TC EC – Resolustion on the
Technical Guideline
TG 4 Rev. 10

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Technical Committee Electrical Characteristics (TC EC) – Decision from 18.03.2026

The Technical Committee Electrical Characteristics (TC EC) resolves to amend Revision 10 of the Technical Guideline Part 4 (TG 4).

This supplementary sheet is intended to facilitate the prompt implementation of the FNN guideline "Technical requirements for grid-forming capabilities including provision of inertia" in Version 2.1 dated January 2026.

TG 4 Rev. 10 is optionally supplemented by this sheet and may still be applied independently. This supplementary sheet applies to PGU and PGS with grid-forming capabilities or for the provision of instantaneous reserve.

On behalf of the Technical Committee Electrical Characteristics

Iyad Chami

Supplement 1 to FGW TG 4 Rev. 10 Demands on Modelling and Validating Simulation Models of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components

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Publisher

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For the sake of readability, gender-neutral language has been used. Such terms apply to both genders in the spirit of equality.

Foreword

This supplement serves the short-term implementation of the FNN guideline “Technical requirements for grid-forming capabilities, including the provision of inertia” in version 2.1 dated January 2026. [1]

TG 4 Rev. 10 [2] is optionally supplemented by this addendum and may still be applied independently. This addendum applies to PGU and PGS that must meet the requirements of the FNN Guideline [1] that must be met.

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Abbreviations used

AR	Automatic reconnection in overhead lines following grid faults
CCGT	Combined Cycle Gas Turbine
CHP	Cogeneration plant
EMT model	Instantaneous value model
EZSE	Netzbildende Erzeugungs- und Speichereinheiten (grid-forming generation and storage units)
FGW	FGW e.V. - Fördergesellschaft Windenergie und andere Dezentrale Energien
FNN	Forum Network Technology & Network Operation in the VDE (FNN)
FRT	Fault Ride-Through
PCNB	Primary control based on network security
PGS	Power Generating System
PGU	Power Generating Unit
RMS model	Root mean square model
TCR	Technical Connection Rule
TG	Technical Guidelines
VDE	Verband der Netzbetreiber (Association of German Power Transmission System Operators)

Symbols

Symbol	Meaning	Unit
P	Active power	W
P/P_{rE}	PGU- relative error of the active power	%
$U_{\mathrm{ll}}/U_{\mathrm{n}}$	Voltage depth	%
$U_{\mathrm{l,12}}/U_{\mathrm{n}}$	Pre-fault voltage	%
u_{R}	Primary controller output signal	pu
y_{Ti}	Final controlling element positions	pu
φ	Phase angle	rad

Terminology

Please refer to terms and definitions issued by the FGW Technical Committee Electrical Characteristics (TC EC).

1 Introduction

Representatives of the following groups participated in the compilation of this supplementary sheet to the Technical Guidelines for Power Generating Units (PGUs) and Systems, Part 4 Rev. 10 (TG 4) [2]:

- Grid operators.
- Manufacturers of Power generating units and components.
- Accredited institutes and universities.
- Testing institutes.
- Certification bodies.

All parties involved have stated that this supplement is intended to compliment TG 4 Rev. 10 [2].

The requirements, specifications and explanations described in TG 4 Rev. 10 [2] also apply to this supplement.

The abbreviations, symbols and units as well as terms and definitions listed in TG 4 Rev. 10 [2] apply to this supplement too.

Chapter 2 of this supplementary sheet lists the modeling and validation requirements for simulation models used to demonstrate the grid-forming characteristics of renewable energy sources. Further specifications regarding amendments to TG 4 Rev. 10 [2] based on the requirements of the FNN guideline [1] are outlined in Chapter 3. These include, in particular, additions or replacements of chapters on model validation, the individual verification procedure, and plausibility checking.

The purpose of the plausibility check is to verify the model behavior for an extended operating range within the requirements of the applicable technical connection regulations, as well as to ensure that the model functions properly under the specified test conditions and is capable of returning to a stable, quasi-stationary operating condition following a disturbance. Furthermore, numerical instabilities (e.g., unexpected oscillations) must be ruled out. Tests based on requirements that fall outside the scope of the applicable Technical Connection Regulation (TAR) should be evaluated solely in terms of the models operational capability. For example, TAR-compliant protective shutdowns would be permissible in this context during simulated FRT tests. Reproducible results must be ensured under identical initial load flow conditions.

2 Requirements for the modeling and validation of PGU simulation models

The requirements for the modeling and validation of PGU simulation models are specified in the following document [1] and must be followed:

> Technical requirements for grid-forming capabilities including provision of inertia, Requirements and verifications for grid-forming units. VDE FNN guideline. Current version 2.1, January 2026.

The documentation requirements are described in the following sections of the VDE FNN guideline [1]:

- Section 5.4: Type 1 grid-forming units
- Section 5.5: Grid-forming units (Type 2, storage and CCUs)

However, the other sections of [1] and the appendices must also be taken into account.

As soon as a new revision of [1] takes effect, it must be followed (references to the FNN guideline refer to version 2.1 [1]).

3 Further specifications

3.1 Introduction

For modelling and the performance of model validation in accordance with [1], the guidelines set out in the following subsections must be taken into account in addition to the specifications and requirements in [1]. Should these conflict with the requirements and specifications in [3], the guidelines in [1] shall apply.

Table 1 provides an overview of the chapters in TG 4 Rev. 10 [2], that are replaced or supplemented by the requirements set out in the FNN guideline on grid-forming capabilities [1]. All information relates exclusively to **Type 2 units/systems** with grid-forming capabilities (grid-following Type 2 units/systems within the scope of the technical connection regulations are not affected by these requirements).

*Table 1: Overview of supplementary or replacement requirements in TG 4 Rev. 10 for grid-forming units (**Type 2 PGU, EZSE as well as storage units**)*

TG 4 Rev. 10	**Criterion**	**FNN guideline** [1]	**Comment**
Chapter 4	Requirements for modelling software/environment	5.5.3.7	Chapter 4 of TG 4 Rev. 10 is supplemented with the requirements set out in the FNN guideline in section 5.5.3.7 (Requirements for the simulation environment and tool independence) in a normative manner.
Chapter 6	Aggregated PGS models according to VDE-AR-N 4110/20		Chapter 6 of TG 4 Rev. 10 does not apply when the FNN guideline is applied. a)
Chapter 7	Scope of delivery	5.5.3.1 5.5.3.8 5.5.3.9	Chapter 7 of TG 4 Rev. 10 is supplemented by the requirements set out in the FNN guideline in sections 5.5.3.1 (Model categories and general specifications), 5.5.3.8 (Manufacturer models for certification purposes) and 5.5.3.9 (Models for use by the network operator).
Chapter 7.2	Model documentation	5.5.3.6.4	Section 7.2 of TG 4 Rev. 10 is supplemented by the requirements set out in the FNN guideline in section 5.5.3.6.4 (Model documentation).
Chapter 8.2	Dynamic RMS simulation models	5.5.3.6.1 5.5.3.6.2	Section 8.2 of TG 4 Rev. 10 does not apply to grid-forming units. Instead, the requirements set out in sections 5.5.3.6.1 and 5.5.3.6.2 (Validation of simulation models) shall apply.
a) As there is currently no experience regarding the various configurations of grid-forming and non-grid-forming units within a generation facility, version 2.1 of the FNN guideline does not require aggregated PGS models.			

Furthermore, some of the plausibility tests defined in TG 4 Rev. 10 [2] are not applicable to the grid-forming Type 2 units operated in accordance with [1]. The corresponding adjustments to the plausibility tests defined in TG 4 Rev. 10 [2] are described in Chapter 3.3. Additional plausibility tests to be carried out for grid-forming Type 2 units are described in Chapter 3.4.

Table 2 provides an overview of the chapters that are replaced or supplemented by the requirements set out in the FNN guideline on grid-forming capabilities [1] with reference to TG 4 Rev. 10 [2]. All information relates exclusively to **Type 1 units/systems (units with a unit certificate)** to which the FNN guideline applies (Type 1 units/systems connected exclusively in accordance with the VDE application rules VDE-AR-N 41XX [3], [4], [5] are not affected by these requirements).

Table 2: Overview of supplementary or replacement requirements in TG 4 Rev. 10 for grid-forming ***Type 1 units with a unit certificate***

TG 4 Rev. 10	**Criterion**	**FNN guideline** [1]	**Comment**
Chapter 6	Aggregated PGS models according to VDE-AR-N 4110/20		Chapter 6 does not apply to Type 1 systems where the FNN guideline is followed. a)
Chapter 8.2.1.3	Dynamic RMS simulation models Validation of the over- and under-frequency ranges (grid security-based primary control)	5.4.2.2	Section 8.2.1.3 of TG 4 Rev. 10 does not apply to the validation of over- and under-frequency behavior for Type 1 units when applying the FNN guideline [1]. Instead, the requirements set out in section 5.4.2.2.2 [1] (behavior of the PCNB in accordance with the test specified in 5.4.3.3.2) shall apply.
a) As there is currently no experience regarding the various configurations of grid-forming and non-grid-forming units within a generation facility, version 2.1 of the FNN guideline does not require aggregated PGS models.			

Moreover, some of the plausibility tests defined in TG 4 Rev. 10 [2] are not applicable to the grid-forming Type 1 units operated in accordance with [1]. The corresponding adjustments to the plausibility tests defined in TG 4 Rev. 10 [2] are described in chapter 3.3. Additional plausibility tests to be carried out for grid-forming Type 1 units are described in chapter 3.4.

Table 3 provides an overview of the chapters that are replaced or supplemented by the requirements set out in the FNN guideline on grid-forming capabilities [1] with reference to TG 4 Rev. 10 [2]. All information relates exclusively to **Type 1 units/systems in the individual verification procedure** to which the FNN guideline applies (Type 1 units/systems connected exclusively in accordance with the VDE application rules VDE-AR-N 41XX [3], [4], [5] are not affected by these requirements).

Table 3: Overview of supplementary or replacement requirements in TG 4 Rev. 10 for grid-forming ***Type 1 units in the individual verification procedure*** *in accordance with this supplementary sheet*

TG 4 Rev. 10	**Chapter**	**TG 4, supplementary sheet**	**Comment**
E.4.1.2 (Introduction)	Modelling procedure	3.2.2.1.1.1	The introductory paragraphs of chapter E.4.1.2 are replaced by 3.2.2.1.1.1.

E.5 (Intro-duction)	Validation of the PGU-/PGS-models	3.2.3 (3.2.3.1)	The introductory paragraphs of chapter E.5 are replaced by 3.2.3.1.
E.5.1	Fundamental model validation procedure	3.2.3.2	Chapter E.5.1 is replaced by 3.2.3.2.
E.5.2.5	Dynamic prime mover characteristics	3.2.3.3.1	Chapter E.5.2.5 is replaced by 3.2.3.3.1.
E.6.1	Scope of conformity studies	3.2.4.1.1	Chapter E.6.1 is supplemented by subsection 3.2.4.1.1.
E.6.4.2.2	Verification of the active power step response	3.2.4.2.1.1.1	Chapter E.6.4.2.2 is supplemented by subsection 3.2.4.2.1.1.1.

3.2 Required amendments to chapters of TG 4 Rev. 10 [2] (for verification using the individual verification procedure)

3.2.1 Introduction

For the convenience of users and readers, the existing text of the chapters in TG 4 Rev. 10 [2] that have been amended or replaced has been retained below and supplemented accordingly. Any changes are highlighted in blue.

3.2.2 Modelling procedure (*E.4 in* [2])

3.2.2.1 MODEL BOUNDARIES (*E.4.1 in* [2])

3.2.2.1.1 PRIME MOVER OF TURBINE UNIT MODEL (*E.4.1.2 in* [2])

3.2.2.1.1.1 General (*Replacing E.4.1.2* [2] *(Introduction)*)

The simulation model of the prime mover (prime mover/turbine, engine) must meet the following basic criteria:

For dynamic behavior that complies with the grid connection conditions, the speed response based on speed control or (market- and grid security-based) primary control is decisive. An overall model must be presented which, starting from a steady-state condition, reproduces the disturbance and reference variables of the plant with the required accuracy after the transient phenomena have subsided, leading to a new steady-state condition. The validity of the model for the analysis of secondary control is thus limited to those cases in which the secondary controller acts directly on the primary controller. Consequently, the aspects of slow-acting control of steam boilers within thermal power stations or combined heat and power plants (CHP plants, industrial power stations, etc.), which are of lesser importance for grid stability, are not considered.

For the simulation-based verification of grid security-based primary control in accordance with section 4.1.2 [1] for Type 1 PGS, a simulation model must be created, including a PGU controller where applicable, for the active power path of a PGS, and, where necessary, for the PGU (e.g. in CCGT). The input variables are power and speed deviations. The output variable of the controlled actuator, i.e. the entire controlled drive unit, is the mechanical drive power.

The basic test setup is shown in Figure 7 [1]. In this context, the load of the fictitious island grid is assumed to be constant, i.e. independent of frequency and voltage. The level of detail of the simulation model must be tailored to the requirements of grid security-based primary control and the tolerances to be observed in accordance with FGW TG 4, Rev. 10 E.5.2.1.1 [2] (specifications for active power output) and FGW TG 8 Rev. 10 [6] in the closed control circuit of the fictitious island grid. This applies in particular to the output variable of the primary controller. If necessary to ensure model accuracy, additional variables, such as controller output, valve position, mass flow, etc., may be included in the model comparison.

This principle must be applied to the relevant types of producers as described in the following chapters.

Note: The phrase "as described in the following chapters …" refers to the chapters subordinate to Chapter E.4.1.2 of TG 4 Rev. 10 [2].

3.2.3 Validation of the PGS/PGU models

3.2.3.1 GENERAL (*replacing E.5* [2] *(Introduction)*)

Replace paragraphs 1 and 2 with the following:

As part of the procedure for verifying the technical characteristics of a Type 1 PGS or PGU, the model representation provided by the plant owner must be validated by comparing the measurements taken on the operational system - as described in Chapter 7 of TG 3 [7] and section 5.4.3.3.3.2 of the FNN guideline [1] by comparing the measurements with the calculations, thereby confirming the model's sufficient validity.

The scope of the model is determined by the evidence established in the conformity studies. Accordingly, the validation steps described in this chapter must be selected and applied.

Note: The phrase "those described in this chapter ..." refers to the chapters listed in this supplementary sheet, as well as the chapters (which have not been superseded by this supplement) of TG 4 Rev. 10 [2].

3.2.3.2 GENERAL PROCEDURE FOR MODEL VALIDATION (*replacing E.5.1* [2])

In accordance with chapter 7 of TG 3 [7] and section 5.4.3.3.3.2 of the FNN guideline [1] the following model documentation and associated measurement results must be submitted to the accredited certification body for the purpose of verifying the validity of the validated simulation model:

1 A full report on the verification tests carried out by taking measurements on the operational installation in accordance with the applicable grid connection rules. This report must refer in particular to the performance and evaluation of the measurements in accordance with chapter 7 of TG 3 [7] section 7.2.1.

2 Submission of the measurements carried out in accordance with chapter 7 of TG 3 [7], chapter 7.2.2 " Response during grid faults" and the measurements carried out in accordance with Section 5.4.3.3.3.2 of the FNN guideline [1] (Metrological determination of *P(f)* behavior) in report form, including the corresponding measurement files. In this context, section 5.4.3.3.3.2 [1] replaces chapter 7.2.2.3.4 (Determining the dynamic characteristics of the prime mover) of TG 3 [7].

3 Report on the validation of the simulation model, carried out on the basis of the measurements referred to in point 2, as part of the conformity study.

4 All necessary documentation (such as models, parameters, etc.) that enables the certification body to carry out an assessment.

The validation runs described in the following chapters, involving a comparison of measurements and simulations, including an assessment of model accuracy, must be submitted as the basis for the model validation carried out in accordance with point 3.

3.2.3.3 VERIFICATION OF MODEL PROPERTIES (*E.5.2 in* [2])

3.2.3.3.1 DYNAMIC PROPERTIES OF THE PRIME MOVER (*replacing E.5.2.5* [2])

The validation of the dynamic characteristics of the prime mover with regard to its behavior when control variables are changed, in accordance with FNN guideline section 5.4.3.3.3.2 [1] comprises the following steps:

1 The simulation model of the PGU or PGS is initialized at the start of the measurements with regard to active power output, speed, reactive power injection and generator voltage. It must be confirmed that the relevant intermediate variables, such as the output signal of the primary controller u_{R} and the positions of the actuators y_{Ti} lie within the permissible tolerances. The operating mode of the generator control and the drive unit control shall be selected in

accordance with the measurement conditions specified in FNN guideline section 5.4.3.3.3.2.2 [1].

2 Starting from the steady-state condition of the model, the step responses of the simulation model must be determined in accordance with FNN guideline section 5.4.3.3.3.2.2 [1] when the setpoints for speed or frequency and power are changed.

3 The simulation must be evaluated in accordance with FNN guideline section 5.4.3.3.3.2.3 [1] and, in accordance with section 5.4.3.3.3.2.4 [1] plotted together with the measurements and the tolerance band within diagrams.

4 It must be verified that the step responses measured and those obtained from the simulation model fall within the specified tolerances. In this context, the operating range of the power output is limited to the measured step (for example, if a power step of 5 % was measured, the reference power is 5 % of the nominal power), the percentage deviations must be expressed relative to this value. This must also be checked for transient parameters such as natural frequencies and damping. The evaluation of discrepancies in active power output between measurements and model simulations is carried out in accordance with the specifications set out in FGW TG 4 Rev. 10, chapter E.5.2.1.1 [2] or the relevant updated specifications in subsequent revisions of TG 4. Should individual measurement points or larger measurement ranges fall outside the specified tolerances, this situation must be assessed to determine whether such deviations are justifiably permissible, for example due to changes in process conditions upstream or downstream of the turbine. In particular, the expected effects of the equivalent circuit model must also be assessed. It should be noted that any remaining discrepancies between the measurement and the simulation model must be assessed in terms of their relevance to compliance with the requirements for the PGU within the specified tolerances. Furthermore, the steady-state relationship between active power output and the effective frequency deviation or the effective power setpoint must be represented by the simulation model with an accuracy of 3 % relative to the nominal value of the active power P_{rE}. If a PI power controller is used, this requirement applies to the output signal of the power controller.

5 In the event that unexplained deviations remain, validation may be carried out by means of a sensitivity analysis of the key characteristics of the PGU or PGS, taking into account their control and fault behavior, in order to assess the impact on the overall behavior of the PGU or PGS in relation to the requirements of the NAR.

3.2.4 Contents and execution of conformity studies (*E.6 in* [2])

3.2.4.1 SCOPE OF CONFORMITY STUDIES (*E.6.1 in* [2])

3.2.4.1.1 CONNECTION IN ACCORDANCE WITH FNN GUIDELINE GRID-FORMING CAPABILITIES [1] (*new as E.6.1.4 in* [2])

When connecting a Type 1 PGU/PGS using the individual verification procedure in accordance with the FNN guideline on grid-forming capabilities [1], the scope of the conformity studies – which is generally determined by the applicable Technical Connection Rule or the voltage level of the grid connection point of the PGU/PGS – must be extended to include verification of the primary control based on network security (PCNB) in accordance with the requirements of section 4.1.2 [1]. The requirements for PCNB fully replace the requirements for active power behavior during over- and under-frequency conditions, as well as sub-network operability (the term 'sub-network operability' is not currently used in TG 4 Rev. 10), in accordance with the applicable Technical Connection Rule.

3.2.4.2 VERIFICATION OF PGU/PGS CHARACTERISTICS (*E.6.4 in* [2])

3.2.4.2.1 VERIFICATION OF PGU/PGS CONTROL FUNCTIONS (*E.6.4.2 in* [2])

3.2.4.2.1.1 Verification of the active power step response (*E.6.4.2.2 in* [2])

3.2.4.2.1.1.1 Verification of the primary control-based network security (new as *E.6.4.2.2.6 in* [2])

When connecting a Type 1 PGU/PGS using the individual verification procedure in accordance with the FNN guideline on grid-forming capabilities [1], this chapter replaces the verification requirements set out in section E.6.4.2.2.5 [2].

Verification of the primary control-based network security in accordance with the requirements of section 4.1.2 [1] is generally carried out in the virtual island network. The basic test setup is shown in Figure 7 [1]. In this context, the load of the virtual island network is to be assumed to be constant, i.e. independent of frequency and voltage. The verification is carried out in accordance with section 5.4.3.3.3.3 [1].

3.3 Required adjustments to plausibility tests in accordance with TG 4 Rev. 10 [2]

3.3.1 Dynamic RMS simulation models in accordance with 9.2 TG 4 Rev. 10 [2]

3.3.1.1 GENERAL

The plausibility checks described below for dynamic RMS simulation models must be carried out for both the detailed RMS model required by the FNN guideline on grid-forming capabilities [1] and the RMS type model.

3.3.2 Plausibility check of the individual model, in addition to the validation in accordance with 9.2.2.2 TG 4 Rev. 10 [2]

The plausibility checks described in chapter 9.2.2.2 TG 4 Rev. 10 [2] (verification of the k-factor in accordance with Tbl. 9-1) are no longer required. This does not affect sections 9.2.2.2.1 and 9.2.2.2.2, nor the tests P5.01-10, P1.06, P1.06.a, P4.06, P4.06.a, P4.09, P4.09.a, P5.09 and P5.09.a of Tbl. 9-1 (verification of correct programming for earth faults, two-phase faults and independence from the voltage phase angle).

3.3.2.1 ONE-OFF VOLTAGE DROPS IN ACCORDANCE WITH 9.2.2.3.1 TG 4 REV. 10 [2] (TYPE 2 UNITS)

To assess the numerical stability of the PGU model and to estimate the required computation times for PGS certification, one-off voltage drops must be performed in accordance with Table 4. The tests specified in Table 4 must be carried out for different grid impedance values. The grid impedances must be determined in each case from a network short-circuit apparent power equal to three times and twelve times the rated apparent power of the PGU at an R/X ratio of 0,1.

Table 4: One-time voltage drops for typical PGS units with a low short-circuit power ratio (Replaces Tbl. 9-6 in TG 4 Rev. 10 [2])

Test scenario (idling failure, fault location)					Test object settings (simulation model)	
Test No.	Type of error	Voltage depth U_{ll}/U_n in %	Preceding error-voltage $U_{l,12}/U_n$ in %	PGU-preceding error-active power P/P_{rE} in %	PGU- preceding error-reactive power cosφ (calculated)	SCR
P9.1	3-phase	75	100	100	1	3
P9.2	3-phase	30				3
P9.3	3-phase	0				3
P10.1	3-phase	75	90	100	0,95 kap.	12
P10.2	3-phase	30				12
P10.3	3-phase	0				12
P11.1	3-phase	75	100	20	1	3
P11.2	3-phase	30				3
P11.3	3-phase	0				3
P12.1	3-phase	75	110	20	0,95 ind.	12
P12.2	3-phase	30				12
P12.3	3-phase	0				12
P13.1	2-phase	75	90	100	0,95 kap.	3
P13.2	2-phase	30				3
P13.3	2-phase	0				3
P14.1	2-phase	75	100	100	1	12
P14.2	2-phase	30				12
P14.3	2-phase	0				12
P15.1	2-phase	75	110	20	0,95 ind.	3
P15.2	2-phase	30				3
P15.3	2-phase	0				3
P16.1	2-phase	75	100	20	1	12
P16.2	2-phase	30				12
P16.3	2-phase	0				12

Evaluation criteria: A positive result is achieved if each simulation runs without any error messages (simulation termination) and shows no signs of instability. Furthermore, the active and reactive power curves of all PGU units must return to their steady-state initial values following the short circuit. The correct model behavior should generally be verified qualitatively and, on a random basis, quantitatively for individual PGU units in individual tests.

3.3.2.2 REPLICATION OF AN UNSUCCESSFUL AR IN ACCORDANCE WITH 9.2.2.3.2 TG 4 REV. 10 [2] (TYPE 2 UNITS)

The replication of an unsuccessful AR is based on the voltage curve shown in Figure 1.

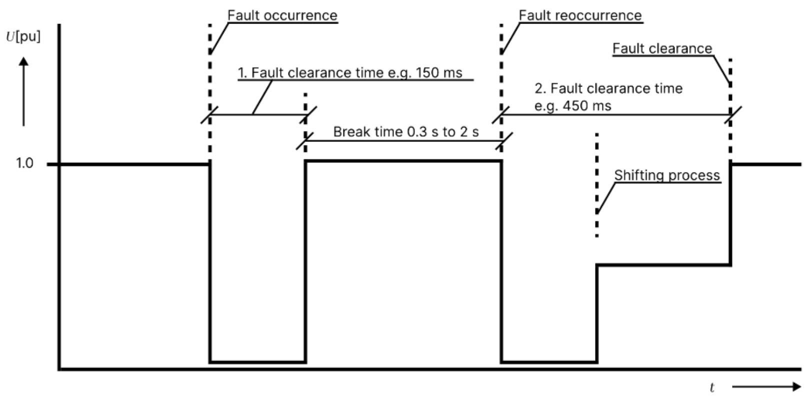

Figure 1: Voltage curve for replicating an unsuccessful AR (Fig. B.6 *[3]*)

If required by the applicable grid connection rule, unsuccessful AR tests must be carried out in accordance with Table 5. The grid impedance is calculated based on a grid short-circuit power equal to three times the design apparent power of the PGS, assuming an *R/X* ratio of 0,1.

Table 5: Replication of an unsuccessful AR for a typical PGS with a low short-circuit power ratio (Replaces Tbl. 9-7 in TG 4 Rev. 10 [2])

Test scenario (idling failure, fault location)					Test object settings (simulation model)
Test No.	Type of error	Voltage depth U_{ll}/U_n in %	Preceding error-voltage $U_{l,12}/U_n$ in %	PGU-preceding error-active power P/P_{rE} in %	PGU- preceding error-reactive power cosφ (calculated)
P17.1	3-phase	50,0 50,0 75,0	100	100	1
P17.2	3-phase	30,0 30,0 50,0	100	100	1
P17.3	3-phase	0 0 20,0	100	100	1
P18.1	2-phase	30,0 30,0 50,0	100	100	1
P18.2	2-phase	0 0 30,0	100	100	1

Evaluation criteria: A positive result is achieved if each simulation runs without any error messages (simulation termination) and shows no signs of instability. Furthermore, the active and reactive power curves of all PGU units must return to their steady-state initial values following the short circuit. It must be evident that the applicable grid connection rule and the FNN guideline on grid-forming capabilities [1] have been correctly implemented, and these must be consistent with the manufacturer's other declarations.

3.3.2.3 REDUCTION OF ACTIVE POWER IN THE EVENT OF OVERFREQUENCY IN ACCORDANCE WITH 9.2.2.4 TG 4 REV. 10 [2]

Plausibility of the unrestricted control range (virtual island network)

Plausibility tests must be carried out in the virtual island network (see section 5.5.4.2 [1]). Various operating points must be checked, taking into account the operating ranges defined in Table 14 [1]. For each of these, load steps must be simulated, taking into account the amplitude of the unrestricted control range as specified in Table 14 [1].

Plausibility of the restricted control range (parallel network operation)

The plausibility check of behavior during overfrequency, as specified in chapter 9.2.2.4 TG 4 Rev. 10 [2] is mandatory for units falling within the scope of VDE-AR-N 4110, 4120 and 4130 and must be carried out in accordance with chapter 9.2.2.4.1 TG 4 Rev. 10 [2]. In this context, the behavior within the limited control range of the primary control based on network security must be evaluated, in particular with regard to the characteristic values specified in Table 15 [1]. Various operating points must be checked, taking into account the operating ranges defined in Table 14 and 15 [1].

Plausibility during the transition from the unrestricted to the restricted control range and vice versa (virtual island network)

The behavior during the transition from the unrestricted to the restricted control range, and vice versa, must be verified. In this context, the test specimen must be subjected to a disturbance power that slightly exceeds the amplitude of the unrestricted control range as specified in Table 14 [1] but which can be stabilised within the virtual island network (Due to the disturbance power, the frequency in the fictitious island network must not exceed the defined frequency limits).

Evaluation criteria: A positive result is achieved if the model behavior matches the required behavior. Furthermore, each simulation must run without any error messages (simulation termination), no instabilities must occur, and the frequency response must exhibit damped behavior.

3.3.2.4 REDUCTION OF ACTIVE POWER IN THE EVENT OF OVERFREQUENCY IN ACCORDANCE WITH 9.2.3.4 TG 4 REV. 10 [2] (TYPE 1 UNITS)

The requirements of section 3.3.2.3 apply.

3.3.2.5 DYNAMIC EMT SIMULATION MODELS FOR ELECTROMAGNETIC PROCESSES IN ACCORDANCE WITH 9.3 TG 4 REV. 10 [2]

3.3.2.5.1 PLAUSIBILITY CHECK OF THE INDIVIDUAL MODEL IN SUPPLEMENT TO VALIDATION IN ACCORDANCE WITH 9.3.1.1 TG 4 REV. 10 [2] (TYPE 2 UNITS)

The tests specified in section 9.2 of TG 4 Rev. 10 [2] must be carried out in full, taking into account the additions and deviations defined in this supplementary sheet to section 9.2 in accordance with section 3.3.1.

3.3.2.5.2 PLAUSIBILITY TEST FOR PGS CONFIGURATIONS (DEPENDENCIES) IN ACCORDANCE WITH 9.3.1.2 TG 4 REV. 10 [2]

3.3.2.5.3 This test was already carried out as part of the verification of the capability of parallel operation in accordance with [1].

Evaluation criteria: A positive result is achieved if, as part of the verification of the capability of parallel operation in accordance with [1], the model behavior of the respective PGU unit differs according to the preceding error settings. Furthermore, each simulation must run to completion without any error messages (simulation termination). No further assessments beyond the FNN guideline are required.

3.3.2.5.4 REDUCTION OF ACTIVE POWER IN THE EVENT OF OVERFREQUENCY IN ACCORDANCE WITH 9.3.1.4 TG 4 REV. 10 [2] (TYPE 2 UNITS)

The requirements of section 3.3.2.3 apply.

3.4 Supplementary plausibility tests (Type 2 units)

3.4.1 General

The plausibility tests described below must be carried out for the detailed RMS model required under the FNN guideline on grid-forming capabilities [1] as well as for the RMS-type model and the EMT model of the Type 2 grid-forming units.

3.4.1.1 PLAUSIBILITY OF MULTIPLE INSTANCING AND INTEROPERABILITY

It must be demonstrated, through plausibility tests in accordance with this chapter, that any number of instances of the model for the same unit can be executed in parallel independently of one another, and that unit models (including those based on DLLs) can be instantiated multiple times.

The plausibility of that is validated on the basis of Test 2 in section 5.5.7.10 of the FNN guideline on grid-forming capabilities [1], using at least two instances of the detailed RMS model.

Evaluation criteria: A positive result is achieved if all model instances can be run in parallel in a stable and error-free manner. Furthermore, each simulation must run to completion without any error messages (simulation termination), and no numerical instabilities must occur.

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[3] VDE (FNN), „VDE-AR-N 4110 Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung),“ Berlin, November 2023.

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