nb}$	Unclaimable capacity	3.22
$P_{ng}$	Unused capacity	3.17
$P_{ns}$	Unusable capacity	3.18

<b>Symbol/Abbreviation</b>	<b>Definition</b>	<b>Chapter</b>
$P_{nv\ p}$	Scheduled unavailable capacity	3.19
$P_{nv\ u}$	Unscheduled unavailable capacity	3.20
$P_{nvH}$	Hydraulic unavailable capacity	3.7
$P_{nvT}$	Technical unavailable capacity	3.13
$P_{nvTr}$	Technical unavailable capacity with repercussions	3.14
$P_{mP}$	Mean capacity for pumping operation	3.11
$P_R$	Standby capacity	3.2
$P_v$	Available capacity	3.16
$P_{vH}$	Hydraulical available capacity	3.8
$P_{vT}$	Technical available capacity	3.15
$Q$	Flow	1.6.1
$Q_A$	Installed flow	1.6.27
$Q_{Ab}$	Total runoff	1.6.12
$Q_{AbI}$	Discharge runoff	1.6.14
$Q_{AbP}$	Runoff for pumps	1.6.20
$Q_{AbT}$	Runoff for turbines	1.6.20
$Q_{ATP}$	Runoff for power plants or pumping stations	1.6.20
$Q_{AV}$	Plant-related waste runoff	1.6.25
$Q_{Bei}$	Tributary inflow	1.6.8
$Q_{BV}$	Operational waste runoff	1.6.26
$Q_{Dot}$	Minimum instream flow runoff (minimum instream flow)	1.6.17
$Q_{Ein}$	Discharge inflow	1.6.9
$Q_{FW}$	Flowing wave	1.6.4
$Q_K$	Power plant flow	1.6.21
$Q_{korr}$	Adjusted inflow/Adjusted runoff	1.6.2
$Q_{KV}$	Power plant waste runoff	1.6.23
$Q_N$	Usable power plant inflow	1.6.24
$Q_{nat}$	Natural inflow	1.6.6
$Q_{OL}$	Upstream inflow	1.6.7

Symbol/Abbreviation	Definition	Chapter
$Q_P$	Pump output flow	1.6.29
$Q_{Pfl}$	Minimum acceptable flow runoff (Minimum acceptable flow)	1.6.18
$Q_{PN}$	Nominal pump output flow	1.6.30
$Q_{Rest}$	Residual water runoff	1.6.19
$Q_{SE}$	Reservoir extraction, make-up water	1.6.10
$Q_{SR}$	Reservoir reserve, retention	1.6.11
$Q_T$	Turbine flow	1.6.22
$Q_{TN}$	Turbine flow	1.6.28
$Q_{Über}$	Diversion runoff	1.6.16
$Q_V$	Available power plant inflow, available reservoir runoff	1.6.13
$Q_{Ver}$	Waste runoff	1.6.15
$Q_{ZTP}$	Inflow from power plants or pumping stations	1.6.5
$Q_{Zu}$	Total inflow	1.6.3
$Q_{ZuP}$	Inflow from pump water	1.6.5
$Q_{ZuT}$	Inflow from turbine water	1.6.5
$S_{SE}$	Reduction	1.4.1.1
$S_{SR}$	Accumulation	1.4.1.2
$t$	Time	2.1
$t_A$	Installed time	2.12
$t_a$	Utilisation time	2.11
$t_B$	Operating time	2.4
$t_{ben}$	Utilisation time	2.10
$t_f$	Filling time for a reservoir	2.13
$t_N$	Nominal time	2.2
$t_{nb}$	Available unclaimable time	2.9
$t_{ng}$	Available non-working time	2.6
$t_{ns}$	Available unusable time	2.8
$t_{nv}$	Unavailability time	2.7
$t_{nv p}$	Scheduled unavailability time	2.7

<b>Symbol/Abbreviation</b>	<b>Definition</b>	<b>Chapter</b>
$t_{nv\ u}$	Unscheduled unavailability time	2.7
$t_{nv\ ud}$	Unscheduled disposable unavailability time	2.7
$t_{nv\ un}$	Unscheduled non-disposable unavailability time	2.7
$t_R$	Standby time	2.5
$t$	Availability time	2.3
$V_B$	Operating volume	1.3.1.4
$V_F$	Free volume	1.3.1.6
$V_G$	Total reservoir volume, total storage area	1.3.1.2
$V_N$	Usable volume	1.3.1.3
$V_{RO}$	Upper reserve volume	1.3.1.7
$V_{RU}$	Lower reserve volume	1.3.1.8
$V_S$	Hydropeaking volume	1.3.1.5
$V_T$	Dead space	1.3.1.9
$W_B$	Generation (energy generated)	4.3
$W_{BH}$	Run-of river energy	4.13
$W_{BW}$	Pumped energy	4.14
$W_H$	Energy capability, energy yield	4.1
$W_{HN}$	Unused energy	4.6
$W_{HR}$	Standard energy capability	4.2
$W_{nvT}$	Technical unavailable energy	4.9
$W_{nvTr}$	Technical unavailable energy with repercussions	4.10
$W_P$	Pumping energy, pump energy (pump power	4.11
$W_{Ph}$	Phase shift energy supply	4.12
$W_S$	Maximum energy content of a reservoir	4.4
$W_{SV}$	Energy content of a reservoir	4.5
$W_{Vv}$	Available energy	4.7
$W_{Verl}$	Impounding loss	4.15
$W_{vT}$	Technical available energy	4.8
$Z_A$	Drawdown level	1.3.3.4
$Z_H$	Highest possible dam	1.3.3.3

<b>Symbol/Abbreviation</b>	<b>Definition</b>	<b>Chapter</b>
$Z_s$	Full reservoir level	1.3.3.1
$Z_T$	Lowest possible drop	1.3.3.5
$\Delta I$	Reservoir content modification	1.4.1.3

## 1 Basic fundamentals

Hydropower can be defined and classified using various approaches. In doing so and in simple terms, the objective of a hydropower plant consists of using the potential energy of water overcoming a height difference in the direction of a lower level, i.e. flowing from top to bottom. The usable energy potential is proportional to the product of the flow volume and the height difference.

There are therefore classification approaches, for example, based on the head in high, medium and low pressure plants. Another approach takes account of the relevant national legislation governing the feeding of renewable energies into the electricity grid and of installed capacity. Admittedly, these approaches are very individual and firmly guided by country-specific circumstances. For example, for so-called small hydropower plants, the limits in Europe vary between 1.5 MW in Sweden and 15 MW in France.

Another approach classifies hydropower by the type of plant created: as a run-of-river hydropower plant, a (pumped) storage power plant or a canal or feeder power plant.

UNIPEDE/EURELECTRIC has devised a further uniform classification for Europe, which has also been accepted by the ESHA and the European Commission. It broadly defines small hydropower plants as having an upper limit of 10 MW of installed electrical capacity and classifies hydropower as follows:

- Run-of-river hydropower plants: Power plants without any or with a relatively low storage capacity. These plants are generally in continuous operation as base load facilities. The time needed to fill any existing reservoir is less than 2 hours ( $D \leq 2$  h). It is determined on the basis of the average annual flow of water.

- Storage power plants: Hydropower plants with a natural inflow and storage capacity in upstream reservoirs designed to generate electricity in line with demand. Depending on the reservoir's draw-off period, the following distinctions are made:
  - Power plant with a compensation reservoir:  $2 \text{ h} < D < 400 \text{ h}$
  - Storage power plant:  $D \geq 400 \text{ h}$ .
- Pumped storage power plants: Storage power plants, where water is pumped from the downstream reservoir into the upstream reservoir.
  - Pumped storage power plants without a natural inflow: Power plants with a reversible turbine system, which generate electricity solely using water pumped previously into the upstream reservoir. The natural inflow is negligible ( $< 5 \%$  of the average annual turbine flow rate). Therefore, this is not a case of renewable energy conversion.
  - Pumped storage power plants with a natural inflow: Pumped storage power plants with an upstream reservoir, where more than  $5 \%$  of the average annual turbine flow rate comes from natural inflows. This natural inflow results in proportional renewable energy conversion.

Based on this, the terms outlined below provide a more detailed explanation of:

- Hydropower
- Reservoirs and upstream reaches
- Operating modes and tasks
- Hydrology

Definition	Symbol	Term definition
1.1		General
1.1.1 Reach		<p>The reach is the stretch of a river that is assigned to a hydropower plant, e. g. the section between the points on the watercourse above and below the plant, at which the affected and unaffected water levels converge at mean low water (<math>M_{NQ}</math>), see Figure 4 (Page 61) and Figure 8 (Page 82).</p> <p>The individual reaches for power plant chains are determined by official or contractual regulations.</p>
1.1.2 Diversion point, tapping point		<p>The diversion point/tapping point is the place where the water used to generate power is drawn from the original body of water (1.1.7).</p>
1.1.3 Diverted reach		<p>The diverted reach (redirected reach, canal stretch) is the intake waterway between the diversion point and the return point.</p> <p>NB:</p> <p>In Austria the original river bed downstream of a tapping point, in which the natural runoff volume is significantly reduced, is referred to as the diverted reach.</p> <p>The diverted reach, as defined in Chapter 1.1.15, is known as the intake waterway in Austria.</p>



Definition	Symbol	Term definition
1.1.4 Penstock		<p>A penstock is a pipe, which is completely filled with water and is pressurised during normal operation. A distinction is usually made between</p> <ul style="list-style-type: none"> <li>– Pressure tunnel/Headrace tunnel (Slope less than around 30°)</li> <li>– Inclined shaft (Slope between around 45° and 90°)</li> <li>– Pressure shaft (Slope 90°)</li> <li>– Pressure pipeline (any slope).</li> </ul>
1.1.5 Deepening reach		<p>The deepening reach is a stretch of a hydropower plant's tailwater influenced by artificial measures (dredging).</p> <p>NB:</p> <p>River bed erosion (natural deepening) refers to extensive degradation of the bed of the body of water, which may be caused by either excessive flow rates and/or by a disrupted bed load sediment balance (removal or lack of bed-load).</p>
1.1.6 Water catchment area		<p>The water catchment area is the area of an expanse, measured on a horizontal plane, from which water flows to a particular place (dam, reservoir). The boundaries between water catchment areas are watersheds.</p>
1.1.7 Extraction reach		<p>The extraction reach (residual flow reach, minimum flow reach, parent river bed) is the original reach of the body of water between the diversion point and the return point (see note in chapter 1.1.3).</p>

Definition	Symbol	Term definition
1.1.8 Gravity pipeline		A gravity pipeline is a line, whose cross-section is not filled to the apex with water during normal operation. A distinction is made between gravity tunnels and gravity pipelines.
1.1.9 Return point, reintroduction point		The return point/reintroduction point is the place where the water used to generate power is returned to the original body of water.
1.1.10 Dam structure		A dam structure is a retaining structure with its associated reservoir or storage basin.
1.1.11 Upstream reach		The upstream reach is the upstream stretch of a river affected by a dam.
1.1.12 Dam		A dam is a structure, which fundamentally only blocks a river and not an entire valley. As a rule, it consists of a power plant, a weir and, if necessary, a sluice.
1.1.13 Reservoir head		The reservoir head is the place where there is no measurable height difference between the un-dammed and dammed watercourse. The location of the reservoir head depends on the runoff.
1.1.14 Feed water - intake		The feed water intake is the structure for extracting the feed water.

Definition	Symbol	Term definition
1.1.15 Intake waterway		<p>The intake waterway is the entire route of the water from the water intake until it is reintroduced into the original body of water (return point).</p> <p>In the machinery (turbine) area these are referred to as feed water compartments.</p>
1.1.16 Surge tank		<p>A surge tank for the energy industry is a structure forming part of the intake waterway, which is used to restrict variations in pressure that occur in the event of rapid flow fluctuations.</p>
1.1.17 Weir		<p>A weir is a retaining structure (also part of a dam), which is used to dam and mainly to control the water level or runoff.</p>
1.1.18 Effective water catchment area		<p>The effective water catchment area is the water catchment area, which changes in area on the basis of feeding and/or drainage from and/or to other water catchment areas.</p>

Definition	Symbol	Term definition
1.2		Hydropower plants
1.2.1 Diversion power plant, canal power plant		A diversion power plant is a hydropower plant situated on a diverted reach (redirected reach). If this reach is an open canal, it is also referred to as a canal power plant.
1.2.2 Surf power plant		A surf power plant uses the energy of waves (surf) breaking on the coast.
1.2.3 River power plant		A river power plant is a hydropower plant, whose key components are located on the course of a river. Construction methods include, for example, pier power plants, inlet power plants (see Figure 7, Page 68).
1.2.4 Tidal power plant		A tidal power plant is a hydropower plant, which uses the sea's/ocean's tides.
1.2.5 High head power plant (High pressure facility)		A high head power plant (high pressure facility) is a hydropower plant with a large head. High head power plants are generally equipped with Francis or Pelton turbines.
1.2.6 Small hydropower plant		A small hydropower plant is a hydropower plant with a low installed capacity. A limit of 10 MW is common in Europe.
1.2.7 Run-of river hydropower plant		A run-of-river hydropower plant is a hydropower plant, which makes immediate use of the particular usable natural inflow.

Definition	Symbol	Term definition
1.2.7.1 Hydropeaking		With hydropeaking, the power plant flow can be influenced by managing the related storage area. The time needed to fill any existing storage basins is less than 2 hours ( $D \leq 2$ h). It is determined on the basis of the average annual flow of water. Run-of-river hydropower plants with hydropeaking capabilities are not considered storage power plants as per the definition 1.2.12.
1.2.7.2 Hydropeaking chain		A hydropeaking chain consists of several run-of-river hydropower plants on the same body of water located immediately behind each other, where the top (head reservoir) and bottom (end reservoir) are partially capable of being held. The run-of-river hydropower plants located in between play a part in hydropeaking, even though they may not individually be capable of hydropeaking.
1.2.7.3 Surge operation		Surge operation represents an extraordinary operating status in the event of a sudden shutdown of the power plant's turbines. In the event of load shedding by the power plant, as much water as possible is discharged with the turbines operating without a load until the weirs are able to acquire sufficient runoff.
1.2.8 Multi-purpose plant		<p>A multi-purpose plant is a hydraulic engineering installation that, in addition to using hydropower, is primarily used for other purposes, for example:</p> <ul style="list-style-type: none"> <li>– River engineering measures (River bed stabilisation)</li> <li>– Raising the water level (groundwater adjustment, alluvial forest conservation, protecting other structures on bodies of water, navigation, drinking water, irrigation)</li> <li>– Flood protection</li> </ul>

Definition	Symbol	Term definition
1.2.9 Low head power plant (Low pressure facility)		A low head power plant (low pressure facility) is a hydro-power plant with a low head. These are mainly equipped with Kaplan or cross-flow turbines.
1.2.10 Pumped storage power plant, pumped storage plant		<p>A pumped storage power plant is a storage power plant, whose reservoir is partly or entirely filled with pumped water (pump water). A downstream reservoir is generally needed to supply the pump water. The downstream reservoir may also be the upstream reach, the reservoir for another hydropower plant or a natural body of water.</p> <p>A distinction is made between pumped storage power plants with a natural inflow and pumped storage power plants without a natural inflow into the upstream reservoir.</p>
1.2.11 Reservoir		<p>A reservoir upstream of a storage power plant (upstream reservoir) is used to hold natural and pumped inflows, in order to transfer all or part of the water supply over time. A reservoir downstream of a storage power plant (downstream reservoir) is used to completely or partially balance the power plant flow (counter-reservoir) or for pumped storage power plants to hold the pendulum water.</p> <p>Reservoirs are distinguished:</p> <ul style="list-style-type: none"> <li>– by the type of filling (natural inflow, pumped storage),</li> <li>– by the draw-off period.</li> </ul> <p>The draw-off period is characteristic in terms of the energy industry.</p>

Definition	Symbol	Term definition
		Draw-off period:
Daily storage reservoir		up to approximately 6 hours
Weekly storage reservoir		between approximately 6 and 25 hours
Seasonal storage reservoir		up to approximately 500 hours
Annual storage reservoir		more than approximately 500 hours
1.2.12 Storage power plant		A storage power plant is a hydropower plant, whose inflow is drawn from one or more reservoirs. This means that its use is largely independent of the chronological sequence of inflows into its reservoir.
1.2.13 Water current power plant		A water current power plant is a hydropower plant, which uses the essential kinetic energy of water currents (historically: boat mills).
1.2.14 Hydropower plant (Hydropower unit)		A hydropower plant (hydropower plant) includes all the structures, machinery and facilities needed to convert the potential and kinetic energy of water into electrical energy and to feed it into the grid.  Hydropower plants are distinguished by location, type and operating mode.
1.2.15 Wave power		A wave power plant is a hydropower plant, which uses the power of waves.

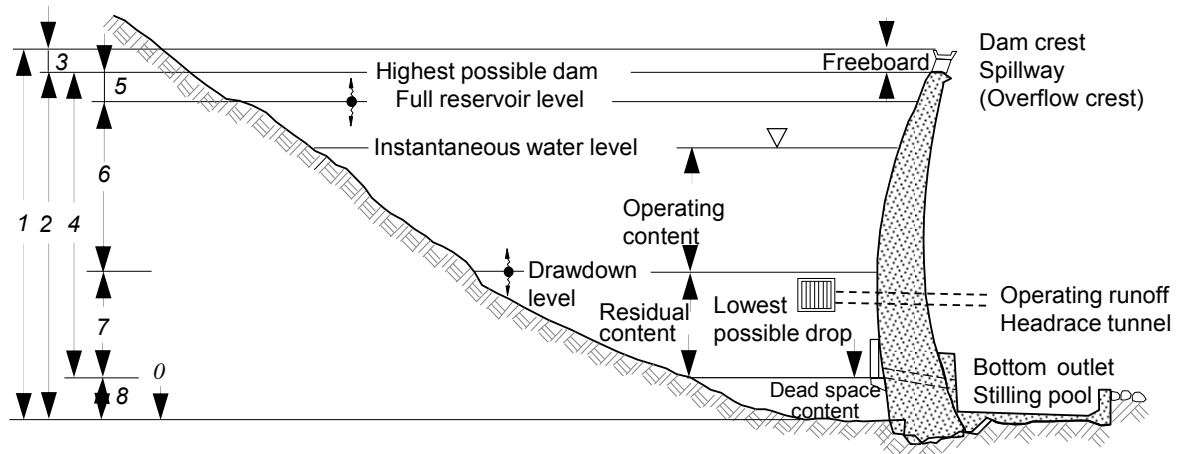
Definition	Symbol	Term definition
1.3		Reservoirs and upstream reaches  A distinction must be made between area (volume) and content: <ul style="list-style-type: none"> <li>– Area is the volume of a certain part of a reservoir,</li> <li>– Content is the water that, at an observation point, partly or entirely fills the area of the part of the reservoir in question, see Figure 1, Page 36</li> </ul>
1.3.1		Reservoir volumes (constant values)
1.3.1.1 Basin volume		The basin volume is the area between the dam crest and the valley floor and consists of the total reservoir volume and the free volume.
1.3.1.2 Total reservoir volume, total storage area	$V_G$	The total reservoir volume or total storage area is the area between the highest possible dam and the river bed.  The term storage area is mainly used for run-of-river hydro-power plants.
1.3.1.3 Usable volume	$V_N$	The usable volume is the area between the highest possible dam and the lowest possible drop.
1.3.1.4 Operating volume	$V_B$	The operating volume is the area between the full reservoir level and the drawdown level.
1.3.1.5 Hydropeaking volume	$V_S$	The hydropeaking volume is the operating volume of a run-of-river hydropower plant with hydropeaking capabilities.
1.3.1.6 Free volume	$V_F$	The free volume is the volume associated with the free-board.



Definition	Symbol	Term definition
1.3.1.7 Upper reserve volume	$V_{RO}$	The upper reserve volume is the area between the particular full reservoir level and the highest possible dam. It is used to influence flood runoff, for example. Its size may vary depending on the season.
1.3.1.8 Lower reserve volume	$V_{RU}$	The lower reserve volume is the area between the particular drawdown level and the lowest possible drop. It is used to release the minimum acceptable flow, for example. Its size (synonymous with content) may vary depending on the season.
1.3.1.9 Dead space	$V_T$	The dead space is the area between the lowest possible drop (bottom outlet) and the river bed. It cannot be used.
1.3.2		Reservoir contents (instantaneous values)
1.3.2.1 Total reservoir content, total dam content		The total reservoir or dam content is the instantaneous content above the river bed.
1.3.2.2 Usable content	$I_N$	The usable content is the instantaneous content above the lowest possible drop.
1.3.2.3 Operating content	$I_B$	The operating content is the instantaneous content above the drawdown level and below the full reservoir level.
1.3.2.4 Hydropeaking volume content	$I_S$	The hydropeaking volume content is the operating content of a run-of-river hydropower plant with hydropeaking capabilities.

Definition	Symbol	Term definition
1.3.2.5 Upper reserve volume content	$I_{RO}$	The upper reserve volume content is the instantaneous content above the full reservoir level and below the highest possible dam.
1.3.2.6 Lower reserve volume content	$I_{RU}$	The lower reserve volume content is the instantaneous content above the lowest possible drop and below the drawdown level.
1.3.2.7 Dead space content		The dead space content is the content above the river bed and below the lowest possible drop.
1.3.3		Reservoir heights (Relative elevations)
1.3.3.1 Full reservoir level	$Z_S$	The full reservoir level is the authorised upper water level for a reservoir or storage area.  Its height (upper or lower full reservoir level) may depend on various factors including, for example, the season, the purpose of the plant, inflows.
1.3.3.2 Full reservoir level tolerance		The full reservoir level tolerance is the permissible positive and negative deviation from the full reservoir level.
1.3.3.3 Highest possible dam	$Z_H$	The highest possible dam (highest full reservoir level) is the construction-related highest possible water level for a reservoir or storage area.
1.3.3.4 Drawdown level	$Z_A$	The drawdown level is the permissible lower water level for a reservoir or storage area.  Its height may depend on several factors including, for example, the season, the purpose of the plant, inflows.

Definition	Symbol	Term definition
1.3.3.5 Lowest possible drop	$Z_T$	The lowest possible drop (lowest drawdown level) is the construction-related lowest possible water level for a reservoir or storage area.  Its relative height elevation is identical to the lower edge of the bottom outlet.
1.3.3.6 Relative crest elevation		The relative crest elevation is the uppermost height of the retaining structure of a reservoir.
1.3.3.7 Relative spillway elevation		The relative spillway elevation is the uppermost height of a spillway crest or the uppermost height of a corresponding gate (upper edge of the gate) up to which a reservoir can be filled.
1.3.3.8 Freeboard	f	The freeboard is the vertical distance between the crest and the highest possible dam.



0		River bed
1		Basin volume
2	$V_G$	Total reservoir volume, total storage area
3	$V_F$	Free volume
4	$V_N$	Usable volume
5	$V_{RO}$	Upper reserve volume, extraordinary flood control retention volume
6	$V_B$	Operating volume
7	$V_{RU}$	Lower reserve volume, residual volume
8	$V_T$	Dead space
	$l_i$	Reservoir content of the corresponding reservoir volumes

Figure 1: Reservoir volumes and full reservoir levels (see also DIN 4048 and 19700) [1], [6] and ÖNORM M7103 [10])

Definition	Symbol	Term definition
1.4		Operating modes and tasks
1.4.1		Reservoir and storage area management
1.4.1.1 Reduction	$S_{SE}$	Reducing the reservoir content ( $\Delta I < 0$ ) is known as reduction and occurs when the total runoff is greater than the total inflow ( $Q_{Ab} > Q_{Zu}$ ).
1.4.1.2 Accumulation	$S_{SR}$	Increasing the reservoir content ( $\Delta I > 0$ ) is known as accumulation and occurs when the total runoff is lower than the total inflow ( $Q_{Ab} < Q_{Zu}$ ).
1.4.1.3 Reservoir content modification	$\Delta I$	Reservoir content modification ( $\Delta I$ ) is the difference between inflow and runoff volumes over a period of time. $\Delta I = (Q_{zu} - Q_{Ab}) \cdot \Delta t$ : Reservoir content modification $\Delta I > 0$ : Accumulation $\Delta I < 0$ : Reduction
1.4.2		Run-of-river hydropower plant
1.4.2.1 Run-of-river operation		With run-of-river operation, the particular power plant's inflow is used immediately, i.e. without storage, to provide basic capacity (base load coverage, see also VGB-S-002-T-01;2012-04.DE [14]).

Definition	Symbol	Term definition
1.4.2.2 Hydropeaking		<p>With hydropeaking, generation within a run-of-river hydro-power plant with hydropeaking capabilities is tailored to power requirements (grid) by managing the storage area. During off-peak periods (off-peak tariff periods, lower demand for electricity), the total inflow <math>Q_{Zu}</math> is retained for a certain period within the storage area (Accumulation). The reservoir content created in this way is used subsequently during heavy load periods (peak times, high demand for electricity) (Reduction).</p> <p>Depending on the type of transition from a lower to a higher flow and vice versa, a distinction is made between the two operating systems, "Continuous operation" or "Intermittent operation".</p>
1.4.2.3 Continuous operation		<p>All plants in a hydropeaking chain involved in continuous operation increase their flow consecutively, ensuring that the full reservoir level is maintained in the storage areas. The same applies to reducing the flow.</p>
1.4.2.4 Intermittent operation		<p>All plants in a hydropeaking chain involved in intermittent operation increase or reduce their flow simultaneously without maintaining full reservoir levels.</p>
1.4.2.5 Shutdown		<p>The electric generator as well as the turbine and any pumps are stopped. The electric generator is disconnected from the grid and is ready to start-up.</p>
1.4.2.6 Pumping operation		<p>With pumping operation, the electric generator acts as a motor and draws electrical power from the grid to drive the reservoir pumps. This feeds water into the upper reservoir.</p>

Definition	Symbol	Term definition
1.4.2.7 Phase shift operation		<p>With phase shift operation, the electric generator (synchronous generator) acts as an idling motor feeding reactive energy into the grid (inductive mode) or draws reactive energy from the grid (capacitive mode). The generator draws active energy from the grid to cover losses.</p>
1.4.2.8 Hydraulic short circuit		<p>With a hydraulic short circuit, one or more turbines and one or more pumps are operated simultaneously in the same power plant. The hydraulic machines involved (turbine and pump) may belong to a generator set.</p> <p>The water, which drives the turbine(s), originates in whole or part directly from pumping operation.</p> <p>NB:</p> <p>A hydraulic short circuit for synchronous generators may be operation with a reduced and controllable power drain, as opposed to pumping operation (constant power drain from the grid). With the aid of a controllable turbine, the electrical power provided/ agreed by the grid for pumping operation can be maintained. A hydraulic short circuit is used to provide an operating reserve.</p>
1.4.2.9 Operating mode changes		<p>Operating mode changes means the interplay between the various operating modes, e. g. turbine and pumping operation. Use of power plants complies with market-based principles as well as the requirements for safeguarding stable grid operation.</p>

Definition	Symbol	Term definition
1.4.2.10 Daily, weekly, seasonal op- eration		Depending on the storage capacity of the upper reservoir, and the resulting time frames for emptying and filling, a distinction is made between daily, weekly and seasonal operation.
1.4.2.11 Pumped stor- age operation		Pumped storage operation takes place in a pumped storage power plant. There is around the same quantity of pendulum water (1.4.2.12) for turbine and pumping operation within the specified time frame.
1.4.2.12 Pendulum water		The quantity of water used for pumped storage operation is known as pendulum water. The electrical energy generated is the pumped energy, see the chapter entitled "Pumped energy" (4.14).
1.4.2.13 Provision of peak capacity		Storage power plants and pumped storage power plants are particularly suited to covering peak loads (frequent start-ups and shutdowns, high power change speeds, peak load coverage, see also VGB-S-002-T-01;2012-04.DE [14]).
1.4.2.14 Standard op- eration	$A_{HR}$	During standard operation, storage power plants and pumped storage power plants are operated at the "load level" of the power-frequency controller. In doing so, the capacity of the generators is tailored to the control signal (see also VGB-S-002-T-01;2012-04.DE [14]).



Definition	Symbol	Term definition
1.4.2.15 Reserve power provision		Storage power plants and pumped storage power plants are used to provide rapidly available reserve power (reserve power provision), which can be activated in the event of changes in load and/or faults affecting another power plant or the grid.

## 1.5 Hydrology

The terms outlined comply with DIN 4049 [2]. Alignment with ÖNORM B 2400 [11] (notwithstanding ÖNORM EN ISO 772 [11], Edition 2011-12-15, which applies in the years 2012 and 2013) has been undertaken, wherever possible. Principal values and statistical key figures are limit values, arithmetic mean values as well as values within or exceeding the specified time frame. These principal values are only covered below in conjunction with runoff  $Q$ . They must always be specified for a particular place.

A capital letter  $M$  is used to denote mean values, e. g.  $MQ$ ,  $MHQ$ . This mean value is the arithmetic mean of all primary observations within the time frame in question. This mean value only acquires its meaning in conjunction with time related information.

For a time frame of up to a year, this mean value is made up of the arithmetic mean of all observations (characteristic values), i.e. of their total, divided by the number of them, for a time frame covering several years of the monthly, half-yearly or annual mean in question, i.e. as the mean of means.

The daily value is the representative value for the particular day, in many cases the daily mean.

In cases where individual values are of unequal importance, special formulae are outlined in DIN 55302 [5].

For an explanation of runoff values, see Figure 2 (Inflow duration curve), Page 46, which is an extract from a hydrological yearbook [15] with additional annotations.

Definition	Symbol	Term definition
1.5.1 Runoff year, hydrological year		<p>The runoff year is a period of one year (365 days) determined from a hydrological point of view.</p> <p>In Germany and Austria, the hydrological year runs from 1<sup>st</sup> November of the previous year to 31<sup>st</sup> October of the reporting year. The hydrological winter runs from the beginning of November to the end of April and the hydrological summer from the beginning of May to the end of October.</p>
1.5.2 Flooding		When a defined limit value for runoff is exceeded this is referred to as flooding.
1.5.3 Flood runoff	$H_Q$	Flood runoff is the defined maximum value (instantaneous value) of runoff.
1.5.4 Calculated maximum flood runoff		The calculated maximum flood runoff is the value calculated as the greatest possible flood runoff.
1.5.5 Maximum flood runoff	$H_{HQ}$	The maximum flood runoff (also known as the peak value) is the upper limit value for runoff (instantaneous value).
1.5.6 Highest navigable flow/water level		The highest navigable flow/water level is the level at which navigation is still possible. It is related to the highest navigable water level (HSW), up to which navigation on a waterway is still permitted (see also DIN 4054 [3]).

Definition	Symbol	Term definition
1.5.7 Mean water runoff	$M_Q$	<p>The mean water runoff is the arithmetic mean value of runoff within a specified time frame.</p> <p>NB:</p> <p>It is expedient to state which values are used to create the mean value (e. g. hourly data).</p>
1.5.8 Mean flood runoff	$M_{HQ}$	<p>The mean flood runoff is the arithmetic mean value (mean upper limit value) of the respective greatest runoff values for a number of similar periods (for example the same days, months, half-years or years). For example <math>M_{HQ1960/80}</math> is the mean value from <math>H_Q</math> the year 1960 to 1980. Daily mean values are used as the basis.</p>
1.5.9 Mean low water runoff	$M_{NQ}$	<p>The mean low water runoff is the arithmetic mean value (mean lower limit value) of the particular lowest runoff values for a number of similar periods (for example the same days, months, half-years or years). For example <math>M_{NQ1960/80}</math> is the mean value from <math>N_Q</math> the year 1960 to 1980. Daily mean values are used as the basis.</p>
1.5.10 Wet year, dry year		<p>When n-years are arranged in order of runoff volume, the n-third-years with the greatest runoff volume are wet years, the n-third-years with the lowest runoff volume are dry years.</p> <p>The number of years n should be as large as possible, e. g. <math>n &gt; 25</math> years.</p>
1.5.11 Extremely wet year, extremely dry year		<p>An extremely wet or extremely dry year is identified as the year with the greatest or lowest runoff volume among a sufficiently large number of years examined.</p>

Definition	Symbol	Term definition
1.5.12 Lowest low water runoff	$N_{NQ}$	The lowest low water runoff is the lowest limit value for runoff (instantaneous value).
1.5.13 Low water runoff	$N_Q$	The low water runoff is the lower limit value (instantaneous value) within a specified time frame.
1.5.14 n-annual flood runoff	$H_{Qn}$	The n-annual flood runoff that is achieved or exceeded, on average, once every n years over a period of many years, e. g. $H_{Q100}$ (occurs, on average, once every 100 years).
1.5.15 Control year		<p>The control year (average year) is a fictitious year, whose water management figures are arithmetic mean values for a coherent series of as many as possible (and at least 10) representative years n, for the designated task. The time series must be stated, when necessary; the figures must be adjusted to reflect any changes in conditions.</p> <p>Should a particular observation be lacking when stating the figures, this must be based on the control year.</p>

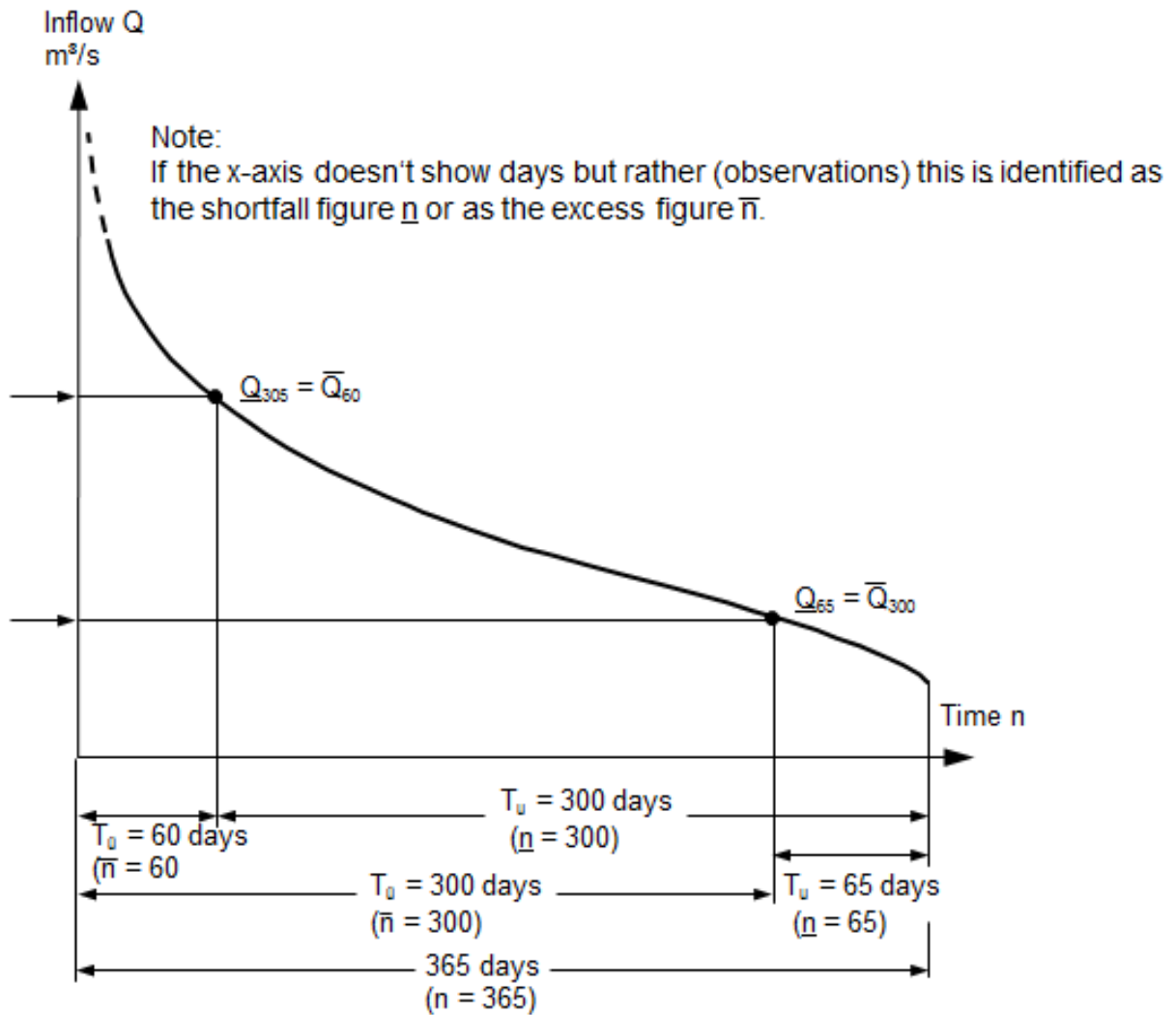


Figure 2: Inflow duration curve

## 1.6 Flows and volume of water (see Figure 3, Page 55)

The flow  $Q$  ( $\text{m}^3/\text{s}$ ) is the volume of water flowing through a cross-section within a unit of time (e. g. a second).

The volume of water  $S$  ( $\text{m}^3$ ) – in Austria “Load” – is the flow incorporated over a period of time. Therefore  $Q_{Zu}$  relates to  $S_{Zu}$ .

It should be noted for the stated terms (flows) that they cannot all be recorded and measured; some are calculated figures.

Should the data relate to the control year, these must also be identified with the letter R, e. g.  $S_{Abr}$  – total runoff volume in the control year.

Definition	Symbol	Term definition
1.6.1 Flow	Q	The flow is the volume of water, which flows through a (flow) cross-section within a particular unit of time.
Inflow	$Q_{Zu}$	The (total) inflow is the volume of water from a water catchment area or reservoir, which flows into an area within a particular unit of time.
Runoff	$Q_{Ab}$	The (total) runoff is the volume of water from a water catchment area or reservoir, which flows out of an area within a particular unit of time.
1.6.2 Adjusted inflow/Adjusted runoff	$Q_{korr}$	The adjusted inflow (adjusted runoff) is the inflow (runoff) for a watercourse, which would occur at a certain time in a certain cross-section, if no reservoir management were to be carried out within the storage area of the effective water catchment area.
1.6.3 Total inflow	$Q_{Zu}$	The total inflow is the sum of all inflows into the reservoir or storage area in question, see Figure 3, Page 55. $Q_{Zu} = Q_{FW} + Q_{ZTP}$ $Q_{Zu} = Q_{OL} + Q_{Bei} + Q_{Ein} + Q_{nat} + Q_{ZuP} + Q_{ZuT}$
1.6.4 Flowing wave	$Q_{FW}$	The flowing wave is the flow of a particular reservoir or storage area, if there is no management and no inflows or extraction by associated pumped storage power plants, for example. $Q_{FW} = Q_{OL} + Q_{Bei} + Q_{Ein} + Q_{nat}$



Definition	Symbol	Term definition
1.6.5 Inflow from power plants or pumping stations	$Q_{ZTP}$	<p>The inflow from power plants or pumping stations forms part of the total inflow and is brought about by the operation of other storage power plants or pumped storage power plants. This inflow may result in an increase in the content of the particular reservoir or storage area. It may also increase the flowing wave. The reservoir or storage area in question may be a downstream or upstream reservoir.</p> $Q_{ZTP} = Q_{ZuP} + Q_{ZuT}$
Inflow from pump water	$Q_{ZuP}$	<p>The inflow from pump water is the proportion of the total inflow, which is fed by pumping stations into the particular reservoir or storage area. The reservoir or storage area may be the upstream reservoir for a pumped storage power plant.</p>
Inflow from turbine water	$Q_{ZuT}$	<p>The inflow from turbine water is the proportion of the total inflow, which is fed by another power plant into the particular reservoir or storage area. The reservoir or storage area may be the downstream reservoir for this power plant.</p>
1.6.6 Natural inflow	$Q_{nat}$	<p>The natural inflow for a reservoir or storage area is the proportion of the total inflow, which originates from the water catchment area for the particular reservoir or storage area and only flows in below the upstream barrier (lateral tributary). This includes precipitation that falls directly into the particular reservoir or storage area.</p>

Definition	Symbol	Term definition
1.6.7 Ups tream inflow	$Q_{OL}$	Upstream inflow is the sum of all direct upstream runoff into the particular reservoir or storage area.
1.6.8 Tributary inflow	$Q_{Bei}$	Tributary inflow is the proportion of the total inflow, which is fed from other water catchment areas into the particular reservoir or storage area below the upstream barrier.
1.6.9 Discharge inflow	$Q_{Ein}$	Discharge inflow feeds back into the particular reservoir or storage area discharge runoff drawn from other points of this reservoir or storage area, in whole or part, $Q_{Abl}$ , e. g. treated wastewater, cooling water.
1.6.10 Reservoir extraction, make-up water	$Q_{SE}$	Reservoir extraction or make-up water is the proportion of the total runoff, which can be ascribed to Reduction $Q_{SE}$ .
1.6.11 Reservoir reserve, retention	$Q_{SR}$	The reservoir reserve or retention is the proportion of the total inflow, which can be ascribed to Accumulation $S_{SR}$ .
1.6.12 Total runoff	$Q_{Ab}$	<p>Total runoff is the sum of all runoff from a reservoir or storage area.</p> $Q_{Ab} = Q_V + Q_{Abl} + Q_{Ver} + Q_{Über} + Q_{Dot} + Q_{ATP}$ <p>NB:</p> <p><math>Q_{Ab}</math> this may be different to <math>Q_{Zu}</math> as the result of managing the reservoir or storage area.</p>

Definition	Symbol	Term definition
1.6.13 Available power plant inflow, available reservoir runoff	$Q_V$	<p>The available power plant inflow, frequently referred to as "Available inflow", is the proportion of total runoff from a reservoir or storage area, which is available to a hydropower plant.</p> <p>Depending on the observer's viewpoint, the available power plant inflow is also known as available reservoir runoff.</p>
1.6.14 Discharge runoff	$Q_{Abl}$	<p>Discharge runoff is the proportion of total runoff, which is drawn from the particular reservoir or storage area for cooling water, drinking water, irrigation water, etc. It is fed back into other points of the reservoir or storage area as discharge inflow <math>Q_{Ein}</math>, in whole or part.</p>
1.6.15 Waste runoff	$Q_{Ver}$	<p>The waste runoff from a particular reservoir or storage area is evaporated and seepage water.</p>
1.6.16 Diversion runoff	$Q_{Über}$	<p>Diversion runoff is the proportion of total runoff, which is drawn from the particular reservoir or storage area and fed into other water catchment areas by means of diversion.</p>
1.6.17 Minimum instream flow runoff (Minimum instream flow)	$Q_{Dot}$	<p>The minimum instream flow runoff (minimum instream flow) is the runoff, which must be released into the extraction reach at the beginning of the diverted reach (see Figure 5, Page 62). Subsequent seepage or water supplies within the extraction reach are not taken into account.</p> <p>NB:</p> <p>The term minimum instream release is commonly used in Austria. The officially stipulated minimum instream release is identified as the minimum instream provision (see ÖNORM M7103 [10]).</p>

Definition	Symbol	Term definition
1.6.18 Minimum acceptable flow runoff (Minimum acceptable flow)	$Q_{Pfl}$	<p>The minimum acceptable flow runoff (Minimum acceptable flow) is the above-ground minimum flow prescribed by the authorities in a particular flow cross-section of an extraction reach (stretch of a river) downstream of a diversion point (1.1.2) at a certain time.</p> <p>NB: The term residual water provision is commonly used in Austria (see ÖNORM M7103 [10]).</p>
1.6.19 Residual water runoff	$Q_{Rest}$	Residual water runoff is the runoff, which is discharged above-ground into an extraction reach at a particular place downstream of a water tapping point.
1.6.20 Runoff for power plants or pumping stations	$Q_{ATP}$	<p>The runoff for power plants or pumping stations is the proportion of total runoff, which is brought about by the operation of other storage power plants or pumped storage power plants. This runoff may result in a reduction in the content of the particular reservoir or storage area or a reduction in the flowing wave. The reservoir or storage area in question may be an upstream or downstream reservoir for other plants.</p> $Q_{ATP} = Q_{AbP} + Q_{AbT}$
Runoff for pumps	$Q_{AbP}$	Runoff for pumps is the proportion of total runoff, which is drawn by pumping stations from the particular reservoir or storage area. The reservoir or storage area may be the downstream reservoir for a pumped storage power plant.

Definition	Symbol	Term definition
Runoff for turbines	$Q_{AbT}$	Runoff for turbines is the proportion of total runoff, which is drawn by the turbines, mainly of a pumped storage power plant, from the particular reservoir or storage area. The reservoir or storage area may be the upstream reservoir for this pumped storage power plant.
1.6.21 Power plant flow	$Q_K$	Power plant flow, for run-of-river hydropower plants and storage power plants, is equal to the sum of the turbine flow and the power plant waste runoff, see 1.6.23.  $Q_K = Q_T + Q_{KV}$
1.6.22 Turbine flow	$Q_T$	Turbine flow is the proportion of power plant flow, which is used by a power plant's turbines.
1.6.23 Power plant waste runoff	$Q_{KV}$	Power plant waste runoff is the proportion of power plant flow, which is not available to the turbines, e. g. for under-slucices, process water, cooling water, fish ladders, etc.
1.6.24 Usable power plant inflow	$Q_N$	Usable power plant inflow is the proportion of total inflow, which can be used by a power plant to generate energy. It is calculated as:  $Q_N = Q_V - Q_{AV}$
1.6.25 Plant-related waste runoff	$Q_{AV}$	Plant-related waste runoff is the proportion of available power plant inflow that, as the result of discharges for weir irrigation, sluicing water, sluice chamber irrigation, ice removal, weir runoff or exceeding the installed flow, cannot be used to generate energy.

Definition	Symbol	Term definition
1.6.26 Operational waste runoff	$Q_{BV}$	Operational waste runoff is the proportion of usable power plant inflow that, as the result of the unavailability of plant components or problems within the grid, cannot be used to generate energy.
	$Q_{BVI}$	Operational waste runoff can be divided into internal waste runoff $Q_{BVI}$ (power plant) and external waste runoff $Q_{BVE}$ (e. g. grid).
	$Q_{BVE}$	
1.6.27 Installed flow	$Q_A$	The installed flow is the flow for which a power plant is designed.
1.6.28 Turbine flow	$Q_{TN}$	Nominal turbine flow is the flow for which the turbine is commissioned. In many cases, a nominal flow range is specified.  NB: The nominal turbine flow may be adjusted by acceptance tests.
1.6.29 Pump output flow	$Q_P$	The pump output flow is the flow provided by pumping stations or pumped storage power plants.
1.6.30 Nominal pump output flow	$Q_{PN}$	The nominal pump output flow is the flow for which a pump is commissioned. In many cases, a nominal flow range is specified.  NB: The nominal pump output flow may be adjusted by acceptance tests.

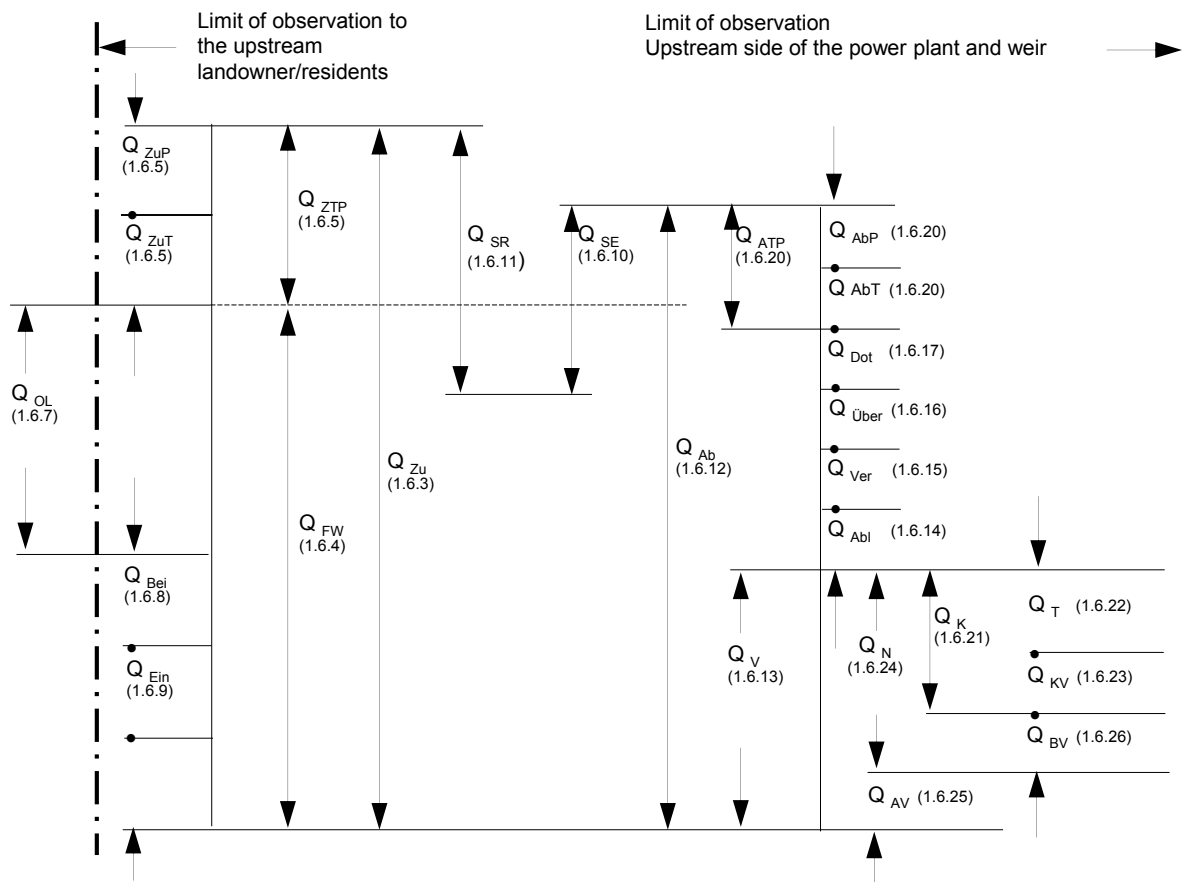


Figure 3: Most general case of a flow figure for a run-of-river hydropower plant

(Assumption: The upstream reach is simultaneously the downstream reservoir for a pumped storage power plant and the upstream reservoir for another pumped storage power plant.)

## 1.7 Heads, discharge heads, suction heads

The head or discharge head is the height difference between two energy levels. In practice, the head generally equates, with sufficient precision, to the height difference in the water level (geodetic head) (see, for example, Figure 4, Page 61).

However, when conducting accepting tests on turbines and pumps, account must be taken of the differences in air pressure and velocity heads. In addition, suitable measuring points must be determined.

In IEC 60041 [7], 60193 [8], 62097 [9], full details of the “Specific hydraulic energy of a “generator” and “Specific hydraulic energy”, in terms of taking account of density, speed and altitude, are explained.

For a run-of-river hydropower plant the head is a function of runoff. As runoff increases the downstream level rises and the head decreases. The head is specified either as a mean value within a time frame or as an upper and lower limit value, in order to identify the operational fluctuation range.

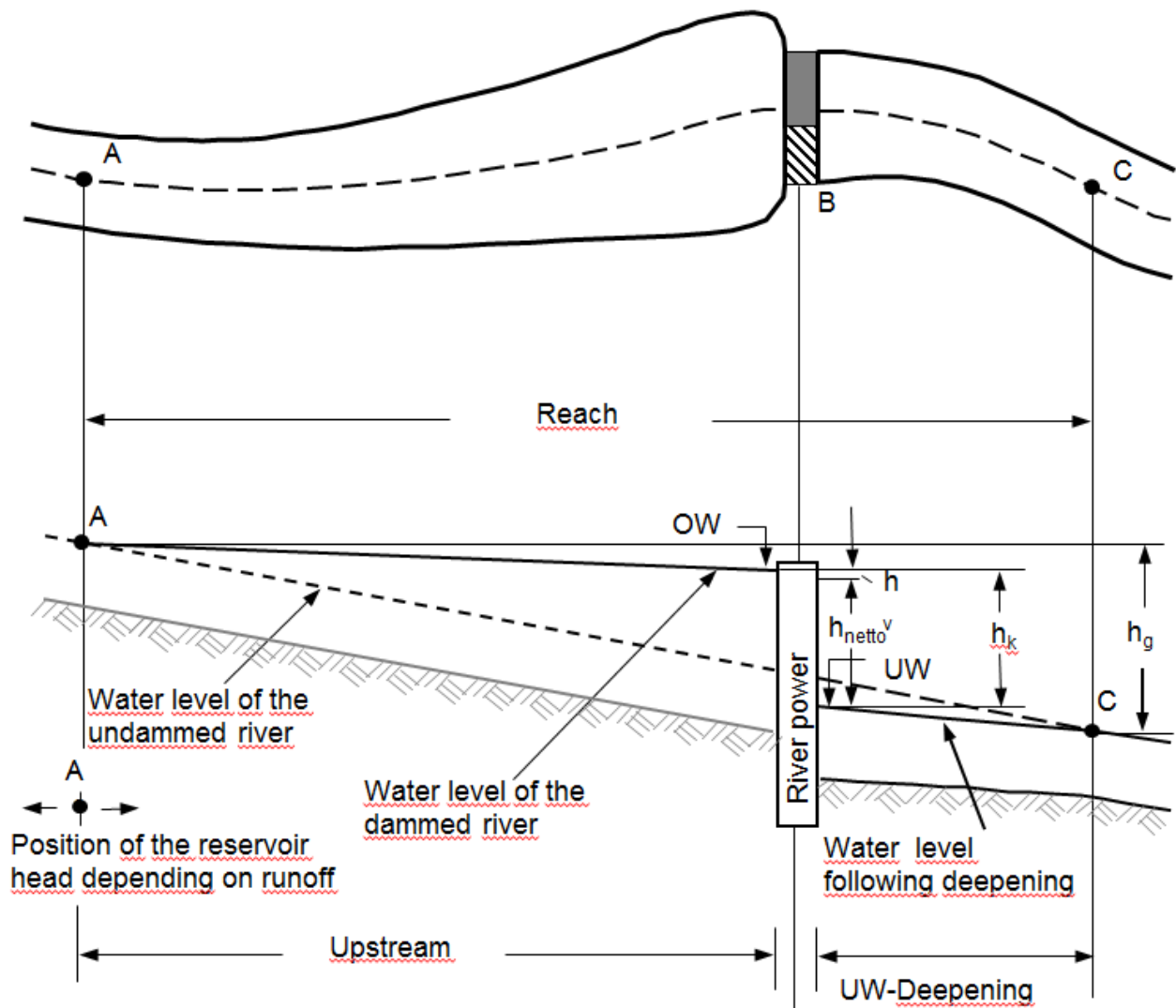


Definition	Symbol	Term definition
1.7.1		Heads with hydraulic generators
1.7.1.1 Net head	$h_{\text{netto}}$	The net head is the difference in kinetic heads between the turbine's inlet cross-section and outlet cross-section. At the same time, note should be taken of the various turbine designs, see DIN 4320 [4].
1.7.1.2 Nominal head	$h_N$	The nominal head is the head for which the turbine is commissioned. In many cases, guarantees regarding capacity and efficiency are agreed between the manufacturer and the power plant operator for several heads.
1.7.1.3 Head loss	$h_V$	Head loss is a measurement of the reduction in kinetic heads, e. g. caused by friction in pipes, shut-off devices, diversions, bypasses, trash racks, inflow losses, outlet losses.
1.7.2		Run-of-river hydropower plants
1.7.2.1 Critical head	$h_g$	The critical head of a reach is the height difference in the water level at the beginning and end of the reach.
1.7.2.2 Power plant head	$h_K$	The power plant head is the height difference between the upstream water level before the trash rack and the downstream water level behind the suction pipe of a power plant, measured as a level difference.
1.7.2.3 Power plant installed head	$h_{KA}$	The power plant installed head is the power plant head with an installed flow.

Definition	Symbol	Term definition
1.7.2.4 Bypass head	$h_U$	The bypass head is the height difference in the water level before water collection and the water level at the re-entry point.
1.7.3		Storage power plants and pumped storage power plants (see also Figure 6, Page 63)
1.7.3.1 Gross head	$h_{brutto}$	The gross head is the height difference between the water level of the upstream reservoir and for reaction turbines (Francis, Kaplan) the water level of the downstream reservoir, for single jet impulse turbines the height of the intersection point of the beam axis and the pitch circle, for multi-jet impulse turbines the mean value of the intersection points between beam axes and the pitch circle. for multi-jet impulse turbines the mean value of the intersection points between beam axes and the pitch circle.
1.7.3.2 Mean head	$h_m$	The mean head is the height difference between the focal points of the operating areas of the upstream reservoir and the downstream reservoir. It may also relate to the centres of energy (influence of efficiency level dependency). Note must be taken of the specific conditions for impulse turbines.
1.7.3.3 Maximum theoretical head	$h_{max\ theo}$	The maximum theoretical head is the height difference between the highest possible dam for the upstream reservoir and the lowest drop for the downstream reservoir.

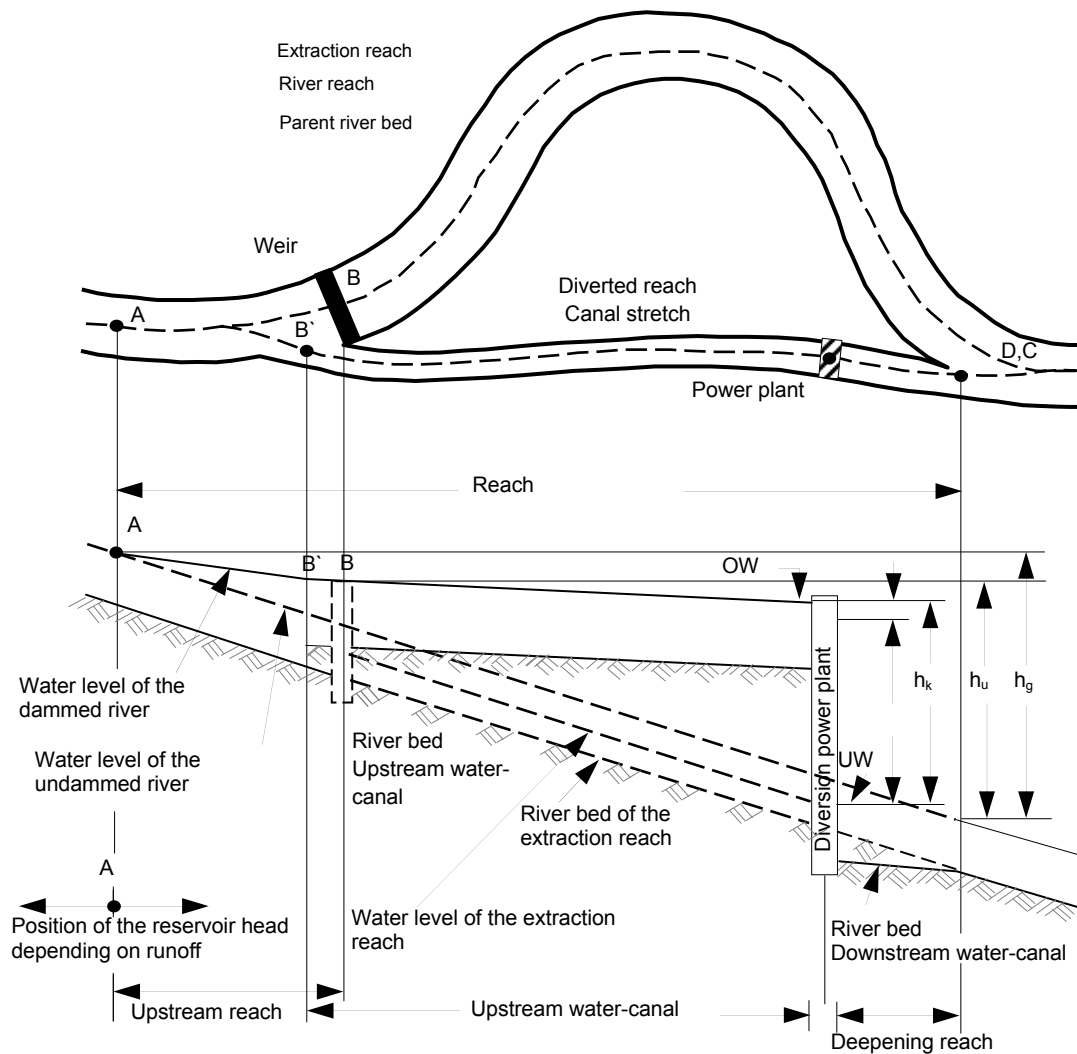
Definition	Symbol	Term definition
1.7.3.4 Maximum head	$h_{\max}$	The maximum head is the height difference between the full reservoir level for the upstream reservoir and the drawdown level for the downstream reservoir.
1.7.3.5 Minimum theoretical head	$h_{\min \text{ theo}}$	The minimum theoretical head is the height difference between the lowest drop for the upstream reservoir and the highest possible full reservoir level for the downstream reservoir.
1.7.3.6 Minimum head	$h_{\min}$	The minimum head is the height difference between the drawdown level for the upstream reservoir and the full reservoir level for the downstream reservoir.
1.7.3.7 Geodetic suction head	$h_{z \text{ geo}}$	The geodetic suction head (pump inlet pressure) is the height difference between the centre of the pump's inlet cross-section (account must be taken of the pump's design) and the water level of the downstream reservoir.
1.7.3.8 Geodetic discharge head	$h_{p \text{ geo}}$	The geodetic discharge head of a pump is the height difference between the water level of the upstream reservoir and the downstream reservoir.
1.7.3.9 Mean discharge head	$h_{pm}$	The mean discharge head of a pump is the height difference between the focal points of the upstream reservoir and the downstream reservoir in relation to the usable volume.

Definition	Symbol	Term definition
1.7.3.10 Manometric discharge head	$h_{p \text{ man}}$	<p>The manometric discharge head of a pump is the maximum difference in kinetic head between the pump's inlet and outlet cross-sections.</p> <p>NB:</p> <p>For discharge heads, other terms may be established on the basis of the head terms.</p>



- A Beginning of influence on the river (reservoir head)
- B Dam site, weir
- C End of influence on the river
- OW Upstream water level at the power plant
- UW Downstream water level at the power plant

Figure 4: Head figure for run-of-river hydropower plants



- A Beginning of influence on the river (reservoir head)
- B Dam site, weir
- B' Water extraction, inlet structure
- C End of influence on the river
- D Re-entry of the downstream water canal
- OW Upstream water level at the power plant
- UW Downstream water level at the power plant

Figure 5: Head figure for diversion power plants (see also Figure 4)

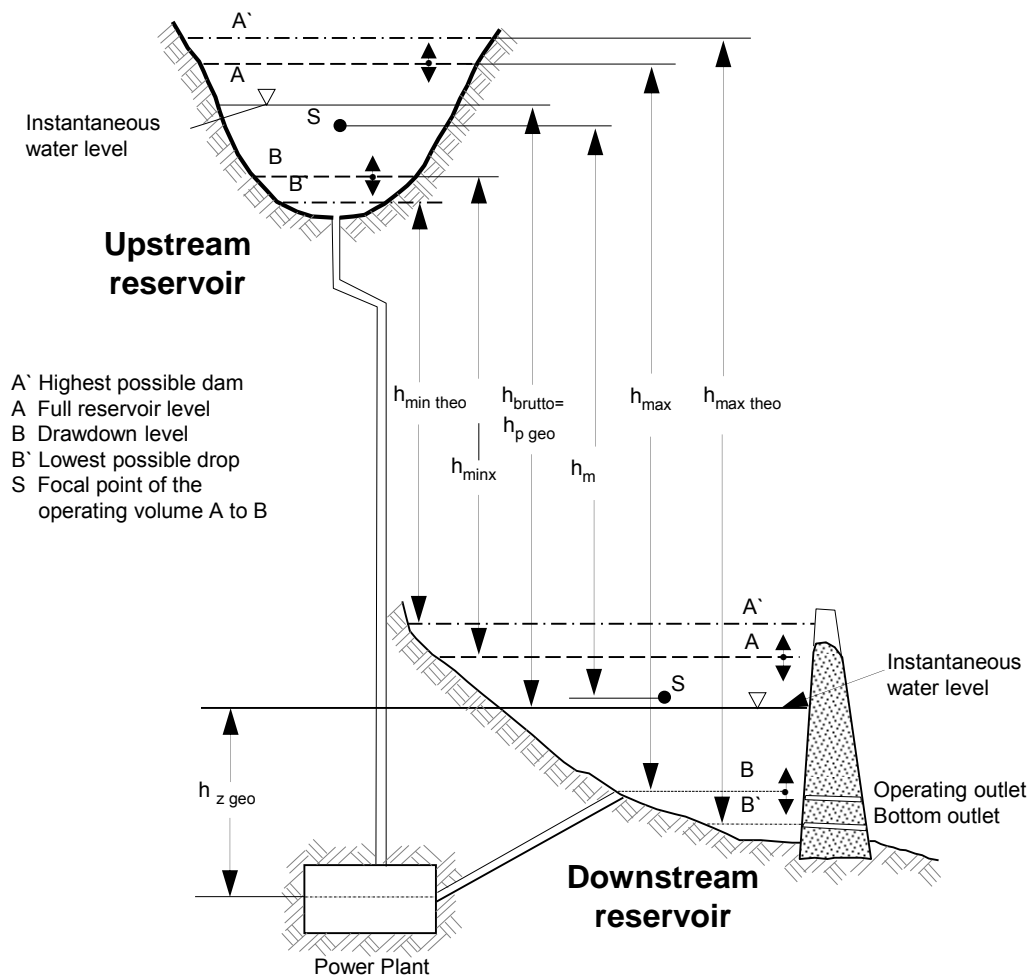


Figure 6: Head figure for storage power plants and pumped storage power plants  
 (see also DIN 4048 [1] and ÖNORM M7103 [9])

## 2 Time related terms

Time generally means a time frame or period  $T$ . The time frame (reporting, collection, observation time frame), in all cases, is an objective coherent time frame, which may also consist of several, not immediately consecutive partial time frames. The particular time frame in question must be clearly identified.



Definition	Symbol	Term definition
2.1 Time	t	Time is a time frame, which indicates the duration of a process.
2.2 Nominal time	t <sub>N</sub>	Nominal time is the entire reporting time frame, without any interruption (calendar time, e. g. day, month, quarter, year)
2.3 Availability time	t <sub>v</sub>	Availability time is the time frame during which, due to its technical condition, a plant or part of a plant converts or transfers energy or could convert or transfer energy, regardless of the extent of the achievable capacity. It is the difference between nominal time and unavailability time.  t = t <sub>N</sub> - t <sub>nv</sub>
2.4 Operating time	t <sub>B</sub>	Operating time is the time frame, during which a plant or part of a plant converts or transfers energy. Operating time begins when the plant or part of the plant is connected to the grid and ends when it is disconnected from the grid. Start-up and shutdown times for generating plants without a usable energy output are not included in operating time.  Operating times can be determined on the basis of operating modes for power plants and generator sets:  Turbine operation (Generator operation) t <sub>TU</sub> Pumping operation (Motor operation) t <sub>PU</sub> Phase shift operation t <sub>PH</sub> Hydraulic short circuit t <sub>HY</sub>  t <sub>B</sub> = t <sub>TU</sub> + t <sub>PU</sub> + t <sub>PH</sub> + t <sub>HY</sub>

Definition	Symbol	Term definition
2.5 Standby time	$t_R$	<p>Standby time is the time frame, during which a plant or part of a plant is ready for operation but is not operated.</p> <p>NB:</p> <p>During standby time, the plant could be started up in accordance with the manufacturer's or operator's instructions. Start-up and shutdown times are deemed to be standby time.</p>
2.6 Available not in operation time	$t_{ng}$	<p>Available not in operation time is the time frame, during which a plant or part of a plant is available but is not used and/or cannot be used because of external influences (see Appendix 1) .</p> $t_{ng} = t - t_B$ $t_{ng} = t_R + t_{ns}$
2.7 Unavailability time	$t_{nv}$	<p>Unavailability time is the time frame during which, due to the technical condition of the plant or part of the plant, a plant or part of a plant cannot be operated for reasons that lie within the plant or are beyond the control of operational management.</p> $t_{nv} = t_N - t$ <p>Unavailability time consists of a planned and an unplanned proportion. The latter is in turn divided into a postponable and not postponable component.</p> $t_{nv} = t_{nv p} + t_{nv u}$

Definition	Symbol	Term definition
Planned unavailability time	$t_{nv\ p}$	Planned unavailability time is the time frame during which, due to a long scheduled shutdown, a plant cannot be operated. The beginning and duration of the shutdown must be determined more than four weeks in advance.
Unplanned unavailability time	$t_{nv\ u}$	<p>Unplanned unavailability time is the time frame during which, due to an unplanned shutdown, a plant cannot be operated, where the shutdown cannot be delayed or can be delayed up to four weeks.</p> <p>Unplanned unavailability time is subdivided into a postponable a not postponable component.</p> $t_{nv\ u} = t_{nv\ ud} + t_{nv\ un}$
Unplanned not postponable unavailability time	$t_{nv\ ud}$	Postponable unplanned unavailability time is the proportion of unplanned unavailability time, which can be delayed for more than twelve hours and up to four weeks.
Unplanned not postponable unavailability time	$t_{nv\ un}$	Not postponable unplanned unavailability time is the proportion of unplanned unavailability time, which cannot be delayed or can be delayed up to twelve hours.
2.8 Available unproductive time	$t_{ns}$	Available unproductive time is the time frame during which, due to external influences, a plant or part of a plant cannot be used, although the plant itself would be operational.
2.9 Available not dispatchable time	$t_{nb}$	<p>Available not dispatchable time is the sum of unavailability time (2.7) and available unproductive time (2.8).</p> $t_{nb} = t_{nv} + t_{ns}$

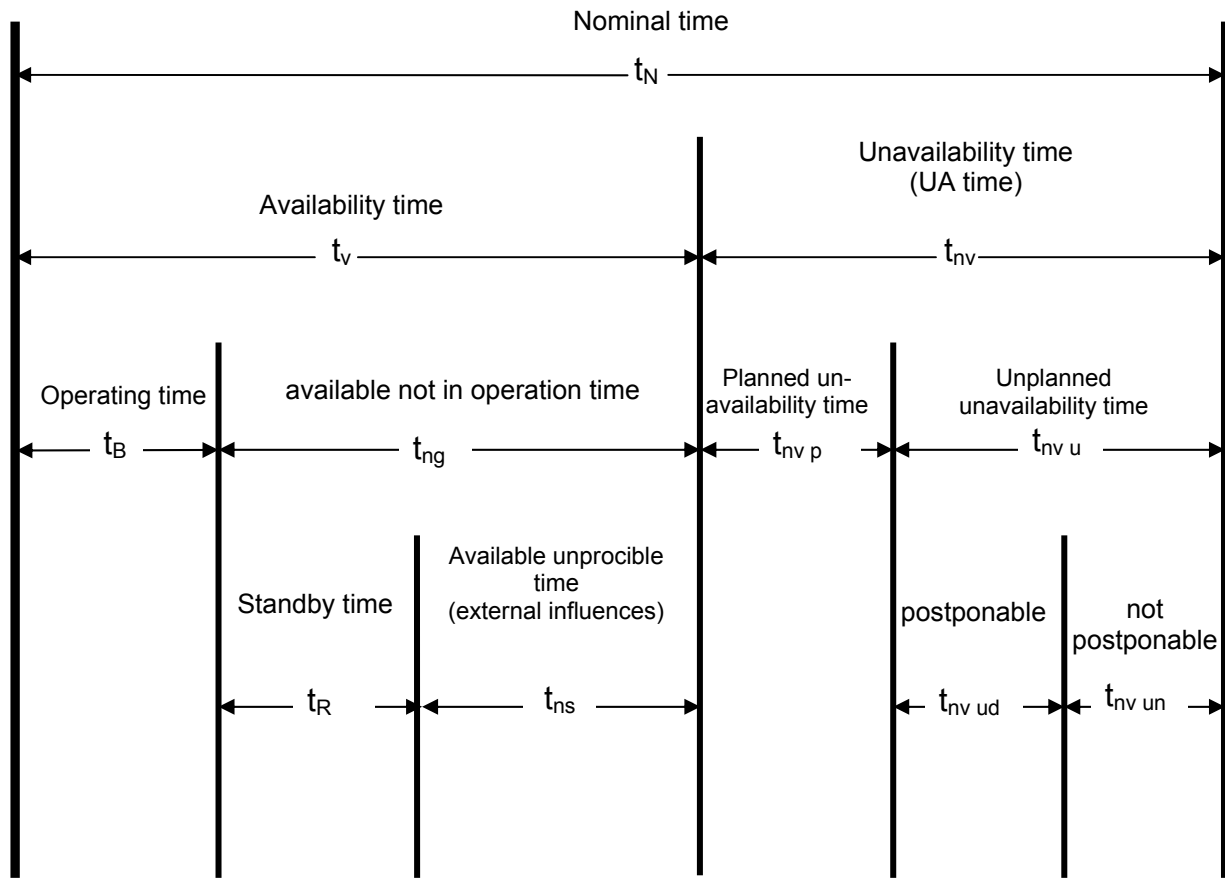


Figure 7: Figure providing an explanation of time related terms

Definition	Symbol	Term definition
2.10 Use time	$t_{ben}$	<p>Use time is generally calculated by dividing the energy through corresponding capacity (output). Output commonly includes maximum output and contractual output.</p> $t_{ben} = \frac{W}{P}$
Degree of use		<p>NB:</p> <p>The degree of use is a content related measure.</p> <p>When using this term, the type of output (e. g. maximum output, contractual output, ordered output, chargeable output) and the time frame (e. g. year, month) must always be specified.</p>
2.11 Utilisation time	$t_a$	<p>The utilisation time for a generation unit or a plant, as a special case of the use time, is the ratio of the energy generated by this generation unit or plant within a certain time frame to an identified output for the plant.</p> <p>Utilisation time is specifically defined:</p> <p>Utilisation time for bottleneck capacity</p> $t_{aE} = \frac{W_B}{P_E}$ <p>Utilisation time for the mean available capacity for storage power plants and pumped storage power plants.</p> $t_{aE} = \frac{W_B}{P_v} = \frac{W_B}{W_v} \cdot t_N$ <p>Where <math>P_v</math> is a mean value over <math>t_N</math>.</p>

Definition	Symbol	Term definition
		<p>NB:</p> <p>A content related measure of utilisation time is the percentage of energy utilisation.</p> <p>In contrast to the calculation of availability, overtime is included in utilisation time.</p>
2.12 Installed time	$t_A$	<p>Installed time (installed days) for a run-of-river hydropower plant specifies on how many days of the control year the installed flow is achieved or exceeded.</p>
2.13 Filling time for a reservoir	$t_f$	<p>The filling time for a reservoir is the ratio of its maximum usable volume to the pump output flow with a mean discharge head.</p> $t_f = \frac{V_N}{Q_p}$ <p>In practice, it is determined approximately:</p> $t_f = \frac{A_s}{\eta_{PT} \cdot P_{Pm}}$

### 3 Capacity terms

Capacity is the differential quotient  $\frac{dW}{dt}$ . Should there be no way within a plant to directly measure capacity/output, Capacity P is derived from Energy W and Time t,  $P = \frac{W}{t}$ .

Hereafter, output always means real electrical power. Output data relates to the values measured at the electric generator's terminals.

For turbine operation, gross output is measured at the generator's terminals. Net output is calculated by deducting the power plant's own power requirement and the generator transformer's power loss.

For pumping operation, net output is measured at the motor's terminals. Gross output is calculated by adding the power plant's own power requirement to the generator transformer's power loss.

VGB-S-002-T-01; 2012-04.DE [14] contains a list of a wide range of capacity terms used in the electricity sector. The following terms are specifically used for hydropower plants.

The conditions for run-of-river power plants appear in Figure 8 on Page 82.

The conditions for pumped storage power plants appear in Figure 9 on Page 83.

Definition	Symbol	Term definition
3.1 Installed capacity	$P_A$	<p>The installed capacity of a run-of-river hydropower plant is the output achievable with the installed flow using the power plant's installed head, see Figure 11, Page 91.</p> <p>NB:</p> <p>Installed capacity is not defined for storage power plants and pumped storage power plants.</p>
3.2 Standby capacity	$P_R$	<p>Standby capacity is the capacity available, at a given time, over and above the operating capacity, but not required to cover the load. It is determined as the difference between the available capacity and the operating capacity.</p> $P_R = P_V - P_B$ <p>In storage power plants and pumped storage power plants, standby capacity may be derived from (see Figure 10, Page 84):</p> <ul style="list-style-type: none"> <li>standing standby capacity</li> <li>rotating standby capacity during phase shift operation</li> <li>rotating standby capacity during generator operation</li> </ul>
3.3 Operating capacity	$P_B$	<p>The operating capacity of a power plant is the actual output generated at a given time (see Figure 10, Page 84).</p>
3.3.1 Maximum output		<p>The maximum output is the maximum operating output generated (international standard: maximum power "produced") by a power plant. It is determined as an instantaneous value or mean value over a short time frame, e. g. over a <math>\frac{1}{4}</math> of an hour.</p>



Definition	Symbol	Term definition
3.4 Consolidated output	$P_{\text{Bil}}$	The consolidated output is the scheduled operating output over a certain time frame.
3.5 Bottleneck capacity, maximum capacity	$P_e$	<p>The bottleneck capacity (international standard: maximum capacity <math>P_m</math>) of a hydropower plant is the highest constantly achievable electrical capacity of the plant provided that the flow, in conjunction with the head, has the optimum value.</p> <p>For run-of-river hydropower plants, in many cases, the bottleneck capacity is the installed capacity.</p> <p>For storage power plants and pumped storage power plants, the bottleneck capacity is the highest achievable output with the maximum head.</p> <p>NB:</p> <p>A change should only be made to the bottleneck capacity if parts of the plant are definitely decommissioned or removed with a conscious acceptance of capacity losses or, because of other influences, a new arrangement is necessary (e. g official requirements, altered inflows, altered full reservoir or drawdown levels, deepening).</p> <p>Short-term unusable parts of the plant do not reduce the bottleneck capacity.</p>

Definition	Symbol	Term definition
3.6 Guaranteed capacity	$P_s$	<p>a) The guaranteed capacity of a run-of-river hydropower plant is the output, which is exceeded on 330 days of the control year (see Figure 11, Page 91).</p> <p>NB: In Austria, guaranteed capacity is the output, which equates to the usable inflow <math>Q_{95}</math> in the control year. The usable inflow <math>Q_{95}</math> is identified as any flow, which is not fallen short of, in the control year, on 95 % of the days in the control year.</p> <p>b) The guaranteed capacity of a hydropower plant equipped with a short-term reservoir (daily or weekly reservoir) (e. g also a run-of-river hydropower plant with hydropeaking capabilities) is determined by its output transfer capacity. The available time for guaranteed capacity (e. g. 10 hours a day) is specified appropriately, e. g. <math>P_{s,10}</math>.</p> <p>NB: In Austria, the guaranteed capacity of a run-of-river hydro-power plant with hydropeaking capabilities is any output, which equates to twice the inflow <math>Q_{95}</math> (see NB at a). For daily and weekly reservoirs, 3 times inflow <math>Q_{95}</math> is used to determine the guaranteed capacity, with the need to prove whether this approach is justified by interim storage in the reservoir.</p>

Definition	Symbol	Term definition
		<p>c) The guaranteed capacity of a storage power plant (seasonal or annual reservoir) is the highest output, which the storage power plant with operating content of 10 % of the operating volume can deliver.</p> <p>d) The guaranteed capacity of a pumped storage power plant is the mean capacity, see chapter 3.10.</p>

Definition	Symbol	Term definition
3.7 Hydraulic unavailable capacity	$P_{nvH}$	<p>Hydraulic unavailable capacity (instantaneous value, time related information required) is the difference between the bottleneck capacity (maximum capacity) and the hydraulic available capacity.</p> $P_{nvH} = P_e - P_{vH}$ <p>Distinction:</p> <p>The unavailable capacity of a generation unit is the output that cannot be generated, at a given time, due to the technical and operating condition of the plant.</p> $P_{nv} = P_N - P_v \text{ for } P_N \geq P_v$ <p>In this respect, a distinction can be made between the scheduled and unscheduled proportion of the unavailable capacity.</p> $P_{nv} = P_{nv p} + P_{nv u}$
3.8 Hydraulic available capacity	$P_{vH}$	<p>The hydraulic available capacity of a run-of-river hydro-power plant is the achievable output, at a given time, subject to the particular conditions of inflow and head, without taking account of technical unavailability.</p> <p>The hydraulic available capacity of a storage power plant or pumped storage power plant is the achievable output, at a given time, with the particular head, without taking account of technical unavailability.</p> <p>In many cases, it is sufficient, on examination, to set a longer time frame</p> $P_{vH} = P_m.$

Definition	Symbol	Term definition
3.9 Capacity for pumping operation, pump output		The capacity for pumping operation (pump output) is the electrical power absorbed by the motor.
3.10 Mean capacity	$P_m$	<p>The mean capacity of a run-of-river hydropower plant is the ratio of the energy generated <math>W_B</math> within a given time frame to the related nominal time.</p> $P_m = \frac{W_B}{t_N}$ <p>The mean capacity of a run-of-river hydropower plant may also be calculated as the ratio of the energy capability <math>W_H</math> to a given time frame.</p> $P_{mH} = \frac{W_H}{t_N}$ <p>The mean capacity of a storage power plant or pumped storage power plant is the greatest achievable output with the mean head <math>h_m</math>.</p>
3.11 Mean capacity for pumping operation	$P_{mP}$	The mean capacity for pumping operation of a pumped storage power plant is the absorbed electrical power with the mean head $h_{pm}$ .
3.12 Nominal capacity	$P_N$	The nominal capacity of a plant is the highest continuous output under nominal conditions, which a plant achieves at the time of transfer. Changes in capacity are only permitted in the event of substantial changes to the nominal conditions and construction/design work on the plant. Unlike bottleneck capacity, nominal capacity may not be adapted to a temporary change in capacity (cf. VGB-S-002-T-01;2012-04.DE [14]).

Definition	Symbol	Term definition
3.13 Technical unavailable capacity	$P_{nvT}$	Technical unavailable capacity (instantaneous value, time related information required) is the difference between bottleneck capacity (maximum capacity) and technically available capacity.  $P_{nvT} = P_e - P_{vT}$
3.14 Technical unavailable capacity with repercussions	$P_{nvTr}$	Technical unavailable capacity with repercussions (instantaneous value, time related information required) is the difference between technical and hydraulical unavailable capacity.  $P_{nvTr} = P_{nvT} - P_{nvH} = P_{vH} - P_{vT}$  Only applies, if $P_{nvTr} > 0$  NB:  Technical unavailable capacity is divided into a proportion with repercussions, where the natural supply cannot be used, and a proportion with no repercussions, where the natural supply is non-existent.
3.15 Technical available capacity	$P_{vT}$	The technical available capacity of a hydropower plant is the achievable output, at a given time, subject to the technical specified conditions, regardless of the hydraulic circumstances. It is equal to the bottleneck capacity (maximum capacity) or smaller by a figure, which corresponds to the failure of parts of the plant within the given period.

Definition	Symbol	Term definition
3.16 Available capacity	$P_v$	<p>Available capacity is the achievable output due to the technical and operating condition of the plant. Available capacity is the sum of operating capacity and unused capacity or the difference between nominal capacity and unavailable capacity.</p> $P_v = P_B + P_{ng}$ $= P_N - P_{nv}$ <p>The available capacity (instantaneous value, time related information required) of a run-of-river hydropower plant is the achievable output, due to the technical condition of the plant (<math>P_{vT}</math>) and water management related influences (the particular usable inflow and head - <math>P_{vH}</math>), where the smaller value should always be applied.</p> $P_v = \min(P_{vH}, P_{vT})$ <p>The available capacity (instantaneous value, time related information required) of a storage power plant or pumped storage power plant is the achievable output, at a given time, due to the condition of the plant (<math>P_{vT}</math>) and the head (<math>P_{vH}</math>). For a longer time frame the mean head must be used as the basis for available capacity (mean value over this time frame). The smaller value must always be applied.</p> $P_v = \min(P_{vH}, P_{vT})$
3.17 Unused capacity	$P_{ng}$	<p>The unused capacity of a generation unit is the proportion of available capacity, which is not in use.</p> $P_{ng} = P_v - P_B$

Definition	Symbol	Term definition
3.18 Unusable capacity	$P_{ns}$	Unusable capacity is determined as the difference between the unused and standby capacity. $P_{ns} = P_{ng} - P_R$
3.19 Planned unavailable capacity	$P_{nv p}$	Planned <sup>1</sup> unavailable capacity is the unavailable capacity, at a given time, due to planned measures.
3.20 Unplanned unavailable capacity	$P_{nv u}$	Unplanned unavailable capacity is the unplanned unavailable capacity, at a given time, due to faults, damage or other events. It is divided into a postponable and a not postponable <sup>2</sup> component.
3.21 Dispatchable capacity	$P_b$	The dispatchable capacity of a generation unit is the sum of operating capacity and standby capacity. $P_b = P_B + P_R$

<sup>1</sup> "Planned" unavailable capacity means established more than 4 weeks beforehand

<sup>2</sup> Unplanned postponable capacity means  $\geq 12$  hours up to  $\leq 4$  weeks. Unplanned "not postponable" capacity means  $\leq 12$  hours



Definition	Symbol	Term definition
3.22 Not dispatchable capacity	$P_{nb}$	<p>The not dispatchable capacity of a generation unit is the sum of unavailable capacity and unproductible capacity.</p> $P_{nb} = P_{nv} + P_{ns}$
3.23 Minimum capacity		<p>The minimum capacity of a generation unit is the output that, for plant-specific or equipment related reasons, cannot be fallen short of during continuous operation. Should the minimum capacity not be applied to a continuous operation, but to a shorter time frame, this must be specifically indicated.</p> <p>In addition to electrical power, within power plant operation, reactive and apparent power are also relevant:</p>
3.24 Reactive power		<p>Reactive power is the electrical power, which is needed to create magnetic fields (e. g. in motors, transformers) or electrical fields (e. g. in capacitors, cables, wires) and does not contribute to usable energy.</p>
3.25 Apparent power		<p>Apparent power is the geometric sum of electrical power and reactive power. It is crucial in the design of electrical facilities, among other things.</p>

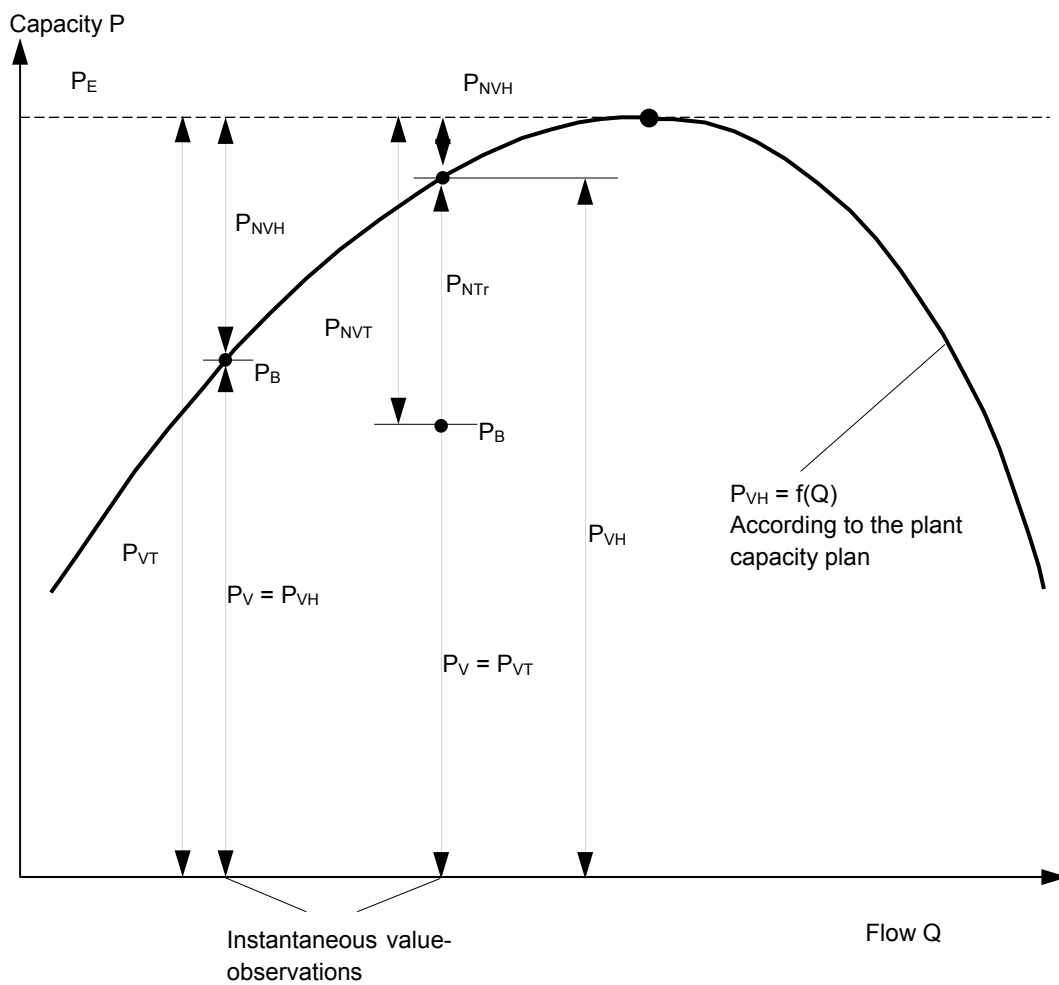


Figure 8: Capacity terms for run-of-river hydropower plants

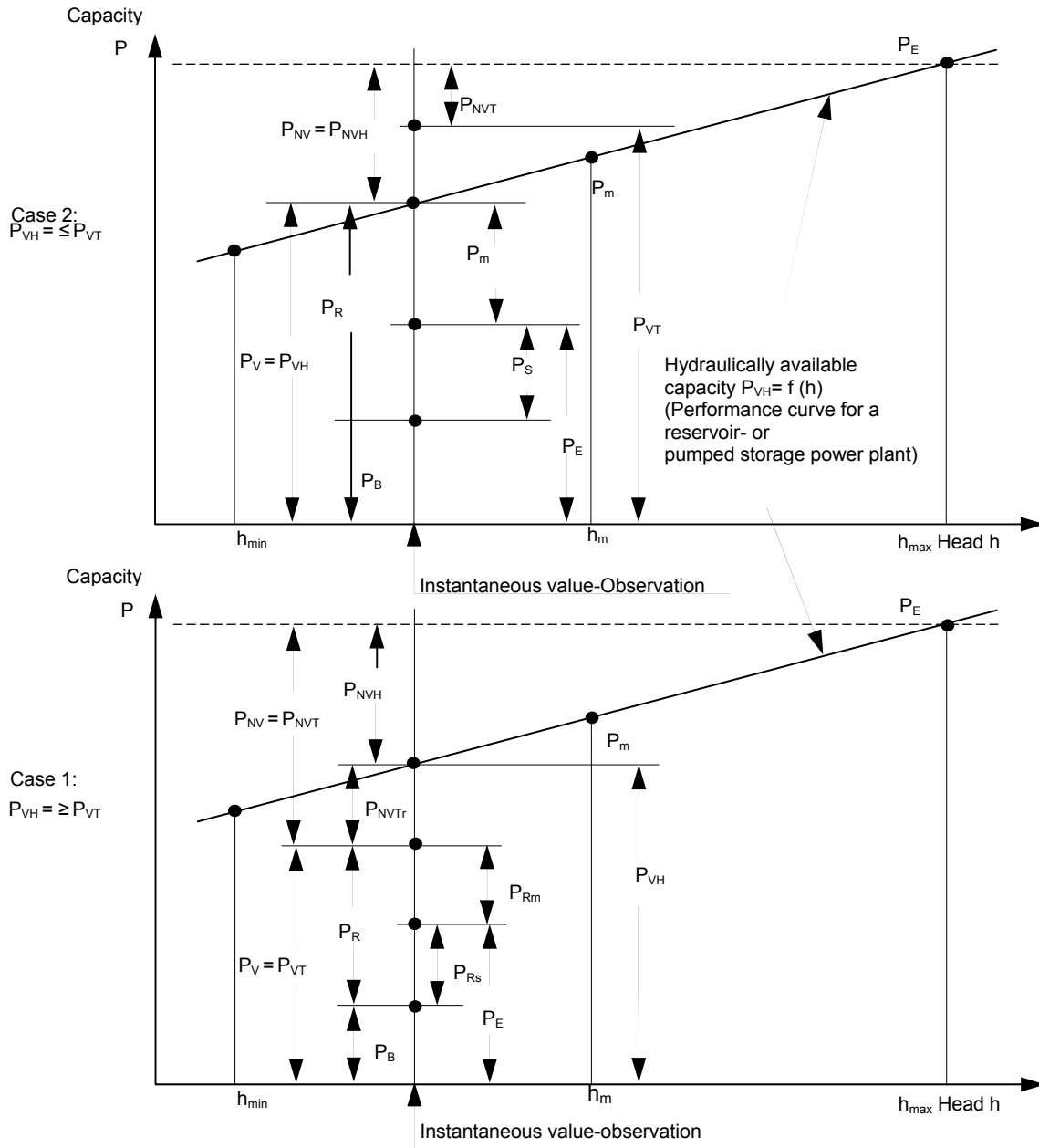
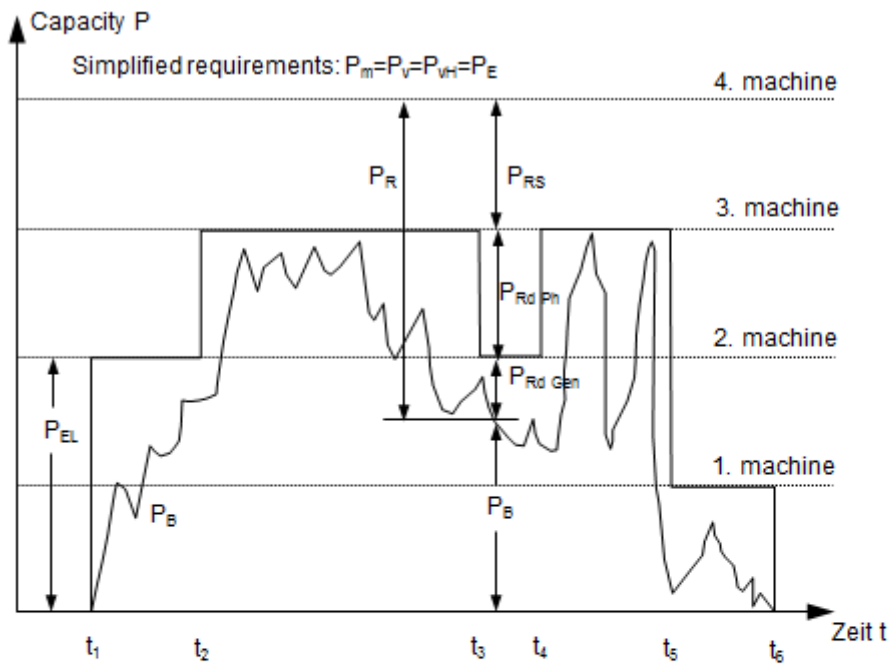


Figure 9: Capacity terms for storage power plants and pumped storage power plants  
 Case 1:  $P_{VH} \geq P_{VT}$ , Case 2:  $P_{VH} \leq P_{VT}$



- $t_1$  1st and 2nd machine started up (generator operation)
- $t_2$  Start up of machine 3
- $t_3$  Switched of one machine to phase shift operation
- $t_4$  Switched of one machine from phase shift operation to generator operation
- $t_5$  Shut off two machines
- $t_6$  Shut off the third machine

Figure 10: Basic representation of the use of a storage power plant or pumped storage power plant

## 4 Energy terms

For turbine operation/generator operation, gross energy is measured at the generator's terminals. Net energy is calculated by deducting the power plant's own requirement including the generator transformer's losses.

For pumping operation, net energy is measured at the motor's terminals. Gross energy is calculated by adding up the power plant's own requirement including the generator transformer's losses.

The description "gross" or "net" should be specified.

VGB-S-002-T-01;2012-04.DE [14] contains a list of a wide range of energy terms used in the electricity sector. The following terms are specifically used for hydropower plants: it should be noted that, for some capacity terms there are no similar energy terms in common use. There are therefore no corresponding definitions. Nominal energy  $W_N$  as defined in VGB-S-002-T-01;2012-04.DE [14] does not apply to hydropower plants.

Definition	Symbol	Term definition
<p>4.1 Energy capability, energy yield</p>	<p><math>W_H</math></p>	<p>The energy capability of a run-of-river hydropower plant is the electrical energy that can be generated using the particular hydraulically available capacity <math>P_{vH}</math> (3.8) within a given time frame.</p> $W_H = \int P_{vH} \cdot dt$ <p>NB:</p> <p>Energy capability is usually determined for a reporting time frame (e. g. month, half-year, year). For the specified types of power plants, energy capability also includes inflows from diversions from other water catchment areas, meaning that the pumping energy for feeder pumps (force pumps) must be deducted.</p> <p>The energy capability of storage power plants and pumped storage power plants with a natural inflow is the electrical energy that can be generated solely using the natural inflow <math>Q_{nat}</math> (total inflow minus pumped inflow).</p> <p>The energy capability of pumped storage plants is divided into the energy capability for turbine energy and pumping energy in relation to the reservoir content of the upper reservoir.</p>

Definition	Symbol	Term definition
4.2 Standard energy capability	$W_{HR}$	<p>Standard energy capability (RAV) is the energy capability for a control year.</p> <p>NB:</p> <p>In simple terms, the value for standard energy capability can be calculated as the mean value for generation from a range of operating years (min. 10 years) - potentially even as a rolling mean value. Note should be taken that technical failures may result in unusable values for RAV. The note in chapter 1.5.1 applies accordingly.</p>
4.3 Generation (Energy generated)	$W_B$	<p>Generation or energy generated by a hydropower plant is the electrical energy actually generated within a given time frame (meter reading).</p> $W_B = \int P_B \cdot dt$ <p>In pumped storage plants with a natural inflow, a distinction is made between pumped energy (<math>W_{BW}</math>) (4.14) and run-of-river energy (<math>W_{BH}</math>) (4.13).</p>
4.4 Maximum energy content of a reservoir  (max. energy capability of a reservoir)	$W_S$	<p>The maximum energy content of a reservoir is the electrical energy that can be generated with the maximum operating content, for pumped storage plants including figures for the pumping energy needed to fill the reservoir.</p>

Definition	Symbol	Term definition
4.5 Energy content of a reservoir  (Energy capability of a reservoir)	$W_{SV}$	The energy content of a reservoir (energy reserve of a reservoir) is the electrical energy that can be generated using the instantaneous operating content with the associated head and the applicable efficiency.  Note on 1.5.10 and 1.5.12 The energy content of a power plant group's reservoirs may be related to the secondary or lowest power plant in the power plant group; the correlation must be specified (see also note in 1.5.10.)
4.6 Unused energy	$W_{HN}$	The unused energy of a run-of-river hydropower plant is the difference between the energy capability and generation (energy generated).  $W_{HN} = W_H - W_B$  The unused energy of a storage power plant or pumped storage power plant is the proportion of energy from the usable power plant inflow, which is not used by the energy industry.
4.7 Available energy	$W_v$	The available energy is the energy, which can be generated on the basis of the available capacity $P_v$ (3.16). <sup>3</sup>  $W_v = \int P_v \cdot dt$
4.8 Technical available energy	$W_{vT}$	The technical available energy is the energy, which could be generated on the basis of the technical available capacity $P_{vT}$ (3.15). <sup>3</sup>  $W_{vT} = \int P_{vT} \cdot dt$

<sup>3</sup> For pumped storage power plants, the available energy depends on the filling level of the upstream reservoir.



Definition	Symbol	Term definition
4.9 Technical unavailable energy	$W_{nvT}$	The technical unavailable energy is the energy, which cannot be generated on the basis of the technical unavailable capacity $P_{nvT}$ (3.13). <sup>3</sup>  $W_{nvT} = \int P_{nvT} \cdot dt$
4.10 Technical unavailable energy with repercussions	$W_{nvTr}$	The technical unavailable energy with repercussions (see note in chapter 3.14) is the energy, which cannot be generated on the basis of the technical unavailable capacity with repercussions $P_{nvTr}$ (3.14). <sup>3</sup>  $W_{nvTr} = \int P_{nvTr} \cdot dt$
4.11 Pumping energy, pump energy (pump power consumption)	$W_P$	Pumping energy (pump power consumption) is the electrical energy, which is used to supply the reservoir water.  NB: For the difference between gross and net values see the introduction in chapter 4.
4.12 Phase shift energy supply	$W_{Ph}$	The energy supply to drive the generator specifically for generating reactive power (capacitive or inductive) (predominantly in pumped storage power plants)
4.13 Run-of river energy	$W_{BH}$	Generation from a natural inflow
4.14 Pumped energy	$W_{BW}$	Pumped energy is the re-producible electrical energy from pumped water taking account of efficiency. It is only determined for pumped storage power plants.  $W_{BW} = W_P \cdot \eta_{PT}$

Definition	Symbol	Term definition
4.15 Impounding loss	$W_{\text{Verl}}$	<p>Impounding loss means the decrease in generation for a run-of-river hydropower plant, which arises as the result of the downstream influence of a downriver power plant (new construction or a change to the full reservoir level). Impounding loss reduces the standard energy capability of a run-of-river hydropower plant.</p> <p>NB: Impounding loss can be recompensed by payment or by means of an actual energy exchange.</p>
4.16 Plant capacity plan/output plan		<p>The plant capacity plan – also known as the output plan – is a graphic representation of the links between flow, head and capacity. Flow is represented as a duration curve, while head and capacity depend on flow. The curves for head and capacity are therefore only indirect duration curves. It is used to determine standard energy capability. Figure 11 shows a plant capacity plan for run-of-river hydropower plants.</p>

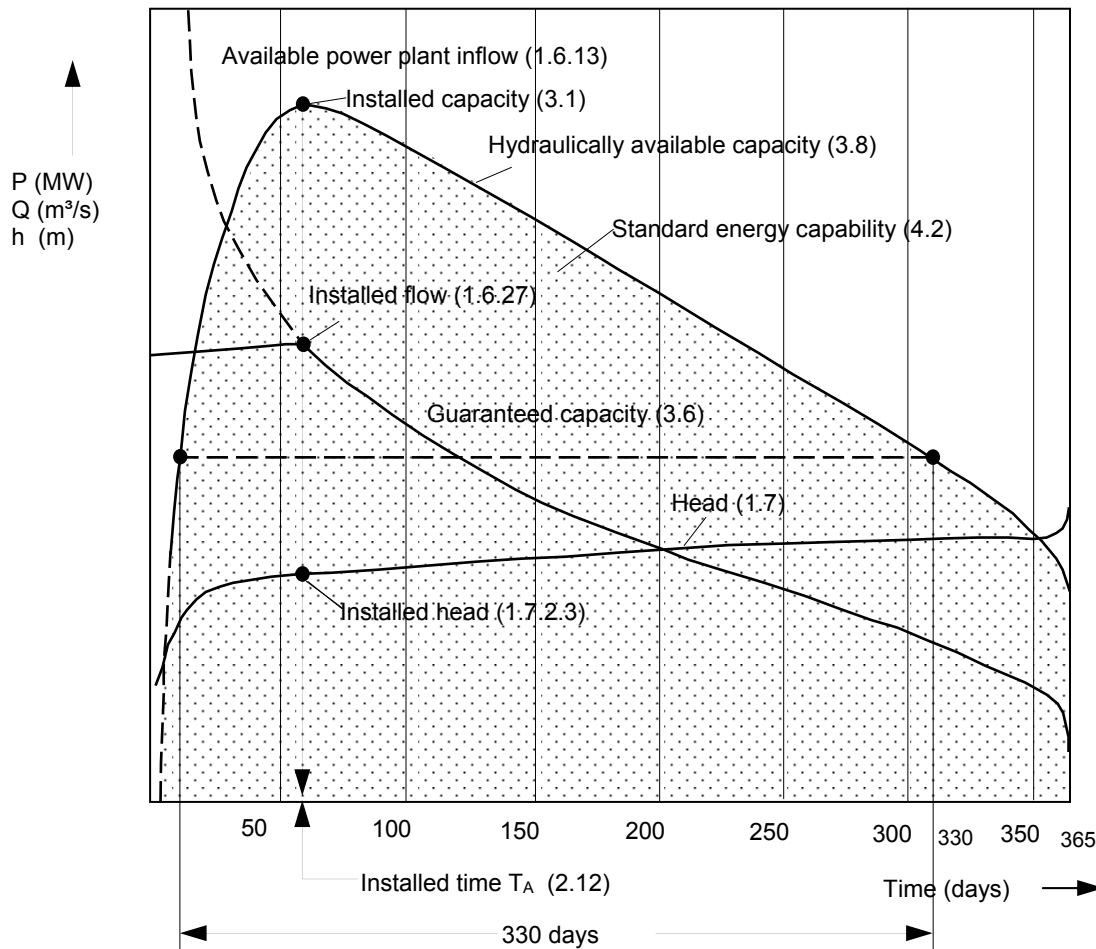


Figure 11: Plant capacity plan for a run-of-river hydropower plant

(Note: The installed flow corresponds to its duration curve; the head and capacity are plotted depending on the available power plant inflow.)

Definition	Symbol	Term definition
4.17 Potential terms		General values for hydropower utilisation (renewable energy) are generally recorded as energy values. Depending on the stated aim, different potential terms are used. The energy values may relate to rivers, river basins, political regions, etc.
4.17.1 Precipitation potential, precipitation area potential		The precipitation potential (precipitation area potential) of a water catchment area or a region is a theoretical potential. It is determined using the precipitation volume for one year or the mean value for a range of years (min. 10 years) and the given topography of this area.
4.17.2 Runoff potential, runoff area potential		Runoff potential (runoff area potential) is a theoretical potential. It is determined using the precipitation potential taking account of evaporation.
4.17.3 Runoff path potential, raw potential		Runoff path potential (raw potential) is a theoretical potential. It is only determined for flowing water on the basis of the stated mean annual volume of water or the mean value for a range of years (min. 10 years) and the existing gradient, without taking account of flow losses and energy conversion efficiency, indirect account is taken of seepage and spring discharges.

Definition	Symbol	Term definition
4.17.4 Technical hydropower potential		<p>Technical hydropower potential is calculated using the runoff path potential, with the assumption of actual locations and taking account of flow losses and energy conversion efficiency.</p> <p>NB:</p> <p>Technical hydropower potential is usually determined using a summation of the generation/generation possibilities (standard energy capability) of all existing plants, plants under construction, the additional generation possibilities of extensions, mothballed plants (where reactivation is possible from a hydraulic perspective) and all other locations deemed practical from a hydraulic/technical perspective (projects, feasibility studies).</p>
4.17.5 Feasible hydropower potential		<p>Feasible hydropower potential is determined using a summation of the standard energy capability of all hydropower plants under construction, as well as all projects judged economically reasonable and ecologically acceptable or necessary at the time of the assessment.</p> <p>NB:</p> <p>In Austria, existing plants are included in feasible hydropower potential. By contrast, in Germany this term only relates to the future.</p>

## 5 Availability and utilisation

Availability is a measure of the ability of a power plant (or part of a plant) to generate power or to perform another operational function, irrespective of its actual use. Availability is primarily used to assess the technical quality of a power plant. Therefore, the scope of assessment only covers the realm of the power plant – usually the high voltage side of the generator transformer.

A more detailed assessment is also possible, which may also include so-called external influences (e. g. grid faults, water shortages, strikes), see Appendix 1.

Utilisation is a measurement of the actual use of a power plant (or part of a plant).

The terms availability and utilisation are quantified by the creation of ratios for time, capacity and energy values. In order to avoid ambiguity, they must always be used with the relevant time, capacity or energy term.

Guideline VGB-RV 808 [13] contains a comprehensive description of how availability and utilisation parameters are determined for thermal power plants. A complete transfer of this methodology to hydropower plants is extremely time-consuming. For example, the different water supplies for run-of-river hydropower plants and the output dependency of storage power plants and pumped storage power plants on the particular head point towards the inappropriateness of connecting energy utilisation and energy availability to the nominal capacity of a plant, in all cases.

For hydropower plants, a distinction is made, for practical purposes, between, on the one hand, availability and utilisation terms for the power plant as a complete unit and, on the other hand, those for individual generator sets or the sum of them. This allows account to be taken of water management requirements for operation of a hydropower plant itself, as well as an independent assessment to be made of one of these conditions for the generator sets.

It should generally be noted that time and energy related availability and utilisation parameters are mean values over certain time frames, but that capacity related availability and utilisation parameters are created as instantaneous values, which must be specifically identified as such.

For pumped storage power plants, the provision of energy utilisation parameters is not usual. For the most part, this is restricted to an analysis of time related values, conducted separately for each generator set.

There follows a list of selected parameters, which take account of the specific conditions for hydropower plants.

Definition	Symbol	Term definition
5.1 Time availability	$k_t$	<p>Time availability is suited to a comparative assessment of generator sets and e. g. parts of a plant, for which energy values are not recorded. It does not take account of capacity levels, but only stoppages.</p> <p>The time availability of a power plant or a part of a plant is the ratio of availability time to nominal time.</p> $k_t = \frac{t_v}{t_N} = \frac{t_B + t_R}{t_N}$ <p>NB:</p> <p>Determining time availability for pumped storage power plants can logically be based on separate time recording of characteristic operation conditions, i.e. turbine operation (generator operation), pumping operation, phase shift operation, hydraulic short circuit and standby (see also chapter 2.4).</p>
5.2 Time unavailability	$k_{tn}$	<p>Time unavailability is the complementary value to time availability.</p> $k_{tn} = 1 - k_t = 1 - \frac{t_v}{t_N}$



Definition	Symbol	Term definition
5.3 Capacity availability	$k_{PH}$	<p>Capacity availability as an instantaneous value is suited to identifying instantaneous availability, e. g. for load distribution.</p> <p>The capacity availability of a power plant, as an instantaneous value, is the ratio of available capacity to hydraulically available capacity.</p> $k_{PH} = \frac{P_v}{P_{VH}}$
5.4 Technical capacity availability	$k_{PT}$	<p>The technical capacity availability of a plant, as an instantaneous value, is the ratio of the technically available capacity to the bottleneck capacity (maximum capacity).</p> $k_{PT} = \frac{P_{vT}}{P_E}$
5.5 Energy availability	$k_W$	<p>Energy availability is generally the comprehensive parameter for overall assessment of the availability of a power plant and allows a long-term quality comparison to be made. It takes account of all reductions in capacity and stoppages.</p> <p>Energy availability is the ratio of available energy within a time frame to energy capability within the same time frame.</p> $k_W = \frac{W_v}{W_H}$

Definition	Symbol	Term definition
5.6 Technical energy availability	$k_{WT}$	<p>Should account be taken of all technical failures, technical energy availability is the ratio of the technically available energy to the technically maximum achievable energy.</p> $k_{WT} = \frac{W_{VT}}{P_E \cdot t_N}$ <p>NB: The creation of energy availability values for pumped storage power plants makes no sense because of the definition of <math>W_H</math>.</p>
5.7 Energy unavailability	$k_{Wn}$	<p>Energy unavailability is the complementary value to the energy availability in question.</p> $k_{Wn} = 1 - k_W$ <p>NB: This value refers indirectly to generation losses, which have occurred due to technical failures of plants affecting the usable water supply. The scale of this value is referred to in the introduction to this chapter.</p>

Definition	Symbol	Term definition
5.8 Time utilisation	$n_t$	Time utilisation is the ratio of operating time to nominal time.  $n_t = \frac{t_B}{t_N}$
5.9 Capacity utilisation	$n_P$	Capacity utilisation, as an instantaneous value, is the ratio of operating capacity to nominal capacity.  $n_P = \frac{P_B}{P_N}$
5.9.1 Capacity utilisation of bottleneck capacity	$n_{PE}$	Capacity utilisation of bottleneck capacity (maximum capacity) is the ratio of operating capacity to bottleneck capacity.  $n_{PE} = \frac{P_B}{P_E}$
5.9.2 Capacity utilisation of mean capacity	$n_{PH}$	Capacity utilisation of mean capacity $P_{mH}$ (see chapter 3.10) is the ratio of operating capacity to mean capacity.  $n_{PH} = \frac{P_B}{P_{mH}}$

Definition	Symbol	Term definition
5.10 Utilisation	$n_w$	<p>Utilisation is a measure of the energy, which a plant actually generates.</p> <p>NB: The key indicators for pumped storage power plants may be determined separately for turbine and pumping operation, however, determining utilisation for pumped storage power plants is not usual.</p>
5.10.1 Energy utilisation	$n_{we}$	<p>Energy utilisation is the ratio of generation to energy capability <math>n_{we} = \frac{W_B}{W_H}</math>, or is simplified for a constant mean head</p> $n_{we} = \sum_{i=1}^5 \frac{(Q_{Ni} - Q_{BVi})}{Q_{Ni}}$
5.10.2 Standard utilisation	$n_{wr}$	<p>Standard utilisation is the ratio of generation to standard energy capability</p> $n_{wr} = \frac{W_B}{W_{HR}}$
5.10.3 Energy utilisation	$n_w$	<p>Energy utilisation is the ratio of generation to the theoretical maximum possible energy from bottleneck capacity or installed capacity, see VGB-RV 808 [13].</p> $n_w = \frac{W_B}{P_E \cdot t_N}$

Definition	Symbol	Term definition
5.11 Time availability of a machine (%)	$k_t$	<p>Time availability is the ratio of availability time to nominal time</p> $k_t = \frac{t_v}{t_N}$ <p>Ratio of the sum of operating time <math>t_B</math> (*) and standby time <math>t_R</math> (both result in availability time <math>t</math>) to the nominal time <math>t_N</math> for a machine for a reporting year (calendar time).</p> $k_t = \frac{t_B + t_R}{t_N}$ <p>(*): <math>t_B = t_{TU} + t_{PU} + t_{PH} + t_{HY}</math></p> <p><math>t_{TU}</math> = operating time for turbine operation  <math>t_{PU}</math> = operating time for pumping operation  <math>t_{PH}</math> = operating time for phase shift operation  <math>t_{HY}</math> = operating time for hydraulic short circuit</p>
5.12 Time availability of a power plant (%)	$k_t$	<p>The time availability of a power plant is the ratio of the time availability of the individual machine sets multiplied by the nominal capacity of the machine(s) to the nominal capacity of the entire power plant <math>P_N</math>.</p> <p>or the ratio of the sum of the operating time <math>t_B</math> and the standby time <math>t_R</math> to the nominal time <math>t_N</math> for all the machine sets for a reporting year.</p> $k_t = \frac{\sum t_B + t_R}{\sum t_N}$

Definition	Symbol	Term definition
5.13 Capacity availability	k <sub>PH</sub>	Capacity availability is the ratio of available capacity to nominal capacity.  $k_{PH} = \frac{P_v}{P_N}$

## Appendix 1      External influences

External influence<sup>4</sup> external influences are all external events, which affect a power plant/machine set, thereby influencing the provision of capacity/availability. The plant operator has no control over the events (e. g. climate, restrictions/requirements).

### Capacity restrictions resulting from external influences

Restrictions on the performance of a plant as the result of external influences, over which operational management have no or very little control, do not reduce availability. Capacity restrictions resulting from external influences are defined as available unproducible capacity, where the cause of the loss of capacity is the result of the events listed below or similar events and these do not involve any technical damage or disruption (regardless of whether they are postponable or not postponable) within the plant.

Should an external influence cause technical damage or disruption within the plant, for which the plant is designed, this is an unavailability.

- Climate
- Water quality (e. g. algae, waterweed)
  - Shortage of water as the result of e. g. ice, ice floes, screenings, floating debris, high/low water, drought, a reduction in the full reservoir level/operation because of high wind speeds
  - Capacity/operational restrictions caused by exceptional environmental influences e. g. storms, avalanches, rock falls, rock stabilisation work

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<sup>4</sup> External influence is defined in VGB-RV 808 [13]. The excerpt reproduced herein is specific to hydropower.

Grid restrictions	<p>Isolation of the plant from the grid takes place on the generator transformer's high voltage terminals.</p> <p>All events, which result in impairment of the discharge of power to lines, transfer points, etc., must be classified as external influences:</p> <ul style="list-style-type: none"><li>– Measures, which do not permit the transmission of power outside the plant operator's area of responsibility (e. g. maintenance work/faults within substations or on transmission lines and transmission capacities that are too low)</li><li>– Measures relating to the safety/security or reliability of the electricity supply system, which is accessed by the grid operator</li><li>– Redispatch TSO (Intraday change to deployment by the grid operator)</li><li>– A protective trip within the transmission grid e. g. as the result of a lightning strike</li></ul>
Shortage of personnel	<p>A lack of operational readiness as the result of a strike, pandemic, siege, occupation</p>
Other	<ul style="list-style-type: none"><li>– Terrorist attack, criminal investigation, ship or aircraft accident, earthquake, force majeure</li><li>– Open day/public relations exercise</li><li>– additional official requirements for existing operating licences e. g. increased (unauthorised) noise levels</li><li>– Restrictions imposed by water legislation/water resources management</li><li>– Rescue/salvage operations</li><li>– Films of oil caused externally (water downstream or upstream)</li></ul>



### Examples of external influences for hydropower plants

Conservation of the plant, stoppages in relation to conservation measures are also deemed to be external influences, where the plant is otherwise entirely technically available.

Admittedly, availability statistics may be distorted by the inclusion of conserved plants (100 % available in terms of external influences) if these plants are not in operation for a lengthy period because of conservation. For statistical evaluation purposes, account should only be taken of conserved plants with a reduced nominal time. Nominal time begins with the first availability notification for a plant following conservation measures and, ends, possibly early, when the plant is (again) conserved.

**List of abbreviations**

BDEW	Bundesverband der Energie- and Wasserwirtschaft ( <i>Federal Association of the Energy and Water Industry</i> )
BGW	Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. ( <i>Federal Association of the Gas and Water Industry</i> )
CO <sub>2</sub>	Carbon dioxide
DIN	Deutsches Institut für Normung ( <i>German Institute for Standardisation</i> )
ESHA	The European Small Hydropower Association
IEC	International Electrotechnical Commission
ISO	Internationale Organisation für Normung ( <i>International Organization for Standardization</i> )
MW	Megawatt
ÖNORM	Österreichische Norm ( <i>Austrian Standard</i> )
VDEW	Verband der Elektrizitätswirtschaft e. V. ( <i>Federation of the Electricity Industry</i> )
VGB	VGB PowerTech e. V.
TSO	Transmission System Operators

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