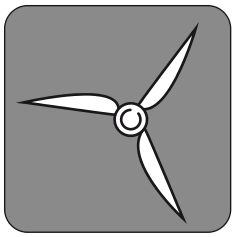
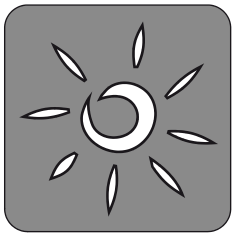
Technical Guidelines

for Power Generating Units, Systems and Storage Systems as well as for their Components





PART 8 (TG 8)

Certification of the Electrical Characteristics
of Power Generating Units, Systems and Storage Systems as well as their Components on the Grid

Revision 09
Dated 01/02/2019

Published by:
FGW e.V.
Fördergesellschaft Windenergie und andere Dezentrale Energien

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In the interest of easier legibility, a gender-neutral differentiation is not used here. Any gender-specific terminology always refers to both genders.

The following parts of the FGW Technical Guidelines are available:

Part 1. Determination of Noise Emission Values

Part 2. Determination of Power Curves and Standardised Energy Yields

Part 3. Determination of the Electrical Characteristics of Power Generating Units and Systems in Medium-, High- and Extra-High-Voltage Grids

Part 4. Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems

Part 5. Determination and Application of Reference Yield

Part 6. Determination of Wind Potential and Energy Yields

Part 7. Operation and Maintenance of Power Plants for Renewable Energy

> **Category A:** Miscellaneous Section Definition of terms, normative references, basic process descriptions and system aspects
>
> **Category A1:** Plant Responsibility
>
> **Category B3:** Specialist Application Notes for Monitoring and Testing Foundations and Supporting Structures for Wind Turbines
>
> **Category D2:** State-Event-Cause Code for Power Generating Units (Zustands-Ereignis-Ursachen-Schlüssel, ZEUS)
>
> **Category D3:** Global Service Protocol (GSP)
>
> **Category D3 – Attachment A:** XML Schema Documentation

Part 8. Certification of the Electrical Characteristics of Power Generating Units, Systems and Storage Systems as well as for their Components on the Grid

Part 9. Determination of High Frequency Emissions from Renewable Power Generating Units

Part 10. Determining the Site Quality after Commissioning

Foreword

Work of the FGW on compiling the Technical Guidelines began in 1992 with the aim of presenting measuring procedures in order to gather reliable and comparable data on wind turbines (WT) in line with the state of the art. The measurements from the three areas of WT power characteristic curve, WT noise emissions and the electrical characteristics, originally only developed for WT are intended to serve as a basis for assessment, e.g. in the event of questions concerning approval, for the evaluation of grid connection possibilities or for reliable yield calculations.

In the meantime, the individual Technical Guidelines and the associated test reports compiled by independent test laboratories are widely recognised in their respective fields. Their uses include instructions for measurement, the preparation of expert assessments, as a contractual basis in orders and purchase contracts, for certification contracts, as well as for approvals.

Regarding the electrical characteristics, for the provision of evidence for grid connection conditions, in the past professional bodies such as VDN, VDEW and BDEW relied on the FGW test regulations, or the FGW test regulations were adapted to these requirements. This includes for example the VDN guidance (high-voltage and extra-high voltage) of 2004, the TransmissionCode of 2007 (high-voltage and extra-high voltage) and the BDEW Guideline (Generating plants connected to the medium-voltage network) of 2008. The further development of the grid connection conditions was transferred to the Network Technology/Network Operation Forum (FNN) in 2008 which is part of the VDE Association for Electrical, Electronic & Information Technologies.

A compliant certification programme was developed from the BDEW Guideline for a certification obligation, and first published in 2009 as TG 8. Along with additions to the BDEW Guideline, the grid connection regulations became binding for other decentralised feed-in technologies in addition to WT, and the FGW set of rules was extended accordingly. The FGW set of rules was also limited to the provision of evidence.

Today, under Section 19 of the German Energy Act (Energiewirtschaftsgesetz, EnWG) all “operators of energy supply networks” must prepare general minimum technical requirements to determine technical connection conditions (TCC) taking into account the specifications of Commission Regulation (EU) 2016/631. In addition, with the “Ordinance on the verification of electrical properties of energy plants” (NELEV) the provision of evidence for the grid connection of power generating systems and for storage systems for electrical energy is regulated, among other things in order to implement Commission Regulation (EU) 2016/631 establishing a network code on requirements for grid connection of generators. In this, the compliance with the generally recognised state of the art is deemed to have been achieved if the technical rules of the association named in Article 49 (2) sentence 1 number 1 of the EnWG have been complied with. The Technical Connection Rules for the Planning, Installation, Operation and Modification of Power Generating Systems and Storage Systems published also by the Network Technology/Network Operation Forum at the VDE (VDE/FNN) mentioned above are such rules. For the connection and operation and/or parallel operation on a medium-, high- and extra-high voltage grid of a grid operator, these have been published as follows:

- “Technical Connection Rules for Medium Voltage (TCR Medium-Voltage)” - VDE-AR-N 4110 [1]
- “Technical Connection Rules for High Voltage (TCR High-Voltage-)” - VDE-AR-N 4120 [2]
- “Technical Connection Rules for Extra High-Voltage (TCR Extra High-Voltage)” - VDE-AR-N 4130 [3](*note: the certification provision will follow in a later revision*)

E/VDE-AR-N 4100 “Technical Connection Rules for Low-Voltage” “ [4] as well as VDE-AR-N 4105 “Power Generating Plants Connected to the Low-voltage Grid - technical minimum requirements for the connection and parallel operation of power generating plants on the low-voltage grid“ [5] have contained certification obligations from the moment they took effect (unit certificates). These can fall within the scope of these Technical Guidelines through an informative procedure updated for this purpose.

Relevant GCR can be easily formulated in separate annexes under the present structure of TR 8 and published at a later date.

Within the framework of the European Network Code “Requirements for Generators” (NC-RfG) certification procedures for power generating units, systems and storage systems performed by certification bodies accredited according to DIN EN ISO/IEC 17065 are possible in order prove that the requirements for grid connection are met. These certification procedures shall be implemented according to this certification regulation.

This revision of Technical Guidelines FGW TG 8 was agreed as part of the work carried out on the FGW Guidelines and a public consultation in German and English involving representatives of all relevant stakeholders, which included a large number of foreign corporations. These Guidelines will subsequently undergo a notification procedure in accordance with the requirements of Directive (EU) 2015/1535 and the German Federal Ministry for Economic Affairs. Substantive amendments to this document based on the procedure and requirements set forth in Directive (EU) 2015/1535 cannot be ruled out and are therefore expressly reserved until the conclusion of the procedure.

Compilation of these Guidelines

The contents of the Technical Guidelines are the responsibility of the respective technical committees and working groups.

These Guidelines provide a framework for the corresponding certification procedures and specifications which has been agreed jointly by manufacturers, system and grid operators, test laboratories and certification bodies, system planners, research institutions, installers, and FGW e.V.

Contents

Abbreviations used

AC	Alternating Current
AVR	Automatic voltage regulator
BDEW	Bundesverband der Energie- und Wasserwirtschaft e.V. (German Association for Energy and Water Supply)
CGP	Cogeneration plant
BMS	Battery management system
BNetzA	Federal Network Agency
CISPR	Comité International Spécial Des Perturbations Radioélectriques
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
SPS	Steam power station
ST	Steam turbine
EA	European Cooperation for Accreditation
AS	Auxiliary services
EEG	German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz) [6]
EMC	Electromagnetic compatibility
EN	European norm/standard
PGS	Power generating systems
PGU	Power generating units: individual units for generating electrical energy
GSC	Generator sign convention
FACTS	Flexible AC Transmission System
FGW	FGW e.V. - Fördergesellschaft Windenergie und andere Dezentrale Energien
FPC	Frequency-led power controller
FNN	Network Technology/Network Operation Forum at the VDE
FRT	Fault ride-through
GenSet	Combination of generator and prime mover, used for CEs
CCPP	Combined cycle power plant
GT	Gas turbine
EHV grid	Extra-high voltage grid
Com	Commissioning
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardization
PC	Power controller
MV	Medium voltage
MV grid	Medium-voltage grid

PCC	Point of common coupling
GCR	Grid connection regulations
GO	Grid operator
NELEV	German regulation on the verification of electrical properties of energy plants (Elektrotechnische-Eigenschaften-Nachweis-Verordnung)
LV	Low voltage
GCP	Grid Connection Point
HC	Harmonic current
OVRT	Over voltage ride-through
PSS	Power system stabilizer
PVS	Photovoltaic system
SMT	Standardized Manufacturer Tests
BB	Busbar
STATCOM	Static Synchronous Compensator
PCSR	Primary controller stability reserve
SVC	Static Var Compensator
TCC	Technical Connection Conditions
TCR Low-Voltage	Erzeugungsanlagen am Niederspannungsnetz – Technische Mindestanforderungen für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Niederspannungsnetz (Power Generating Plants Connected to the Low-voltage Grid - technical minimum requirements for the connection and parallel operation of power generating plants on the low-voltage grid) [5]
TCR Medium-Voltage	Technical Connection Rules for Medium Voltage (TCR Medium-Voltage) [1]
TCR High-Voltage	Technical Connection Rules for High Voltage (TCR High-Voltage) [2]
TCR Extra High-Voltage	Technical Connection Rules for Extra High-Voltage (TCR Extra High-Voltage) [3]
THC	Total Harmonic Current Distortion
TG	Technical Guidelines
TG 3	Technical Guidelines 3 by FGW [7]
TG 4	Technical Guidelines 4 by FGW [8]
UEL	Underexcitation limiter
UVRT	Under voltage ride-through
TS	Transformer substation
VDE FNN	Network Technology/Network Operation Forum at the VDE
VDN	Verband der Netzbetreiber e.V. (Association of German Power Transmission System Operators)

CE	Combustion engines
PCC	Connection point
LSC	Load sign convention
WT	Wind turbine
HS	Hydropower plant
WaTu	Water turbine

Symbols and units

Symbol	Meaning	Unit
A	Tangent of the impedance angle of the fault impedance	
a_T	Prime mover medium control cross-section	
b_p	P degree of rotational speed controller	%
$b_{pö}$	Local P degree of rotational speed controller	%
$\cos \varphi$	Cosine of the phase angle between the fundamental components of a phase-to-neutral voltage and a current	
c_D	Damping coefficient	
$F; f$	Frequency	Hz
f_R	Resetting ratio of an undervoltage	
$G(s)$	Transfer function	
H	Energy level/pressure	m
k	Proportionality constant	
$k_{i\,max}$	Switched current factor: ratio of the current I_{max} and the current I_n	
K_L	Power controller amplification	
k_u	Voltage step factor	
M	Moment	Nm
N	Denominator	
I	Current	A
I_1, I_2, I_3	First, second and third phase currents	A
$i_b(t)$	Reactive current history	A
$I_{B\,Set}$	Reactive current setpoint	A
I_{max}	Maximum current	A
I_k	Root mean square of anticipated symmetrical breaking current	A
$\underline{I}_{L1}, \underline{I}_{L2}, \underline{I}_{L3}$	Current in one of the three conductors	A
I_n	Rated current	A
I_m	Current in the positive phase sequence system	A
p, q	Auxiliary variables for calculating the resistance of the fault impedance	Ω
P	Active power	W
$p_{averaging\ period}$	Maximum active power with respect to the rated power	1
$p_{averaging\ period}$	Highest measured PGU active power values	W
P_{AV}	Active power agreed upon by grid operator and system operator	W
$P_{b\,inst}$	Operating, installed active power	W

P_{max}	Maximum active power output	W
P_{inst}	Installed active power	W
P_{rE}	Design active power	W
Q	Fixed reactive power	var
R	Ohmic resistance	Ω
R_a	Real component of grid impedance	Ω
R_F	Real component of fault impedance	Ω
S_{Total}	Total connectable or planned apparent power at the GCP	VA
S_k	Apparent short-circuit power of the grid (at a defined point)	VA
S_{kv}	Apparent short-circuit power of the grid at the connection point	VA
S_n	Rated apparent power	VA
S_{rE}	Design apparent power of a power generating unit	VA
T	Time	s
t_A	Response time of an overvoltage	s
T_A	Turbine set start-up time constant	s
T_{an}	Time between the sudden occurrence of a control deviation and reaching the tolerance band for the first time	s
$T_{ein\Delta x}$	Time between the sudden occurrence of a control deviation and remaining in the tolerance band	s
$T_{d'}$,$T_{q'}$	Transient time constant of d or q axis	S
$T_{d''}$,$T_{q''}$	Subtransient time constant of d or q axis	s
t_R	Resetting time of an overvoltage	s
THC	Total Harmonic Current Distortion	
T_y	Prime mover final controlling element time constant	s
U	Voltage	V
U_1, U_2, U_3	First, second and third phase voltages	V
U_c	Agreed supply voltage	V
u_f	Residual voltage in case of a fault	p.u.
u_k	Relative short-circuit voltage of a transformer.	
$\underline{U}_{LE}$,	Phase-to-ground voltage	V
$\underline{U}_{L1E}$, $\underline{U}_{L2E}$, $\underline{U}_{L3E}$		
$\underline{U}_{LL}$, $\underline{U}_{L1-L2}$,	Phase-to-phase voltage	V
$\underline{U}_{L1-L3}$, $\underline{U}_{L2-L3}$		
U_n	Rated voltage of the PGU as specified by the manufacturer	V
U_{Grid}, U_{Lx}	Grid voltage	V
U_m	Voltage in positive phase sequence system	V

u_R	Controller output signal	
$U_{setpoint}$	Voltage (setpoint) at which the voltage regulator controls regulated transformers under load	V
ν	Ordinal number of a harmonic	1
V	Wind speed measured at hub height	m/s
v_N	Lowest wind speed at which the rated power of the PGU is achieved according to specifications of the manufacturer	m/s
x	State variable	
X_a	Imaginary component of grid impedance	Ω
x_d	Control deviation	
x_d, x_q	Synchronous reactance in the d and q axes	
$x_{d'}$, $x_{q'}$	Transient reactance in the d and q axes	
$x_{d''}$, $x_{q''}$	Subtransient reactance in the d and q axes	
X_F	Imaginary component of fault impedance	Ω
Z	Meter	
$\underline{Z}_a$, $\underline{Z}_b$	Complex equivalent impedance of the grid	Ω
$\underline{Z}_F$	Complex fault impedance	Ω
$\underline{Z}_N$	Grid impedance at the GCP	Ω
$\underline{Z}_T$	Short-circuit impedance in the positive phase sequence system of the upstream transformer	Ω
y_T	Position of control organ for prime mover power take off	
$\Delta\alpha$	Phase step	°
ΔI_b	Change in reactive current	A
Δt_{min}	Time between two switching operations	s
φ	Phase angle between current and voltage	°
λ	Ratio of the value of active power P to apparent power S	1
ψ_F	Impedance angle of the fault impedance	°
ψ_k, Ψ_{kv}	Assumed phase angle of short-circuit impedance at a defined point	°
α	Relative synchronising coefficient	
δ_p	Generator load angle in the dq system (external polar wheel angle)	rad
ε	Fault signal (controller)	
ε	Deviation between the measured and simulated signal	
η	Efficiency	
λ	Inherent value	
σ	Real component of the inherent value	
φ_p	Polar wheel angle in the R-I coordinate system	rad
φ_u	Voltage angle	rad

$\boldsymbol{\omega}$	Angular velocity	rad/s
$\boldsymbol{\theta}$	Mass moment of inertia	kgm

Indices

D	Damping
D	Steam
HP	High pressure
n	Rated value
LP	Low pressure
R	Controller
S	Controlled system
SE	Final controlling equipment
T	Turbine
ä	External
d	Direct axis
e, err	Exciter, excitation
el	Electric
i	Number of PGU within a PGS
i	State variable i
i	Internal
Actual	Actual value
m	Measured
o	Steady state, initial value
q	Quadrature axis
s	Simulated
s	Stator
setpoint	Setpoint value
z	Fault
∞	Steady-state condition

Notation

A	Matrixes
I,i	Absolute values are in upper case. Variables relative to the rated value are written in lower case
I´	Transient values use a prime sign
I´´	Subtransient values use a double prime
∞	Infinity

Terms and definitions

The definitions used in these guidelines do not exactly match with those used in the regulations published by the grid operators. Harmonisation is aimed for.

1-period rms value: Rms value determined over one period. Within these Guidelines the 1-period rms values of the symmetrical components in the positive and negative phase sequence system (see below) are meant, unless stated otherwise.

Accredited certification body: body accredited under the applicable GCR, according to DIN EN ISO/IEC 17065 [9] for the TG 8 certification programme by a national member of a body accredited for the area of grid integration within the framework of the European Cooperation for Accreditation ("EA") established in accordance with Directive (EC) No 765/2008 of the European Parliament and of the Council [10].

Accredited test laboratory: test laboratory accredited under the applicable GCR according to DIN EN ISO/IEC 17065 by a national member of a body accredited for the area of grid integration within the framework of the European Cooperation for Accreditation ("EA") established in accordance with Regulation (EC) No 765/2008 of the European Parliament and of the Council [10].

Actual value: Value of a variable at a given time. [11]

Agreed connected active power P_{AV}: Active power agreed upon by grid operator and system operator. (Definition in accordance with TCR Medium-Voltage and TCR High-Voltage).

Apparent short-circuit power S_k: Assumed apparent short-circuit power of the grid at a defined point (usually the PCC).

Automatic reconnection AR: Reconnection by an automatic device controlling a circuit breaker associated with a faulty section of the grid, in anticipation that the cause of the fault will no longer exist at the time of reconnection (TCR Medium-Voltage and TCR High-Voltage).

Basic planning data: PGS data based on a fundamental design but without type-specific information in accordance with the grid operator's requirements.

Certificate holder for PGS: The certificate holder is generally the operator or the contractual partner of the grid operator at the PCC.

Certificate holder for PGU: The certificate holder is generally the manufacturer or the contractual partner of the grid operator at the PCC.

Circuit breaker: Switching device (consisting of one or more elements) for galvanic and all-pole interruption of the main current path.

Client for PGS certificates: The client for the system certificate can be the operator, the future certificate holder or a third party.

Client for PGU certificates: The client for the unit certificate can be the PGU manufacturer, the future certificate holder or a third party.

Combustion engine (CE): Electricity generating unit (Genset): A combination of generator and CE for generating electrical energy, among other things. The components of the PGU are specified in the unit certificate. The CE requirements also apply accordingly for the power generating units with gas turbines and steam turbines.

Comparing element: Functional unit with two inputs and one output, the output variable of which is the difference between the two input variables. [11]

Component: Power generating system equipment, which has an influence on the electrical response at the point of common coupling (PCC).

Component certificate: Certificate issued by certification bodies accredited for this purpose, presenting the behaviour of active equipment of a power generating system which have an influence on the electrical response at the point of common coupling.

NOTE 1: Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators uses the term "equipment certificate" for the component certificate.
NOTE 2: A component certificate is a product certificate equiring surveillance for all equipment rin accordance with DIN EN ISO/IEC 17067 (TCR Medium-Voltage).

Conformity verification: Conformity verification is a term used in order to describe the fact that all or some requirements from guidelines such as the GCR are fulfilled.

Connection point: The nearest point to the connecting system in the national grid where additional subscribers are connected or can be connected. It is generally the same as the point of common coupling. The connection point is used in assessing system perturbations. (Definition in accordance with BDEW MV guideline).

Connection situation type A: In the immediate electrical vicinity there are one or more additional PGS with a total of at least half the installed power of the PGU or PGS to be investigated.

Connection situation type B: In the immediate electrical vicinity there are no additional PGS with a total of at least half the installed power of the PGU or PGS to be investigated.

Control device: Entirety of functional units aimed at influencing the controlled system corresponding to the closed or open loop control task. [11]

Control difference: Difference between the reference variable and the feedback variable. [11]

Controlled system: Functional unit influenced by the closed or open loop control task. [11]

Controlled variable: Controlled system output variable, on which one or more manipulated variables act. [11]

Controlled variable overshoot: Overshoot Δx_{max} is the maximum temporary control deviation relative to the rated value when the controlled variable is transitioning from a steady-state condition to a new steady-state condition, see TCC High-Voltage.

Controller: Functional unit, which forms the controller output variable from the control difference input variable supplied by the comparing element such that the controlled variable in the control circuit – even given disturbance variables – follows the reference variable as quickly and precisely as necessary. [11]

Controller core: Here, the setpoint and actual values are compared and the manipulated variables computed.

Controller setpoint voltage $U_{setpoint}$: Voltage (setpoint) at which the voltage regulator controls regulated transformers under load.

Control system: System consisting of the controlled system, its control device, the measuring element and the associated converters. [11]

Conventions

The information given in these Guidelines preferably corresponds to the load sign convention. Reports and certificates compliant with these Guidelines must be based on the load sign convention.

Declaration of conformity: Confirmation and verification that the erection and commissioning of the whole power generating system was in compliance with the requirements of the GCR and the specifications in the system certificate.

NOTE 1: The process of system certification is completed upon issuance of the declaration of conformity.

Design active power P_{rE}: Active power of the PGU at reference conditions as specified by the manufacturer.

Design apparent power of a power generating unit S_{rE}: Apparent power for which the components of the power generating unit are designed.

Detailed planning data: Data on the individual, manufacturer- and type-specific power generating units or the power generating system with a high degree of detail.

Displacement factor cos φ: The displacement factor is the cosine of the phase angle between the fundamental frequencies of a phase-to-ground voltage and a current (TCR Medium-Voltage and TCR High-Voltage).

Disturbance variable: Undesirable, independent and generally unpredictable input variable, acting on the system from the outside. [11]

Equipment: Active and passive components required for a PGS. This includes generating units, PGS controller, storage and other components. The PGU, the PGS controller, FACTS, grid protection devices and storage systems are regarded as active components which may be

Existing systems: Existing systems represent an existing PGS, regardless of whether this has been certified or not.

certified under these Guidelines. Passive components, such as cables, switching device, reactive power compensation systems (capacitors and solenoids), etc., do not need a separate certificate but they have to be taken into account at the level of the PGS.

Extended declaration of conformity: Confirmation and verification that the erection and commissioning of the whole power generating system was in compliance with the requirements of the GCR and the specifications in the system certificate C.

The extended declaration of conformity contains an assessment of the measurements performed as well as the model validation of the simulation model of the power generating unit, among other things.

FACTS: FACTS elements (Flexible AC Transmission Systems) can be divided into two categories: parallel and series FACTS. Parallel FACTS are used to control voltage, reactive power and power factor, as well as to compensate for voltage drops and voltage peaks (flicker). This category includes STATCOMs for example. The series FACTS allow control of the active and reactive energy flows by changing the line impedance or by inserting a series voltage. There are also FACTS that represent a combination of series and parallel types.

Fault clearance time: Release and operating time of the circuit breaker.

Feedback variable: Variable, which models the controlled variable and which is fed back to the comparing element. [11]

Final conformity study: Study to verify the characteristics of the power generating units or PGS compliant with the applicable connection regulations and based on the "Validated simulation model".

Final controlling element/final controlling element in the control circuit: Functional unit forming part of the plant controlled system and positioned at the plant controlled system input, influenced by the manipulated variable and influencing the mass flow or energy flow. [11]
NOTE 1: An additional positioner is occasionally used for mechanically actuated final controlling elements.
NOTE 2: The final controlling equipment's output variable is generally not non-reacting. The interface between the actuator and the final controlling element must be selected such that the final controlling element does not influence the manipulated variable.

Final simulation model: Power generating unit and power generating system simulation model based on the data verified by measurements on the ready-to-operate system. The "Final simulation model" is thus validated.

Grid connection point (GCP): The nearest point to the power generating system in the national grid where additional subscribers are connected or can be connected.

Grid connection regulations (GCR): Document containing the technical requirements concerning grid connection (application rules) and inasfar as available the legal requirements of the respective country. (GridCode)

Grid impedance phase angle ψ_{xx}: Arctangent of the ratio of reactance X_k to resistance Rk of the short-circuit impedance at the grid point considered, $\psi_k = \arctan (X_k/R_k)$ (TCR Medium-Voltage and TCR High-Voltage).

Grid operator questionnaire: Requirements concerning the exchange of information and for use during system certification. Insofar as no requirements are stipulated the requirements of the GCR shall apply accordingly.

Half-wave rms value: Rms value determined over half a period.

Index ν: Ordinal number of a harmonic: Integer ratio of the harmonic frequency to the fundamental frequency.

Initial symmetrical short-circuit AC current I_k": Rms value of the share of alternating current in a short circuit current anticipated at the point of short-circuit occurrence. [12], [1] and [2]

Installed active power P_{inst}: Total of design active power of all PGUs in a PGS.

Interface: Boundary between two functional units, which is deemed suitable by way of functional features, signal parameters or other features. [11]
NOTE: This term incorporates the interface description for the connection between two devices with different functions.

k-factor: See proportionality constant

Manipulated variable: Control device output variable, which is also the controlled system input variable. [11]

Manufacturer's declaration: A manufacturer's declaration has to be signed and it has to be justified in such a way that the person providing the evidence is able to comprehensible verify adherence of the requirements as confirmed with regard to the technical aspects. This means that there has to be:

- a clear reference to the company making the declaration;

- stamp and signature of an authorised and/or responsible person;
- clear reference to the product certified (clear identification as in the planned certificate);
- comprehensible technical justification/evidence about how compliance with the requirements is ensured (reference to additional technical documents is possible).

Maximum active power peak $P_{\text{averaging period}}$: Highest measured PGU active power values. There are several values for $P_{\text{averaging period}}$ and $p_{\text{averaging period}}$, which are determined for various averaging periods (10 grid periods, 1 minute and 10 minutes). The relative effective power maxima are designated as $p_{0.2}$, p_{60} and p_{600}, corresponding to the mean durations of 10 grid periods, 1 minute and 10 minutes.

Maximum switched current factor k_{imax}: The ratio of current I_{max} to current I_n:

$$k_{\text{i max}} = \frac{I_{max}}{I_{\text{n}}} \qquad \textbf{(0-1)}$$

I_{max}: Root mean square over a period = 20 ms rms (defined as peak value)

Measuring element: Functional unit, which forms the feedback variable at the output from the controlled variable at the input. [11]

Mixed farms: Mixed farms are power generating systems in which predominantly electrical energy is generated and new power generating units requiring certification are added to an existing system (e.g. wind, solar farms, CHP, existing systems (generator)). The power generating units in a mixed farm must be differentiated according to the applicable commissioning requirements of the respective PGU.

Mixed grids: Mixed grids are grids representing a combination of consumption systems and power generating systems and are generally designed to use electrical energy. The power generating systems can represent mixed farms.

Models: Models of the individual PGUs should be taken into consideration for unit certification. The following two types are differentiated:
An open model must allow the certification body to follow the logical links between control circuits in the relevant system controls.
The open model can describe individual aspects of PGU behaviour in a simplified manner, without considering transient changes to the overall system. In particular, the open model need not be executable, i.e. need not be able to run on a computer.
b) A computer-based model, on the other hand, must be capable of describing the transient response of the PGU in terms of individual electrical characteristics as a simulation in a commercial grid analysis application. In particular, the model needs to be suitable to represent the measuring situation of the type testing in accordance with TG 3, in order to facilitate verification of the model simulation based on the measurement results. The model may be encapsulated as a black box model.
The PGU model can be subdivided into several models specifically for verifying particular characteristics. To simplify matters, these Guidelines refer to the PGU model in general only.

Negative phase sequence system: Symmetrical rotating system of three components of the fundamental frequency with reversed phase sequence.

Old power generating units (PGU_{Old}): Power generating units in accordance with Section 5 of SDLWindV commissioned before 1 January 2009.

Output variable: Recordable variable generated by a system, which is only influenced by this and by its input variables via the system. [11]

PGS controller: The term “PGS controller” refers to a technical device setting or controlling the active power feed-in and reactive power at the control point of the PGS based

on static or variable setpoint specifications of the grid operator. Active and reactive power can be set and/or controlled using a controller with own measurement (Fig. 0-1) or a superimposed controller including secondary control circuits (Fig. 0-2:). Typically, the PGS controller consists of an active power controller valve body and a reactive power controller valve body. Generally, the PGS controller not only contributes to dynamic grid support but also enables the provision of other system services (e.g. voltage stability).

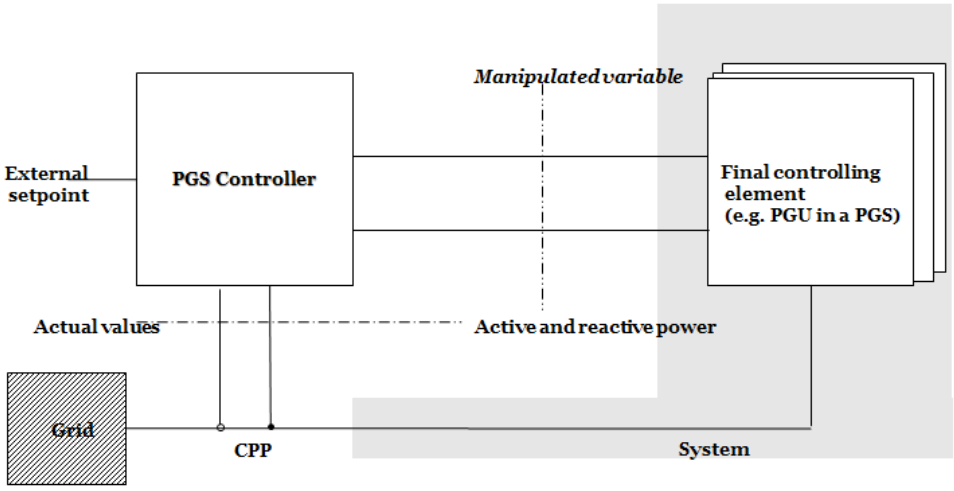

Fig. 0-1: Example of a controlled system without secondary control circuits in a PGS controller, consisting of PGU final controlling elements and the PGS grid

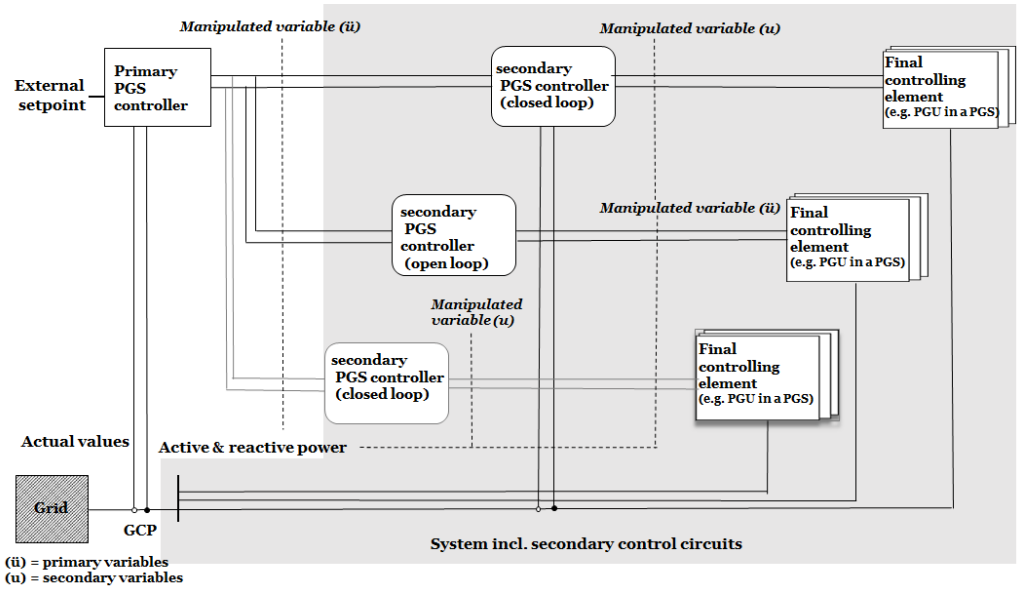

Fig. 0-2: Example of a controlled system including secondary control circuits

NOTE 1: A PGS controller may also control several secondary PGS controllers.

NOTE 2: Terms, such as "power plant controller" and "central control" are also used for "PGS controller" (TCR Medium-Voltage and TCR High-Voltage).

PGS control system: Is a control system that adopts the grid operator's setpoint values and in part the specifications and transmits them to the PGU. The setpoint values are configured at the GCP for P and Q via the PGU or components that are installed in the PGS.

Photovoltaic system (PVS): PGU with inverter, where the solar radiation is directly converted to electrical energy by the PV modules. The PVS consists of modules, which provide a DC voltage as a function of solar radiation, and the balance of system (BoS) components, including the inverter. Feed-in is always via an inverter. The inverter defines the electrical characteristics of the PVS and is decisive for measurements.

Plausibility check: Verification of model simulations for electrical behaviour corresponding to that of a real product for different setpoint value specifications or grid conditions.

Point of common coupling (PCC): The point at which the connecting system is connected to the national grid.

NOTE 1: The point of common coupling is of particular significance in grid planning. It is not necessary in all cases to make a distinction between the point of common coupling and the grid connection point.
NOTE 2: The point between the property of the grid operator and the connected party is agreed by the two parties regardless of the point of common coupling (TCR Medium-Voltage and TCR High-Voltage).

Positive phase sequence system: Symmetrical rotating system of three components with normal phase sequence.

Power circuit breaker operating time: Reaction time of circuit breaker.

Power factor λ: The ratio of the value of active power P to apparent power S. The power factor refers to the root mean square values of the total variable, i.e. the sum of its fundamental frequency and all harmonics, similar to P and S respectively.

Power generating system Type 1: Power generating system being exclusively composed of Type 1 power generating units.

NOTE 1: If a Type 1 power generating unit uses the same operating equipment as other Type 1 power generating units (e.g. a common transformer or common central controller), and these power generating units are therefore not operated independently, these power generating units form a power generating system Type 1 (TCR Medium-Voltage and TCR High-Voltage).

Power generating system Type 2: Power generating system which does not meet the conditions for Type 1 (TCR Medium-Voltage and TCR High-Voltage).

Power generating unit Type 1: Power generating unit that only has one synchronous generator for the generation of electrical power which is directly (only via a machine transformer) coupled to the grid (TCR Medium-Voltage and TCR High-Voltage.

Power generating unit Type 2: Power generating unit not fulfilling the conditions of Type 1 (TCR Medium-Voltage and TCR High-Voltage).

Preliminary conformity study: Study to verify the characteristics of the power generating units or power generating system compliant with the applicable connection regulations and based on the “Preliminary simulation model”.

Preliminary simulation model: Simulation model of the power generating unit and the power generating system based on the detailed planning data, but without validation of the simulation model based on measurements on the ready-to-operate system.

Product certificate: A product certificate is the provision of the confirmation, by an independent third party, that adherence to specified requirements has been verified. Product certification is performed by product certification bodies, which comply with ISO/IEC 17065

[9]. Specified product requirements are generally included in standards or other normative documents.

Proportionality constant (k-factor): Contribution of the PGU or PGS to voltage support in accordance with the GCR applied in the individual case.

Note: The definition of the k-factor may vary depending on the respective GCR.

Protective device time to operate: Time passing between excitation and generation of a tripping command.

Prototypes: A prototype is the first PGU of a type displaying fundamental technical advances or innovations, and all additional power generating units of this type put into operation within two years of commissioning the first PGU of this type. The prototype rule can be applied accordingly in case of components of a PGS requiring a component certificate.

Note: This definition meets the definition of the term according to the GCR VDE-AR 4110, -20 and -30. There is no connection with the term “Pilot wind energy installation” in the EEG.

Substantial technical developments and innovations are usually present if components or software versions are modified such that the electrical behaviour of the PGU on the grid changes significantly and a unit certification of this new type becomes necessary.

Rated voltage U_n: Voltage identifying a grid or system. In case of power generating units the rated voltage is specified by the manufacturer as phase-to-phase voltage.

Rated current I_n: Current value determined from the rated apparent power S_n and the rated voltage U_n:

$$I_\mathrm{n} = \frac{S_n}{\sqrt{3} \cdot U_\mathrm{n}} \qquad \textbf{(0-2)}$$

Reference variable: Control device's comparing element input variable derived from the target variable and defining the controlled variable setpoint. [11]

Relative active power maxima $p_{averaging\ period}$: Maximum active power with respect to the rated power.

Relative short-circuit voltage u_k: Relative short-circuit voltage of a transformer.

Rise time T_{an}: Time between the sudden change of a setpoint and the time the target value has reached 90% of the change in the setpoint for the first time.

NOTE 1: The rise time is a characteristic parameter of the step response. It also includes the time needed to recognise the control deviation ([1] [2].

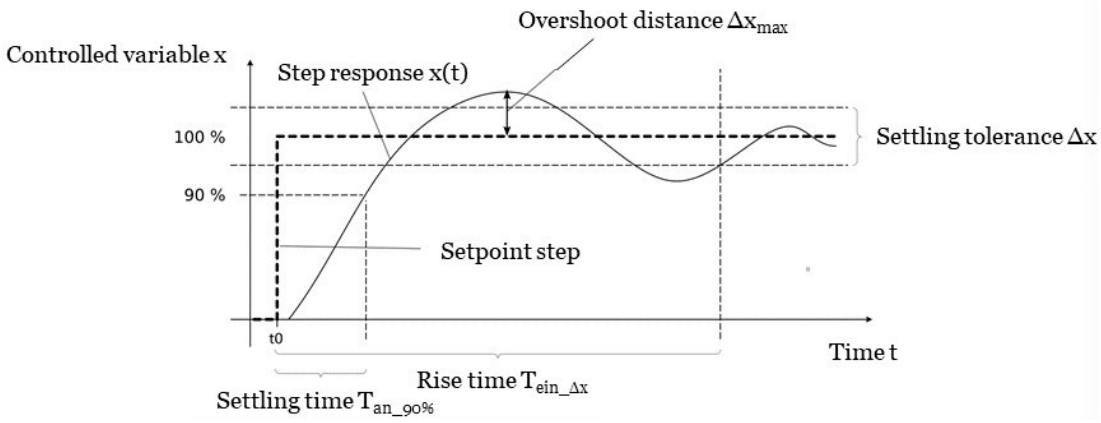

Fig. 0-3: Rise time and settling time after a setpoint step

Settling time ($T_{ein\Delta x}$): Time between the sudden occurrence of a control deviation until the time at which the transient phenomena have dissipated to the extent that the controlled variable (such as the reactive current I_B) is within the tolerance band around the steady-state final value and (Fig.0-3) and remains there (TCR Medium-Voltage and TCR High-Voltage).

Setting value: A parameter entered on the device.

Short-circuit power S_{kV}: Decisive minimum grid short-circuit power for the evaluation of system perturbations at the grid connection point as well as dynamic grid support at the point of common coupling.

NOTE 1: For the medium- and high-voltage, the minimum expected short-circuit power in normal operation, which is taken as a basis from the overlaid grid (generally the overlaid medium- or high-voltage grid) without taking all power generating systems in the medium- or high-voltage grid into consideration. For short-circuit calculations according to DIN EN 60909-0 (VDE 0102) [13]this equates to the short-circuit power Sk"min, determined from the smallest three-pole starting short-circuit AC current Ik"min, with the resistances of wires and cables being considered at 20 °C (see TCR Medium-Voltage and TCR High-Voltage).

STATCOM (Static Synchronous Compensator): The STATCOM is a self-commutated current rectifier, which generates a three-phase voltage system with a variable voltage amplitude, the currents of which are phase displaced by 90° compared to the corresponding grid voltages. Reactive power can be exchanged between the STATCOM and the grid.

Static Var Compensators (SVC): A Static Var Compensator (SVC) is a system for compensating reactive power in electrical power transmission grids.

System certificate: Certificate issued by accredited certification bodies, which confirms the conformity of a planned power generating system with the technical requirements of grid connection regulations or any other grid connection-related technical specifications.

NOTE 1: Commission Regulation (EU) 2016/631 [14] of 14 April 2016 establishing a network code on requirements for grid connection of generators [14] uses the term "power-generating module document" for the system certificate.
NOTE 2: Unit certificates (or unit proof) [only for TCR Medium-Voltage], and component certificates (or component proof [only for TCR Medium-Voltage] as well as grid calculations and simulations are the basis for the system certificate.
NOTE 3: Unlike the unit certificate and component certificate, the system certificate is no product certificate in accordance with DIN EN ISO/IEC 17067 requiring surveillance but a certified grid connection planning. Notes in accordance with TCR Medium-Voltage and TCR High-Voltage.

System certificate A: Standard system certificate

System certificate B: Simplified system certificate for power generating systems

System certificate C: System certificate granted in the individual verification procedure

Technical Connection Conditions (TCC): Connection conditions of the German grid operators under the EnWG.

Technical Connection Rules (TCR): Designation of the German GCR by VDE/FNN, such as TCR Medium-Voltage (VDE-AR-N 4110).

Test documents: Generic term for all documents submitted in the course of the certification procedure (e.g. manufacturer's declarations, measuring reports, specifications, etc.) which are used on order to assess conformity of the equipment.

Total connectable apparent power S_{Total}: Total connectable or planned apparent power at the GCP.

Total Harmonic Current Distortion (THC): THC is defined as:

$$\mathrm{THC} = \frac{\sqrt{\sum_{v=2}^{50} I_v^2}}{I_\mathrm{n}} \cdot 100 \qquad \textbf{(0-3)}$$

The definition is taken from IEC 61400-21 [15].

Transitional systems: WTs in accordance with Section 8 SDLWindV commissioned between 01 January 2009 and 01 April 2011.

Trigger time: Reaction time of protection device.

Trigger value: Value of the voltage, current, reactive power or frequency, at which the grid protection device is triggered.

Unit certificate: Type-specific certificate issued by certification bodies accredited for this purpose in accordance for each power generating unit presenting the electrical properties of the power generating unit as proof of conformity of a planned energy generating system with the technical requirements of grid connection regulations or any other grid connection-related technical specifications.

Validate: Comparison of test results based on measurements with the results of model simulations for different setpoint specifications and/or grid conditions.

Validated simulation model: Power generating unit and power generating system simulation model validated on the basis of model validation tests carried out in accordance with TG 4 Annex E on the ready-to-operate system.

Wind speed v: Wind speed, measured at hub height either by means of a met mast in an adequate position or measured by means of the nacelle anemometer.