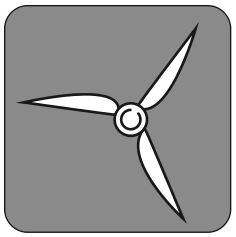
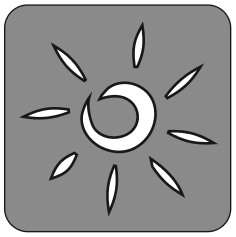
Technical Guidelines
for Power Generating Units and Systems

PART 4 (TG 4)





Demands
on Modelling and Validating
Simulation Models
of the Electrical Characteristics
of Power Generating Units and Systems,
Storage Systems as well as their Components

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, Storage Systems as well as for their Components 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, Storage Systems as well as their Components

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

The FGW's Technical Guidelines serve to aid in presenting measuring and testing methods allowing determination of reliable and comparable data for power generating units (PGU) and power generating systems (PGS) based on state-of-the-art technology.

These Guidelines describe the demands on modelling and validating simulation models of PGUs and PGS for describing the electrical characteristics on the grid.

A description of the methods for validation and modelling of the electrical response of PGUs and PGS in accordance with these Technical Guidelines serves to verify that the simulation models can model the electrical response of the PGUs and PGS with sufficient accuracy in terms of the measurements given in TG 3.

This revision of Technical Guidelines FGW TG 4 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.

Contents

Abbreviations used

AC	Alternating Current
ADC	Analogue to Digital Converter
ASM	Asynchronous machine
AVR	Automatic voltage regulator
AR	Automatic reconnection in overhead lines following grid faults
BDEW	Bundesverband der Energie- und Wasserwirtschaft e.V. (German Association for Energy and Water Supply)
CGP	Cogeneration plant
BNetzA	Federal Network Agency
CISPR	Comité International Spécial des Perturbations Radioélectriques
DAkkS	Deutsche Akkreditierungsstelle GmbH (national accreditation body for the Federal Republic of Germany)
DASM	Double-fed asynchronous machines
DC	: Direct Current
DIN	Deutsches Institut für Normung e.V. (German Institute for Standardisation)
SPS	Steam power station
ST	Steam turbine
AS	Auxiliary load
EEG	German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
EMC	Electromagnetic compatibility
EMT model	Instantaneous value model
EMC	Electromagnetic compatibility
EN	European norm/standard
EGD	Equivalent grid documentation
PGS	Power generating system
PGU	Power generating unit
GSC	Generator sign convention
FACTS	Flexible Alternating Current Transmission System
FGW	FGW e.V. - Fördergesellschaft Windenergie und andere Dezentrale Energien
FPC	Frequency-directed power controller
FNN	Network Technology/Network Operation Forum at the VDE
FRT	Fault ride-through capabilty
GENSET	Combination of generator and prime mover
GT	Gas turbine
CCPP	Combined cycle power plant

HV grid	High-voltage grid
EHV grid	Extra high-voltage grid
COM	Commissioning
IEC	International Electrotechnical Commission
IGBT	Insolated Gate Bipolar Transistors
ISO	International Organization for Standardization
PC	Power controller
MOSFET	MetalOxide Semiconductor Field-Effect Transistor
MPP	Maximum Power Point (solar modules are normally operated at the point of maximum performance).
MV	Medium voltage
MAE	Mean absolute error between simulation and measurement [1]
ME	Mean error between simulation and measurement [1]
MXE	Maximum error between simulation and measurement [1]
PCC	Point of common coupling the point at which the system is connected to the grid of the grid operator
GCR	Grid connection regulations
GO	Grid operator
LV	Low voltage
OEL	Overexcitation limiter
HC	Harmonic current
OVRT	Over voltage ride-through
PSS	Power system stabilizer
PVS	Photovoltaic system
RMS model	Root mean square model
SDLWindV	Ordinance on System Services by Wind Energy Plants (Verordnung zu Systemdienstleistungen durch Windenergieanlagen)
SL	Slip ring rotor
BB	Busbar
STATCOM	Static Synchronous Compensator
PCSR	Primary controller stability reserve
SVC	Static VAR Compensator
TCC	Technical Connection Conditions
THC	Total Harmonic Current Distortion
TG	Technical Guidelines
TG 3	Technical Guidelines 3 by FGW [2]
TG 8	Technical Guidelines 8 by FGW [3]
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 engine
LSC	Load sign convention
WT	Wind turbine
HS	Hydropower station
WaTu	Water turbine
ZVEI	German Electrical and Electronic Manufacturers' Association

Symbols and units

SYMBOLS

Latin letters

Symbol	Meaning	Unit
A	Amplitude	
A	Swept rotor area of a wind turbine	m²
D	Rotor diameter	m
$G(s)$	Transfer function	
H	Energy level/pressure	m
I	Current	A
I_B, i_b	Reactive current in SI and/or p.u., standardised in relation to the rated active current	
I_W, i_w	Active current in SI and/or p.u., standardised in relation to the rated active current	
K_L	Power controller amplification	pu
M	Moment	Nm
N	Denominator	
P	Active power	W
P, p	Active power of a PGU in SI or p.u., standardised in relation to the rated active power	kW
P_{AV}	Agreed connected active power of the customer system	W
P_{st}	Short-term flicker coefficient	
Q	Reactive power	VA
Q, q	Reactive power of a PGU in SI or p.u., standardised in relation to the rated active power	VA
R	Ohmic resistance	Ω
T	Time constant	s
T_A	Turbine-generator acceleration time constant	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_y	Prime mover final controlling element time constant	s
U	Voltage	V
U_0, u_o	Zero phase sequence voltage in SI and/or p.u.	
U_1, u_1	Positive phase sequence voltage in SI and/or p.u.	
U_{L12}	Phase-to-phase voltage measured from conductor 2 to conductor 1	
U_{L1N}	Phase-to-ground voltage	
Z	Numerator	

a_T	Prime mover medium control cross-section	pu
b_p	P degree of rotational speed controller	%
$b_{pö}$	Local P degree of rotational speed controller	%
c_D	Damping coefficient	pu
c_P	Power coefficient	
$c(\psi_k)$	Flicker coefficient	
f	Frequency	Hz
u_R	Controller output signal	pu
x	State variable	
x_d	Control deviation	pu
x_d, x_q	Synchronous reactance in the d and q axes	pu
$x_{d'}$, $x_{q'}$	Transient reactance in the d and q axes	pu
$x_{d''}$, $x_{q''}$	Subtransient reactance in the d and q axes	pu
y_T	Position of control device for prime mover power take off	pu

Greek letters

α	Synchronising coefficient	pu
δ_p	Generator load angle (external polar wheel angle)	rad
ε	Fault signal (controller)	pu
ε	Deviation between the measured and simulated signal	pu
η	Efficiency	
λ	Inherent value	
σ	Real component of the inherent value	
$\boldsymbol{\varphi}$	Phase angle	rad
φ_p	Polar wheel angle (internal polar wheel angle)	rad
φ_u	Voltage angle	rad
ψ_k	Grid impedance phase angle	rad
ω	Angular velocity	rad/s
θ	Mass moment of inertia	Kgm²

INDICES

A	Acceleration
ä	External
AV	Agreed at the connection
B, b	Reactive part
CFCT	Critical Fault Clearing Time
D	Damping

D	Steam
d	Direct axis, d axis
d	Deviation
e, err	Exciter, excitation
el	Electric
f	Exciter
HP	High pressure
i	Number of PGU within a PGS
i	State variable i
i	Internal
Actual	Actual value
L	Load angle
L	Power controller
lt	Index of long-term flicker coefficient
M	Measured
max	Maximum value
min	Minimum value
mom	Instantaneous value
N, n	Rated value
LP	Low pressure
0	Steady state, initial value
P	Power
P	Polar wheel
p	p degree
pö	Local p degree
Q, q	Quadrature axis, q axis
R	Controller
Rot	Rotor
S	Stator
S	Controlled system
s	Simulated
SE	Final controlling equipment
Setpoint	Setpoint value
st	Index of short-term flicker coefficient
T	Prime mover
T	Turbine
U	Voltage

W,w	Active part
y	Prime mover final controlling element
Z	Fault
_xMin	Mean value over x minutes
_xSec	Mean value over x seconds
_123	Operating value = 123
0	Zero phase sequence
1	Positive phase sequence system
2	Negative phase sequence system
L12	Measured from conductor 2 to conductor 1
L1E	Phase-to-ground
∞	Steady-state condition

NOTATION

I,*i*	Absolute (SI) values are in upper case. Variables relative to the rated value (p.u.) are written in lower case
I´	Transient values use a prime sign
I´´	Subtransient values use a double prime
I	Variables are written in italics, constants not
∞	Infinity

LABELLING

a, b, c	Component line bundles
AVR	Automatic voltage regulator
D	Damping winding in the direct axis
E	Exciter device
e	Control difference
f	Exciter winding
f	Output variable
f	Disturbance variable
G	Generator
L1, L2, L3	Three-phase system conductors
m	Actual value
N	Grid
n	Final controlling element
PI	Proportional-integral (controller)
PID	Proportional-integral-differential (controller)
Q	Damping winding in the quadrature axis

R	Controller
TR	Transformer
U, V, W	Component line bundles
V	Load
w	Reference variable

Terms and definitions

Note: *Currently, there is no complete agreement on terms and definitions, either within the TG 3/4/8 Guidelines or between the FGW Guidelines and the grid operators' regulations. The terms and definitions primarily reflect the demands of Annex J to the TG 3/Annex F to TG 4 in terms of verification methods for PGUs/PGS with synchronous generators (Type 1). The aim here is to eradicate specifications not relevant to Type 1 PGUs/PGS. Overall agreement is aimed for.*

Harmonisation of terms between TGs is aimed for, but not yet completely implemented.

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

Actual value *m*: Value of a variable at a given time [10].

Agreed connected active power P_{AV}: Active power of the customer system at the point of common coupling agreed between the grid operator and the connection owner [5, 6].

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

Area grid: see definition of 'Closed distribution system'.

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 does not exist anymore at the time of reconnection [5, 6].

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

less of whether this has been certified or not.

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.

Certification body: A body accredited compliant with DIN EN ISO/IEC 17065 [7]for the certification programme of FGW TG 8 for the field of grid integration compliant with the applicable grid connection regulations.

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

Circuit breaker operating time: Reaction time of circuit breaker.

Closed distribution systems: Closed distribution systems, previously also referred to as area grids or object grids, refer to grids meeting the specifications in [11].

Cogeneration plant (CGP): PGU with combustion engine, from which both electrical and thermal energy are utilised.

Comparing element: Functional unit with two inputs and one output, the output variable of which is the difference between the two input variables (see Figure 0–3) [10].

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

Component certificate: Certificate issued by accredited certification bodies according to DIN EN ISO/IEC 17065 [7] which identifies the behaviour of active power generating system components having influence on the electrical response at the PCC.

NOTE 1 on this term: The term “equipment certificate” is used for the component certificate in Commission Regulation (EU) 2016/631 [8] of 14 April 2016 establishing a network code on requirements for grid connection of generators.

NOTE 2 on this term: A component certificate is a product certificate subject to monitoring for all equipment according to DIN EN ISO/IEC 17067 [9] (definition in accordance with [5]).

Connection owner: Natural or legal person (e.g. owner), whose customer system is directly connected to the grid of the grid operator via a connection and who is responsible for complying with the VDE application rules and therefore for the proper operation of the grid connection.

NOTE 1 on this term: The connection owner enters into the necessary agreements with third parties (the ones building and using the connection and the system operator) in this regard independently [5, 6].

Control device: Entirety of functional units aimed at influencing the controlled system corresponding to the closed or open loop control task (see Figure 0–3) [10].

Control difference e: Difference between the reference variable and the feedback variable (see Figure 0–3) [10].

Controlled system: Functional unit influenced by the closed or open loop control task (see Figure 0**–3,** Figure 0**–1,** Figure 0–2) [10].

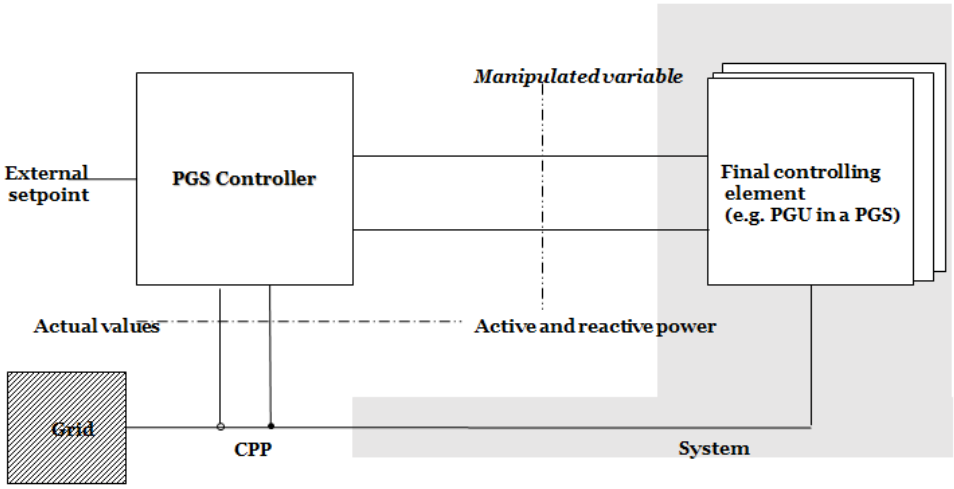

Figure 0–1: Example of a controlled system without secondary control circuits in a PGS controller, consisting of PGU final controlling elements and the PGS grid

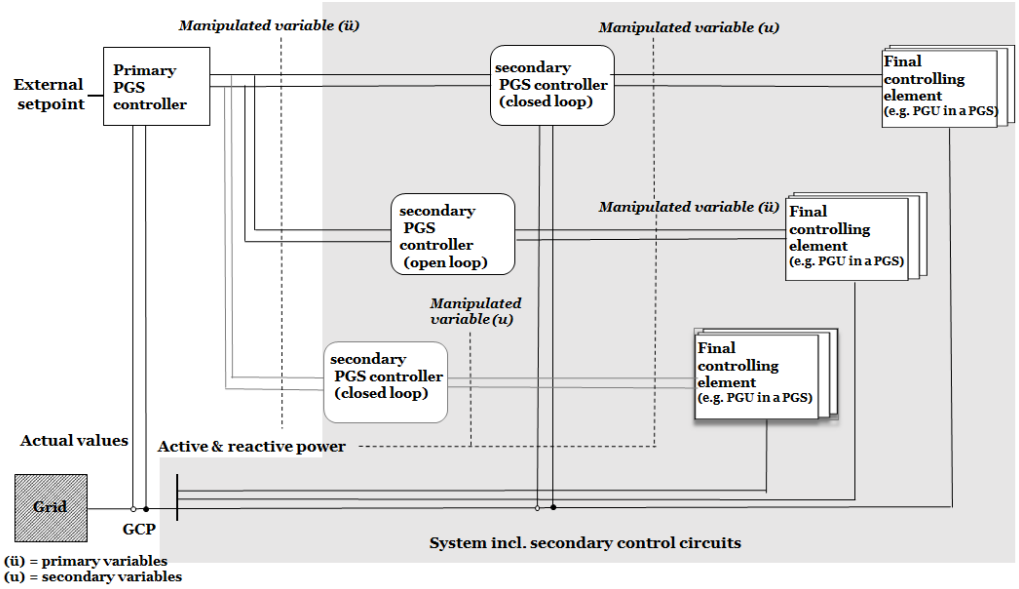

Figure 0–2: Example of a controlled system including secondary control circuits

Controlled variable: Controlled system output variable, on which one or more manipulated variables act (see Figure 0–3) [10].

Controlled variable overshoot Δx_{max}: 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 [5, 6].

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 (see Figure 0–3) [10].

Control system: System consisting of the controlled system, its control device, the measuring element and the associated converters (see Figure 0–3) [10].

Customer system: A customer system (Sec. 3 No. 24a EnWG [12]) is an energy system for supplying energy (Sec. 3 No. 15 EnWG [12]), (a) located in a spatially coherent territory, (b) connected to a power supply grid or a power generating system, (c) which is irrelevant for ensuring effective and undistorted competition in the supply of electricity and gas and (d) which is made available to anybody for the purpose of supplying the connected end consumer by way of transit, regardless of the choice of energy supplier, free of discrimination and free of charge.

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: Cosine of the phase angle between the fundamental frequencies of a line-to-neutral voltage and a current in this line [5, 6].

Disturbance variable f: Undesirable, independent and generally unpredictable input variable, acting on the system from the outside [10].

Duration of disconnection: Trigger and operating time of the circuit breaker.

Effective range of inversion: Superposition of effective range of inversion (hysteresis) and dead bands, in particular when considering the path: Rotational speed or frequency measurement -> controller output signal -> position of control devices for rising and falling input signals.

EMT model: Model on the basis of the instantaneous value of all phases.

Existing systems: Existing systems represent an existing power generating system, regard

FACTS: FACTS elements (Flexible AC Transmission System) 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 dips 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 or parallel types.

Fault clearing: Process in an electrical system causing electric current to no longer flow through a faulty section, i.e. the fault is cleared, once the last circuit breaker limiting the fault location has switched off and interrupted the (fault) current [5, 6].

Fault Ride-Through-Capability (FRT): Ability of a PGS or a PGU to not disconnect from the grid during sudden voltage changes, the subsequent equalization and absolute deviation of the grid voltage [5, 6].

Feedback variable: Variable, which models the controlled variable and which is fed back to the comparing element (see Figure 0–3) [10].

Final 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 validated simulation model.

Final controlling element n/final controlling element in the control circuit n: Functional unit forming part of the plant controlled feedback loop and positioned at the plant controlled feedback loop input, influenced by the manipulated variable and influencing the mass flow or energy flow (see Figure 0–3) [10].

NOTE 1 on this term: An additional positioner is often used for mechanically actuated final controlling elements.
NOTE 2 on this term: 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 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 impedance phase angle ψ_k: Arc tangent of the ratio between the reactance X_k and the resistance R_k of the short-circuit impedance at the grid point considered, $\psi_k = \arctan(X_k/R_k)$ [5, 6].

Grid impedance phase angle S_n: S_n is numerically equated with the rated active power P_n and is adopted as a reference value for the calculations described in these guidelines.

Initial symmetrical short-circuit AC current I_k": RMS value of the AC current portion of an anticipated short-circuit current at the instant of short-circuit occurrence (DIN EN 60909-0 (VDE 0102) [4]) [5, 6].

Interface f: Boundary between two functional units, which is deemed suitable by way of functional features, signal parameters or other features [10].
NOTE 1 on this term: This term incorporates the interface description for the connection between two devices with different functions.

Manipulated variable: Control device output variable, which is also the controlled system input variable (see Figure 0–3) [10].

Mean time data stream: Triggered mean time recording with uniform sampling rates of 50-100 Hz. This mean time data stream comprises the slow signals and the signals determined using a calculation formula.

Measuring element: Functional unit, which forms the feedback variable at the output from the controlled variable at the input (see Figure 0–3) [10].

Measuring institute: Measuring institute compliant with DIN EN ISO/IEC 17025 [13]body accredited by DAkkS for the field of grid integration compliant with the applicable German grid connection regulations.

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.

Models: Models of the individual PGUs and the entire PGS should be taken into consideration for unit and system certification.

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

Output variable f: Recordable variable generated by a system, which is only influenced by this and by its input variables via the system [10].

Prime mover: Prime mover component of the PGU which drives the generator, e.g. steam, water or gas turbine.

PGS controller: Controller which records the difference between the setpoint and actual values of a variety of controlled variables at the PCC (e.g. reactive power) and from them determines the necessary change to the corresponding manipulated variable for forwarding to the power generating units or components.

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

NOTE 2 on this term: For 'PGS controller', the terms ‘park controller’ and ‘central controller’ are also often used [5, 6].

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 setpoints at the PCC are defined for P, Q or U via the PGU or components contained within the PGS.

PGS declaration of conformity: Confirmation and verification that the entire PGS has been erected and commissioned in accordance with the requirements of the grid connection regulations and with the specifications in the system certificate.

NOTE 1 on this term: Upon issuance of the declaration of conformity, the process of system certification is completed.

PGS rated active power $P_{n,\,PGS}$: The PGS rated active power comes from the sum of all rated active power of all the PGUs 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 that 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 converts the PVS supply to a load-independent supply. The inverter is decisive for metering.

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

Polar wheel angle: The polar wheel angle is the angle with which the polar wheel voltage precedes compared to the terminal voltage (or with which the excitation rotating field precedes compared to the synchronous rotating field) of the synchronous generator.

The *internal* polar wheel angle, φ_{pi}, describes the angle between the generator's q axis and the phasor of the generator terminal voltage (φ_u, phase L1). The *external* polar wheel angle, $\varphi_{pä}$ describes the angle between the generator's q axis and the phasor of the reference voltage (machine in stiff system) or the reference polar wheel (machine in a system consisting of synchronous machines). The usual designation for the external polar wheel angle is "load angle, δ_p" or "rotor angle, δ_p". It is important for assessing the transient stability.

Positive phase sequence system: Symmetrical rotating system of three components with normal phase sequence. Unless otherwise stated, the positive phase sequence system of the fundamental frequency is considered.

Power curve: The relationship between primary energy supply and power output identified for each PGU type.

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 (PGS): System in which one or more units generating electrical energy and all electrical installations necessary for operation are located [5, 6] ..

Power generating unit (PGU): Individual unit for generating electrical energy [5, 6].

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.

Primary controller: Proportional prime mover's control device for controlling active power output by directly influencing the utilised medium. Here, the control target is to control the gradient of a rotational speed deviation of the GENSET towards zero ($d\omega_m/dt = 0.$). By selecting different structures, the primary controller can often be operated as a pure speed controller, power controller or frequency-directed power controller.

Quasi-steady-state operation: Quasi-steady-state operation in the case of connection to the medium-voltage grid is defined by a voltage gradient of <5% U*c*/min and a frequency gradient of <0.5% f_n/min. Quasi-steady-state operation in the case of connection to the high-voltage grid or extra-high-voltage grid is defined by a voltage gradient of <5% U_n/min (or <0.05 p.u./min) and a frequency gradient of < 0.5% f_n/min.

Quasi-steady-state operation during FRT: Validation period for the evaluation of FRT according to IEC 61400-27-1 Ed. 1 [1]

Range of inversion: The range of inversion designates the difference at the end of a state movement to the same tar-get state, if the state movement was performed from a variety of directions (hysteresis).

Rated active power P_n: Rated active power of the PGU at reference conditions as specified by the manufacturer [14].

Rated voltage U_n: Voltage which is used to describe or identify a grid or system. For PGU or components, the rated voltage is given as the phase-to-phase voltage by the manufacturer.

Rated current I_n: Current value determined from the rated apparent power S*n* and the rated voltage U_n:

$$I_{\mathrm{n}} = \frac{S_{\mathrm{n}}}{\sqrt{3} \cdot U_{\mathrm{n}}} \qquad \textbf{0-1}$$

NOTE 1 on this term: 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 on this term: The line of ownership is agreed upon between grid operator and connection owner independent of the point of common coupling [5, 6].

Reference variable w: Control device's comparing element input variable derived from the target variable and defining the controlled variable setpoint (see **Figure 0–3**) [10].

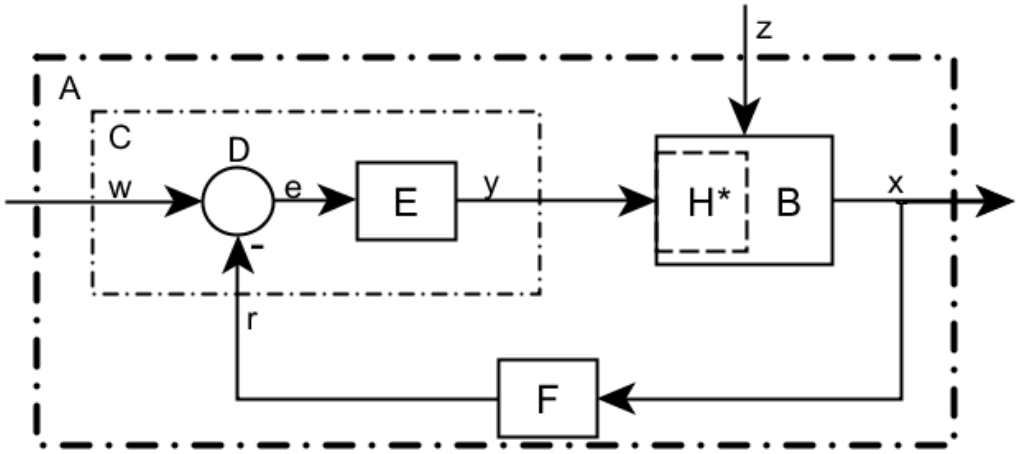

Figure 0–3: Action plan with typical elements of an elementary control system

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 moment when the controlled variable reaches 90% of the change in the setpoint for the first time.

NOTE 1 on this term: The rise time is a characteristic parameter of the step response. It also includes the time it takes to recognise the control deviation (see Figure 0–4 [5, 6].

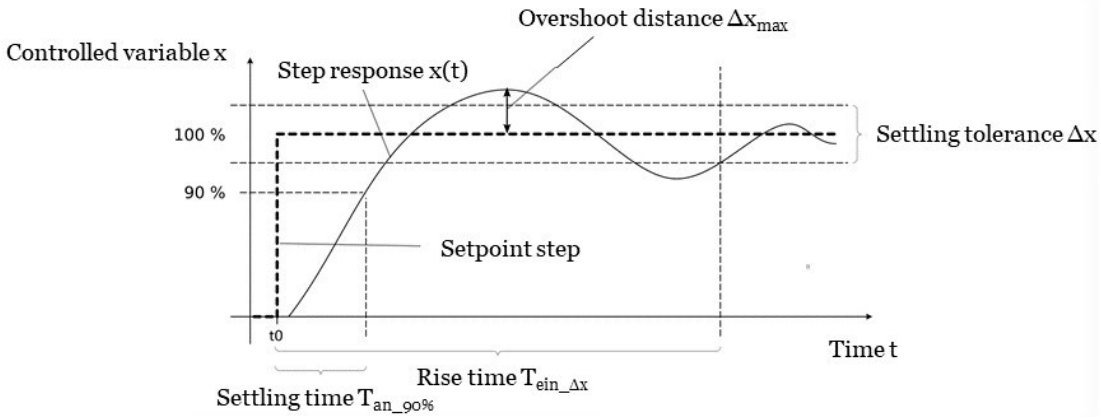

Figure 0–4: Rise time and settling time after a setpoint step

RMS model: Model of the positive phase sequence system and, where applicable, the negative phase sequence system of the fundamental frequency.

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 (e.g. the reactive current I_B) is within the tolerance band around the steady-state final value and remains there (see Figure 0–4) [5, 6].

Simulation: Numerical solution of model equations encompassing the components of the electrical grid and the PGU or PGS. Depending on requirements of the grid connection regulation, the electrical grid can be represented as a root mean square model (RMS) or as an instantaneous value model (EMT).

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 Compensator (SVC): A static reactive power compensator (SVC) is a system for compensating reactive power in electrical power transmission grids.

Steady-state condition: State of a system or its state variables, free of initial displacement or transient input signals, inasmuch as any remaining deviations from the steady-state conditions are below the demand-ed resolution or measurement accuracy of the measuring system. Of particular importance for measurements compliant with these Guidelines are remaining transient input signals from the grid or upstream processes that make a steady-state condition impossible according to a strict definition (e.g. variations in grid frequency and grid voltage at the PCC, boiler pressure (steam power station), the hydraulic pressure (hydropower station), vibrations, etc.). Here, it is the duty of the party performing the measurements to minimise the remaining transient conditions, to adapt measuring procedures where necessary and to evaluate analysability with the party performing the conformity study.

Switching current factor $k_{i\Psi}$: System-specific, dimensionless variable, which – given as a function of the grid impedance angle – evaluates the influence of the PGU/PGS current during switching operations on the change in voltage and grid flicker thus caused.

System certificate: Certificate issued by certification bodies accredited for this purpose in accordance with DIN EN ISO/IEC 17065 [7] which confirms the conformity of a planned generating system with the technical requirements of a grid connection regulation or another technical specification with regard to the grid connection.

NOTE 1 on this term: The term “power-generating module document“ is used for the system certificate in Commission Regulation (EU) 2016/631 [8] of 14 April 2016 establishing a network code on requirements for grid connection of generators.

NOTE 2 on this term: Unit certificates (or unit verifications [5]) and, when appropriate, component certificates (or component verifications [5]) as well as grid calculations and simulations form the basis for the system certificate.

NOTE 3 on this term: Unlike the unit certificate and component certificate, the system certificate is no product certificate in accordance with DIN EN ISO/IEC 17067 [9] requiring surveillance but a certified grid connection planning. Comments in accordance with [5, 6].

System certificate Stage I: A certification body carries out the evaluation in terms of the applicable grid connection regulations based on the preliminary conformity study and the preliminary simulation model. If the evaluation is positive the certification body issues the system certificate S1.

System certificate Stage II: A certification body carries out the evaluation in terms of the applicable grid connection regulations based on the final conformity study and the validated simulation model. If the evaluation is positive the certification body issues the system certificate S2.

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

Trigger time: Reaction time of protection device.

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

Type 1 PGS: PGS, which only includes Type 1 PGUs.

NOTE 1 on this term: If a Type 1 PGU uses equipment in common with other Type 1 PGU (e.g. a common transformer or central control) and these generating units therefore are not operated independently of each other, these generating units form a Type 1 generating system [5, 6].

Type 2 PGS: PGS, which does not meet the conditions for Type 1 [5, 6].

Type 1 PGU: PGU, which contains for generating electrical energy only a directly grid-connected (only via a generator transformer) synchronous generator [5, 6].

Type 2 PGU: PGU, which does not meet the conditions for Type 1 [5, 6].

Unit certificate: Type-specific certificate issued by certification bodies accredited for this purpose in accordance with DIN EN ISO/IEC 17065 [7] 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.

NOTE 1 on this term: The term “equipment certificate” is used for the unit certificate in Commission Regulation (EU) 2016/631 [8] of 14 April 2016 establishing a network code on requirements for grid connection of generators.

NOTE 2 on this term: A unit certificate is a product certificate subject to monitoring according to DIN EN ISO/IEC 17067 [9] for all generating units, cf. [5, 6].

Validated simulation model: Simulation model of the power generating unit and the power generating system, which can be assumed to be valid based on measurement and simulation comparisons for defined model requirements and validation tests within defined tolerances.