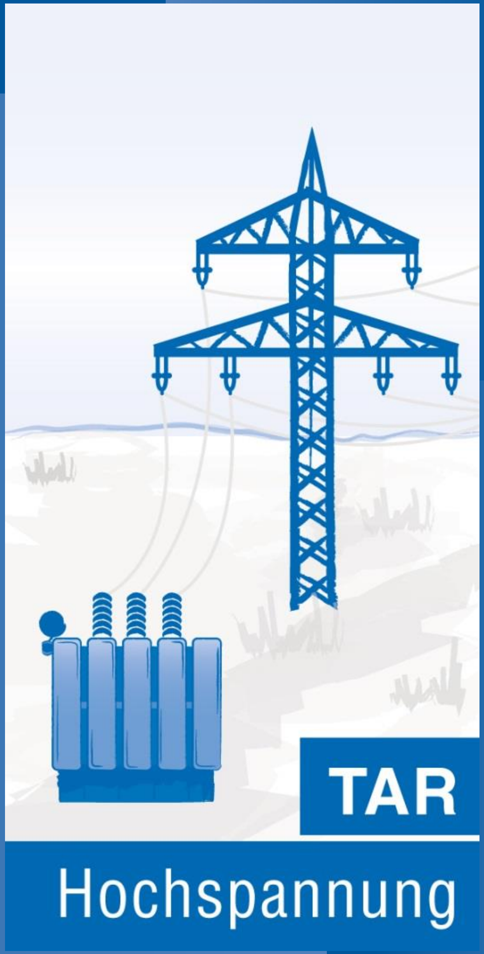
FNN

VDE

# Summary of the draft VDE-AR-N 4120:2017-05

The following summary:

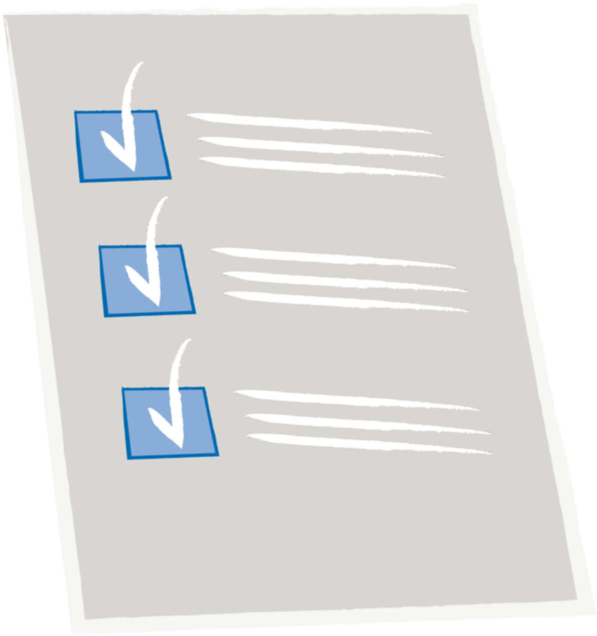
- does not cover all parts of the VDE-AR-N 4120 and is therefore not exhaustive;
- mainly covers the technical requirements for customer installations;
- and is purely informative.




Mai 2017

# Overview

- Section 5 und 10.2.2 Static Voltage Stability
- Section 10.2.3 Dynamic Grid Support
- Section 10.2.4 Active Power Supply
- Section 10.3 Protection systems and protection settings
- Section 10.4 Connection conditions and synchronization
- Section 10.5 Additional requirements for power generating modules



Section 5 and 10.2.2

# Static Voltage Stability

# 5.5 Reactive power behavior (demand facilities)

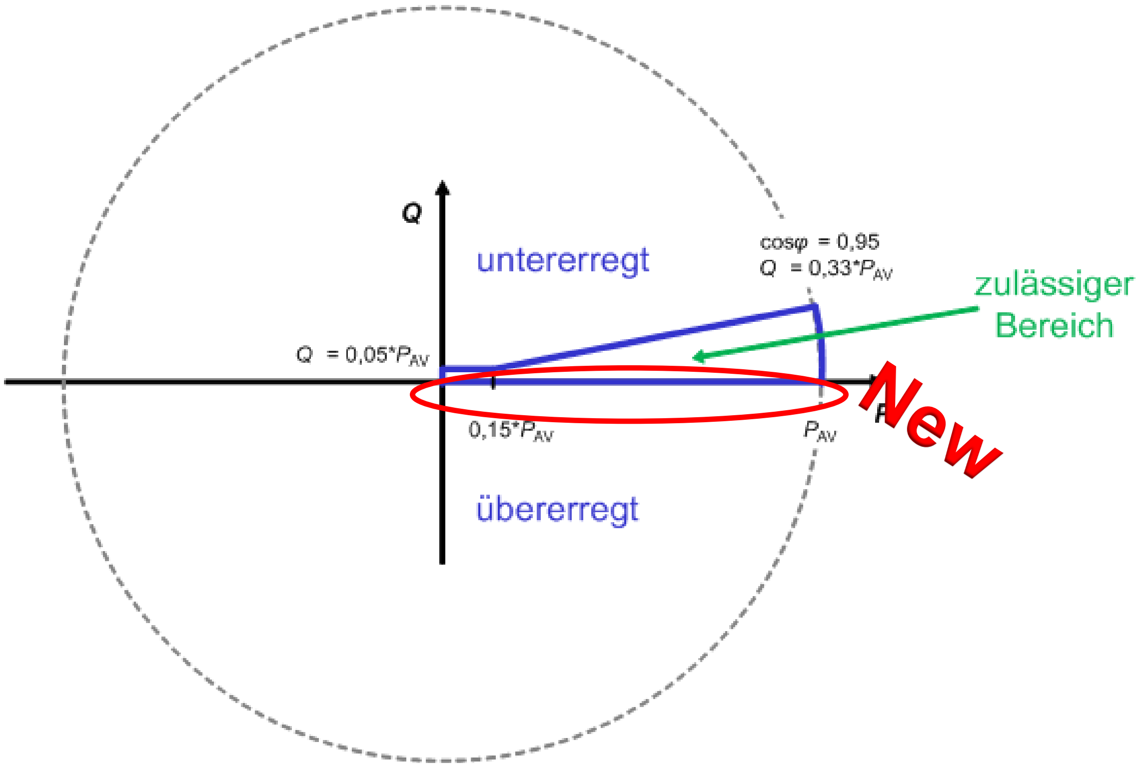



**Bild 2 – Zulässiger Bereich des Verschiebungsfaktors cos $\varphi$ bei Wirkleistungsbezug der Kundenanlage (dargestellt im Verbraucherzählpfeilsystem)**

# 5.5 Reactive power behavior (demand facility)

- Inclusion of inductive reactive power allowed (I. quadrant in Figure 2) up to maximum 5 % of the agreed active connection power $P_{AV, B}$ independent of active power;
- Inclusion of capacitive reactive power (IV. quadrant in Figure 2) not permitted; New
- above 15 % of the agreed active connection power $P_{AV, B}$, a displacement factor cos $\varphi = 0.95$ (inductive) is not allowed to be lower;

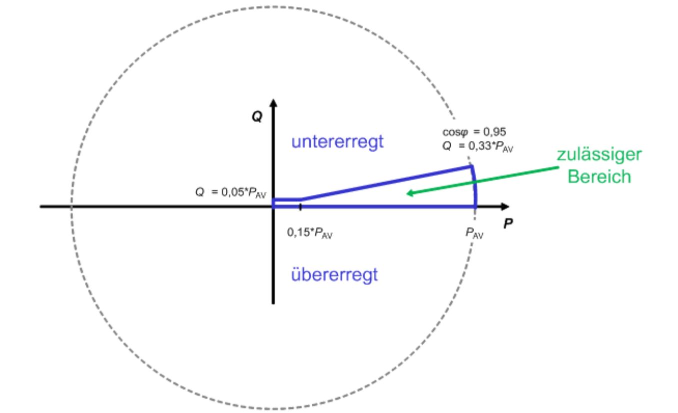



**Bild 2 – Zulässiger Bereich des Verschiebungsfaktors cos $\varphi$ bei Wirkleistungsbezug der Kundenanlage (dargestellt im Verbraucherzählpfeilsystem)**

# 10 Power generating modules

- Requirements apply equally to
  - power generating modules / power generating units
  - storage
  - combined facilities with generation/demand/storage (characteristics described separately)

New

New

- Caveat:

*“In the FNN’s Technical Connection Rules, currently being formulated or processed, additional requirements are under discussion for reactive power produced by power generating modules compared with previous regulations. This discussion has, with the current draft for TAR high voltage, not yet been concluded within the project group and will be finalized in the course of processing the statements.”*

# 10.2.1.1 Steady-state operation

- Voltage gradient < 5 % $U_n$/min and
- frequency gradient < 0.5 % $f_n$/min
- Voltage changes on the GCP of ≤ 10 % $U_n$ with ≥ 5 % $U_n$/min possible within the voltage range of 96 kV to 127 kV

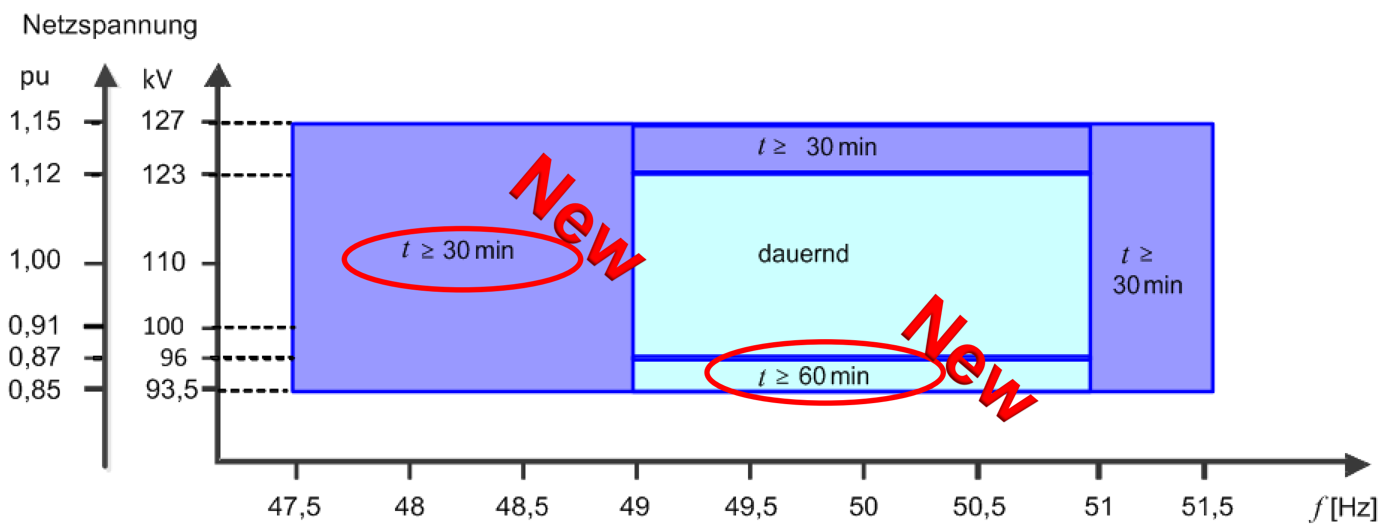



**Bild 3 – Anforderungen an den quasistationären Betrieb von Erzeugungsanlagen**

# 10.2.2 Static voltage stability/ Reactive power supply

- Definition:

  “S*tatic voltage* stability *denotes the supply of reactive power through a power generating module to maintain voltage in the high voltage grid. Due to the static voltage* stability, *slower (steady-state) voltage changes in the distribution grid should be kept within tolerable limits.”*

- The power generating modules’ power transformers must be equipped with a step switch that is adjustable under load.
- Requirements for reactive power behavior are to be met at the grid connection point.

# 10.2.2.2 Reactive power capability at P b inst

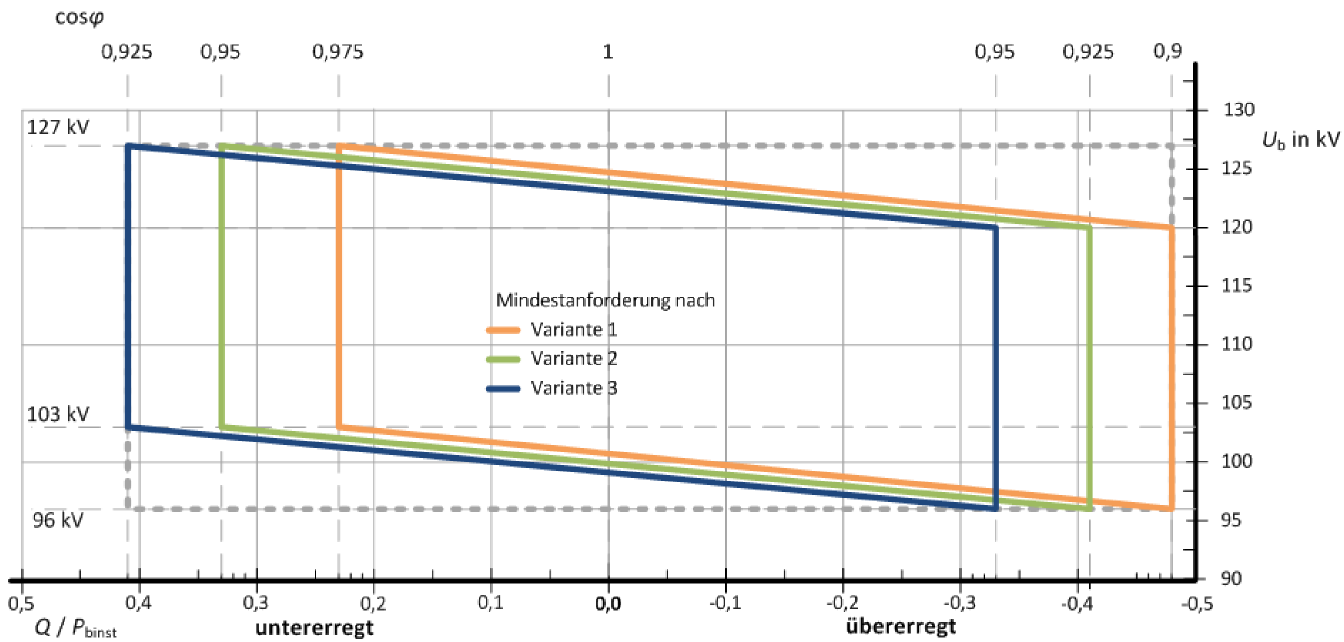



**Bild 4 – Varianten der Anforderungen an Erzeugungsanlagen an die Blindleistungsbereitstellung am Netzanschlusspunkt**

- Grid operator provides one of three possible variations in the course of planning for grid connection

# 10.2.2.3 Reactive power capability below P b inst


**Bild 5 – Varianten der PQ-Diagramme der Erzeugungsanlage am Netzanschlusspunkt im Verbraucherzählpfeilsystem**

# 10.2.2.3 Reactive power capability below $P_{b\ inst}$

New

- between $0 \leq P_{mom}/P_{AV,E} <$ **0.05** or the technical minimum performance for Type 1 modules, there are no requirements for controlled reactive power supply at the grid connection point, however the permitted range is defined as follows:
  - under-excited operation amounting to up to a maximum of 5 % of the agreed active connection power $P_{AV,E}$ is permitted, independent of active power
  - over-excited operation is normally not permitted

New

- maximum, remaining deviation between setpoint and actual value in the range $P_{mom}/P_{AV,E} \geq 0.05$ → maximum **± 2 %** relative to $P_{AV,E}$

New

# 10.2.2.4 Procedures for reactive power supply

- power generating modules must master the following procedures for reactive power supply:

a) Reactive power-voltage curve Q (U);

b) Idle power curve as function of active power Q (P);

c) Reactive power in Mvar;

d) Displacement factor cos $\varphi$.

- must be switchable by remote control system upon request by the grid operator

New

- fixed setpoint or variable setpoint via remote control system (or other control technology)
- transfer of setpoint to the substation
- Control behavior for procedures a), **b) and c)** should correspond to PT2 behavior (see attachment C.2)

New

# 10.2.2.4 Procedure for reactive power supply

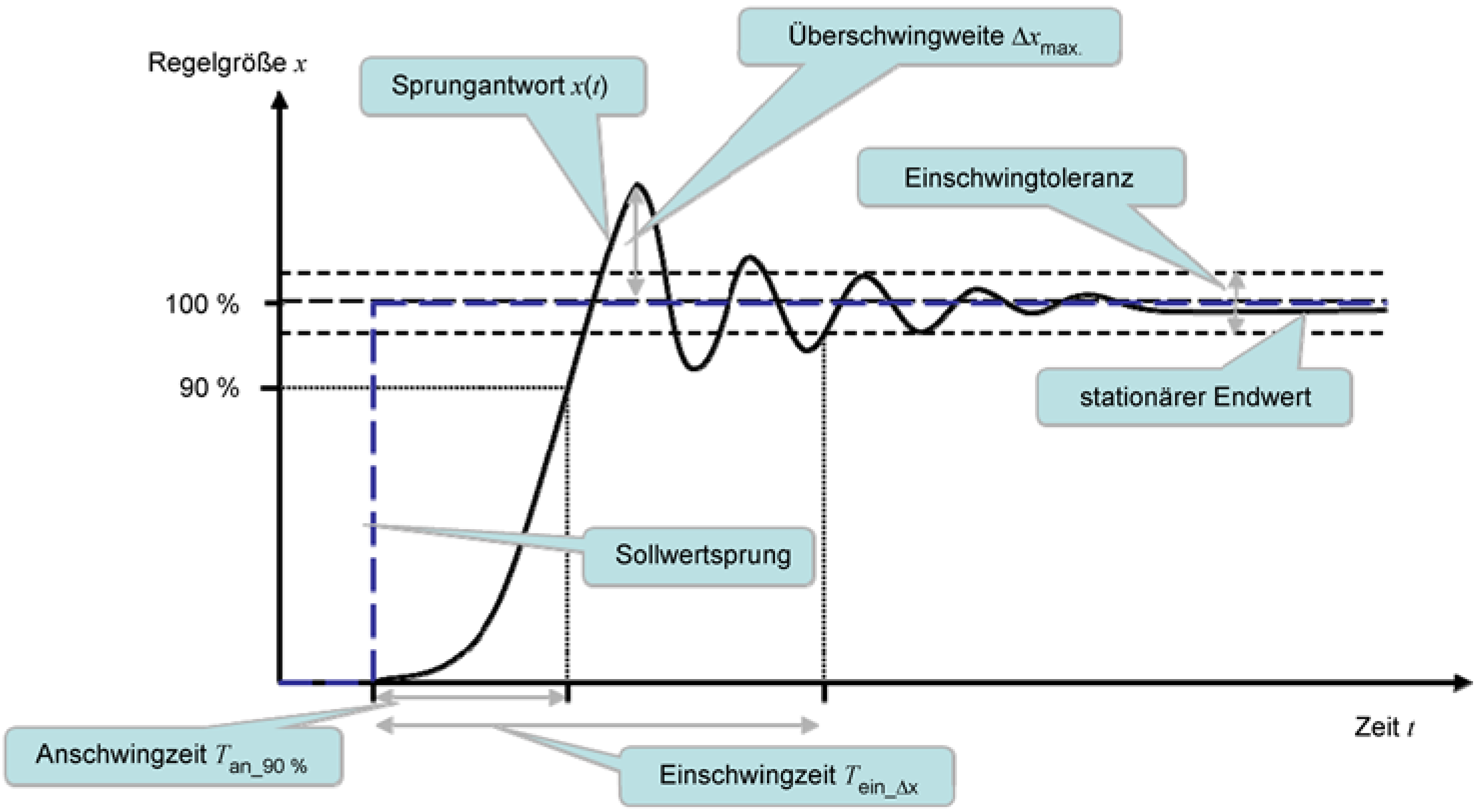



**Bild C.2 – Prinzipielles Reglerverhalten einer Erzeugungsanlage**

New

# 10.2.2.6 Special requirements for combined facilities with generation/demand/storage with demand facilities

- all requirements for power generating modules and storage at the grid connection point must follow Section 10.2.2.
- Impact of loads is not taken into account
- Agreement on measurement concept is essential (i.a. to ensure reactive power operation for the power generating module is not at the expense of the demand facility; decentralized measurement of the power generating module and/or shared operating equipment in the current path up to grid connection point)
- Simplification of an agreement with the grid operator is possible if the installed active power $P_{inst}$ of the power generating module ≤ 50% of the agreed reference power $P_{AV, B}$ of the combined facility with generation/demand/storage (does not apply to power generating modules with storage or storage alone)

New

# 10.2.2.6 Special requirements for combined facilities with generation/demand/storage with demand facilities

Simplification

- different location to GCP for the measuring point of the regulator
- for b), c) and d) measurement of Q and P can be done at the PGU → calculations adjusted and set at the GCP (without demand facility)

Beispiel der Erfüllung der Q-U-Regelung an alternativem Erfüllungspunkt bei Mischanlagen

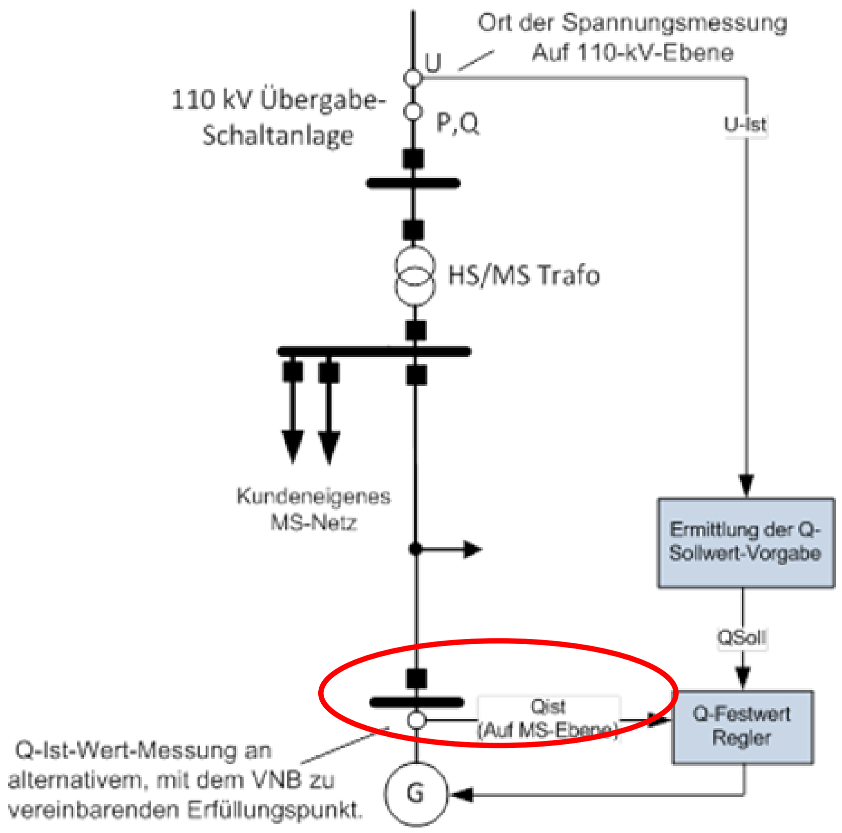


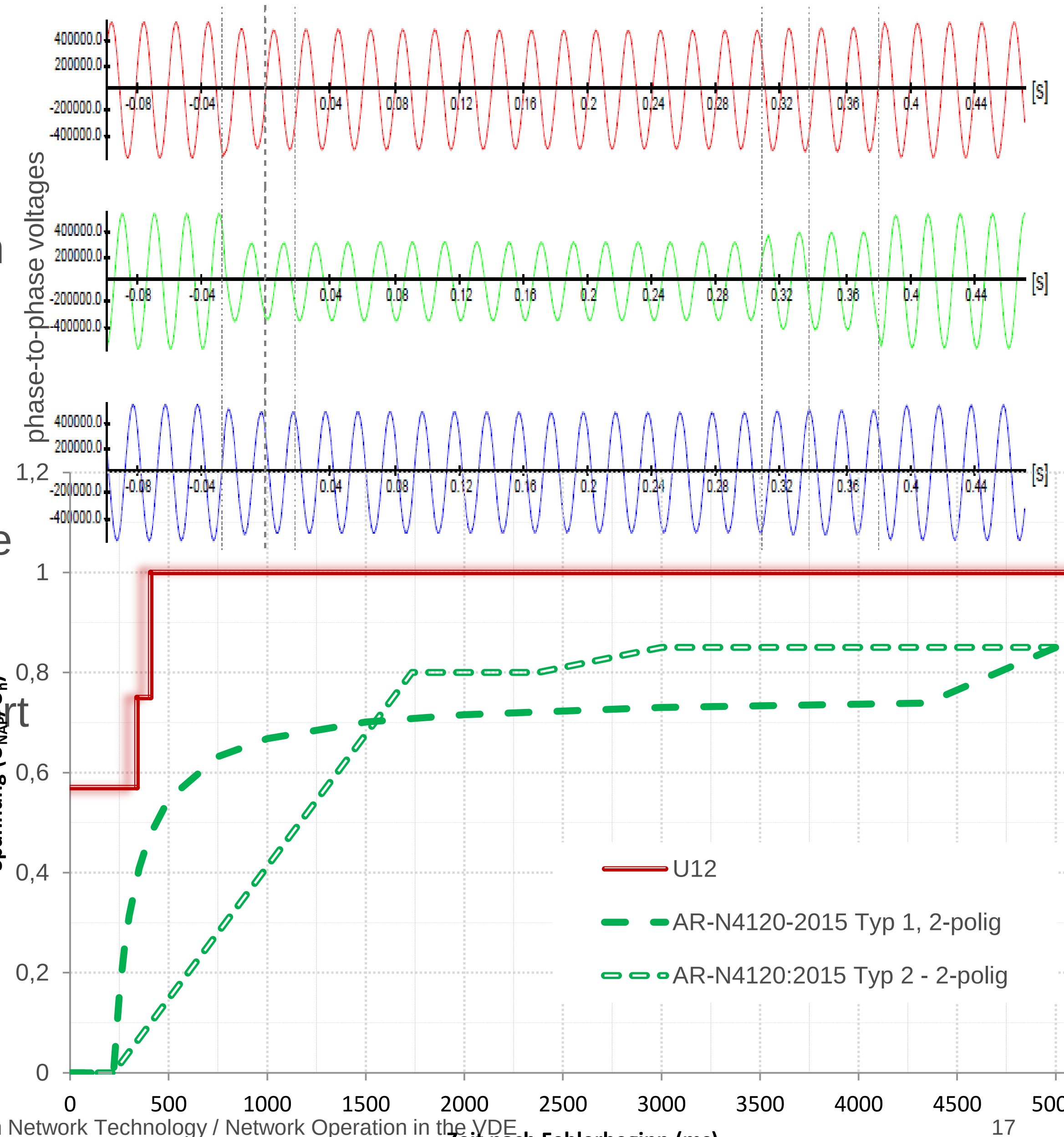

**Bild 8 – Beispiel der Erfüllung der $Q(U)$-Kennlinien-Regelung an zu vereinbarendem Ort bei Mischanlagen**

## Section 10.2.3

# Dynamic Grid Support

# Motivation

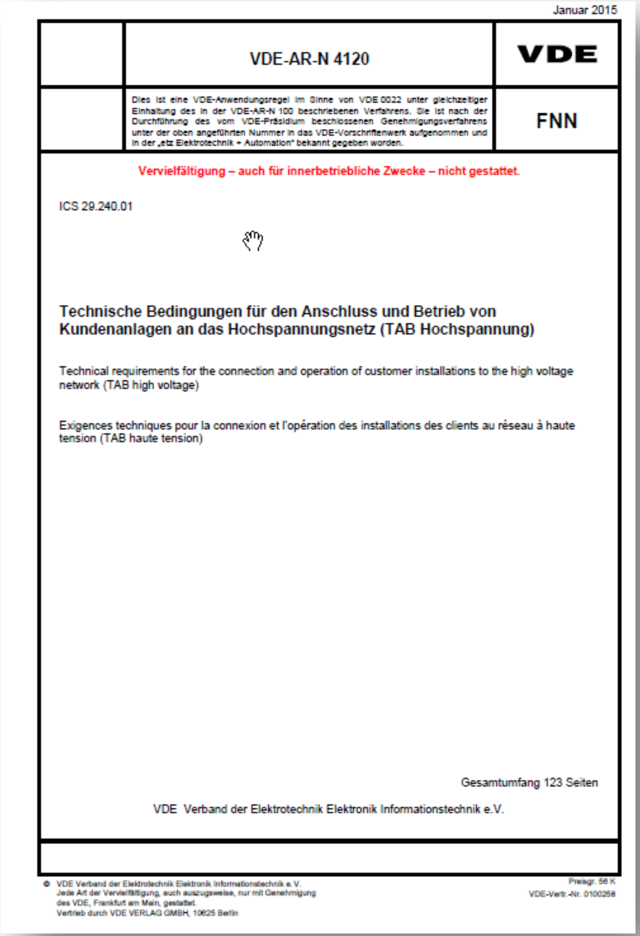
- example: Two-phase faults in high voltage grid
- max. changes to voltage: positive sequence: 20% negative sequence: 21%
- unsymmatrical faults far more frequent than symmatrical
- also incorporate fault-remote systems in the voltage support
- support also after fault clearing, to maintain reactive power allowance



# Status Quo: dyn. grid support in TAB high voltage 2015

- riding through grid faults with defined timed limits
- dyn. reactive current in positive and negative sequence (limitation on increase in voltage in non-faulty phases)
- riding through multiple faults
- return of active current min. 20% $I_r$/s

→ nature of requirements predominantly similar to current draft



Januar 2015

VDE-AR-N 4120

VDE

Dies ist eine VDE-Anwendungsregel im Sinne von VDE 0022 unter gleichzeitiger Einhaltung des in der VDE-AR-N 100 beschriebenen Verfahrens. Sie ist nach der Durchführung des vom VDE-Präsidium beschlossenen Genehmigungsverfahrens unter der oben angeführten Nummer in das VDE-Vorschriftenwerk aufgenommen und in der „etz Elektrotechnik + Automation" bekannt gegeben worden.

FNN

Vervielfältigung – auch für innerbetriebliche Zwecke – nicht gestattet.

ICS 29.240.01

**Technische Bedingungen für den Anschluss und Betrieb von Kundenanlagen an das Hochspannungsnetz (TAB Hochspannung)**

Technical requirements for the connection and operation of customer installations to the high voltage network (TAB high voltage)

Exigences techniques pour la connexion et l'opération des installations des clients au réseau à haute tension (TAB haute tension)

Gesamtumfang 123 Seiten

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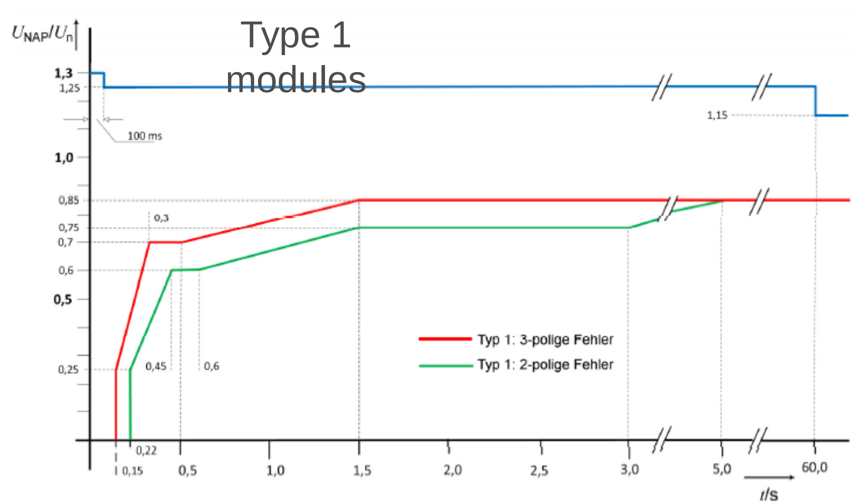
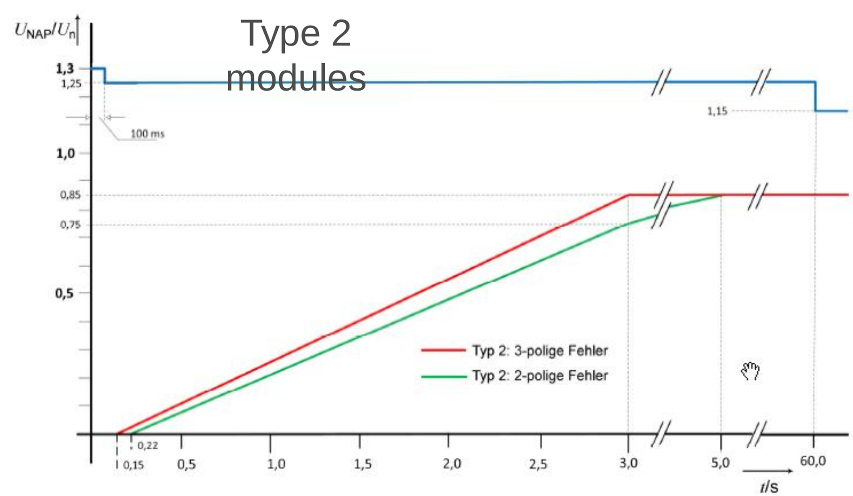
# Dynamic grid support in current draft of AR-N-4120

- power generating modules must ride through symmetrical and unsymmetrical grid faults
- to evaluate: smallest/largest of the three phase-to-phase voltages on the GCP
- Dynamic reactive current support in the positive and negative sequence
- an arbitrary sequence of multiple faults must be ridden through
- voltage surges within the FRT curves must not lead to tripping (≤10%, or ≤15% from 2021)
- under and over-voltage limit curves apply independently of one another
- requirements also apply to auxiliary systems!

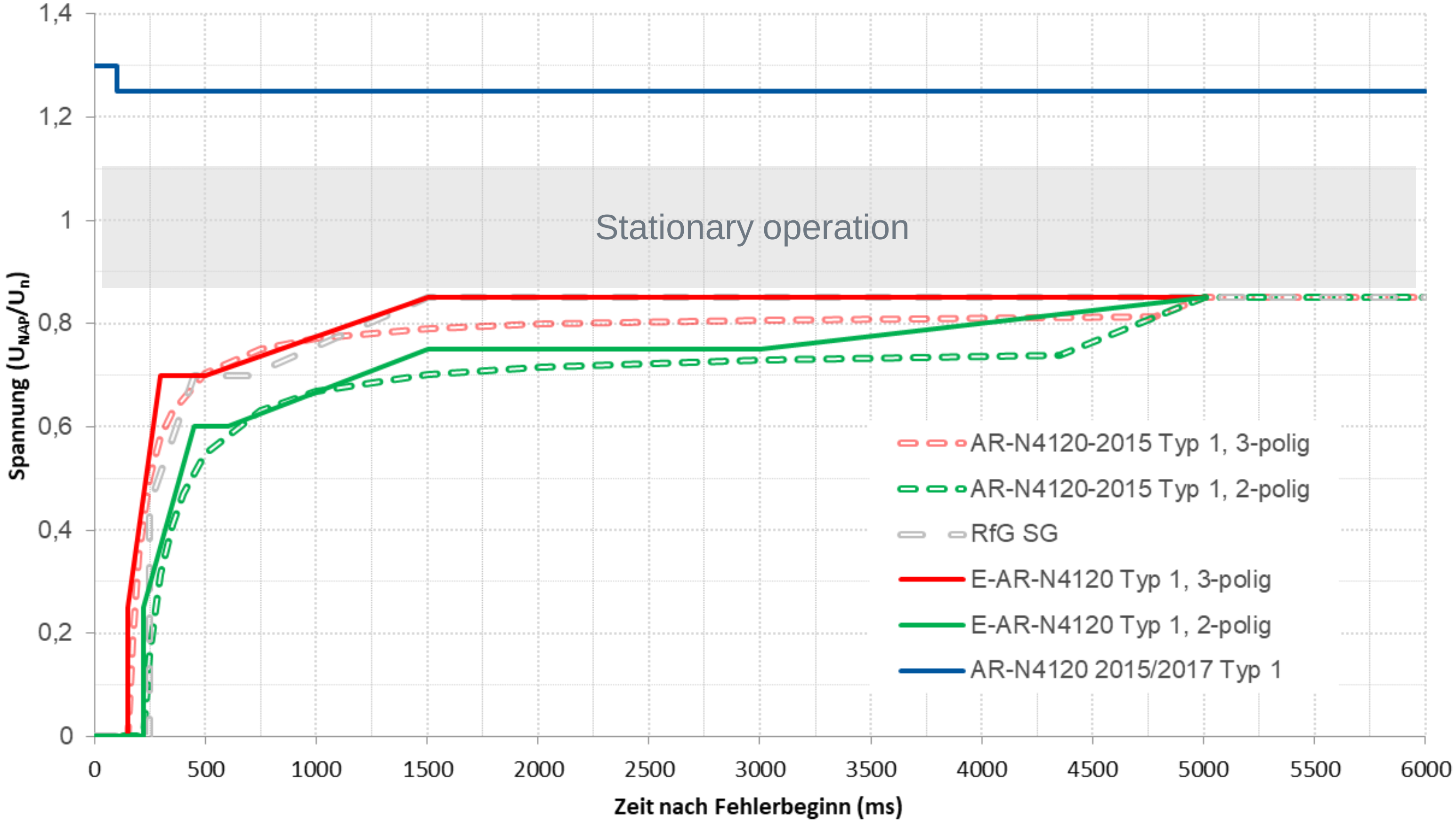


## Section 10.2.3.2

# Dynamic Grid Support for Type 1 modules

# Type 1 modules: Time constraints




- Lower limit curves were slightly adjusted (dependence on RfG curve for symmetrical faults)
- Two-phase faults: often a more profound issue, usually non-critical for PGM (green curve)
- Requirements for riding through surges (upper limit curve) unchanged compared to AR-N-4120-2015 (after 60s to U=1.15)

# Other / general requirements Type 1 modules

- Voltage drops within the a.m. limit curves should be ridden through if $S_k$" at connection point is > 6 $S_{A,Ges}$ after the End of fault in the relevant grid
- Voltage regulator settings and software status must be defined and traceable
- Plants >10MW shall be prepared for Power System Stabilizers and have to be equipped by request of the grid operator
- After fault end: Increase active current as quickly as possible, response time maximum 3 seconds

# Multiple faults

- It must be possible to ride through multiple consecutive faults
- Thermal design of the generator according to DIN EN 60034-1 must be guaranteed
- tripping permitted, if
  - these thermal limits are exceeded by multiple faults
  - instability threatens (e.g. oscillation of the shaft)

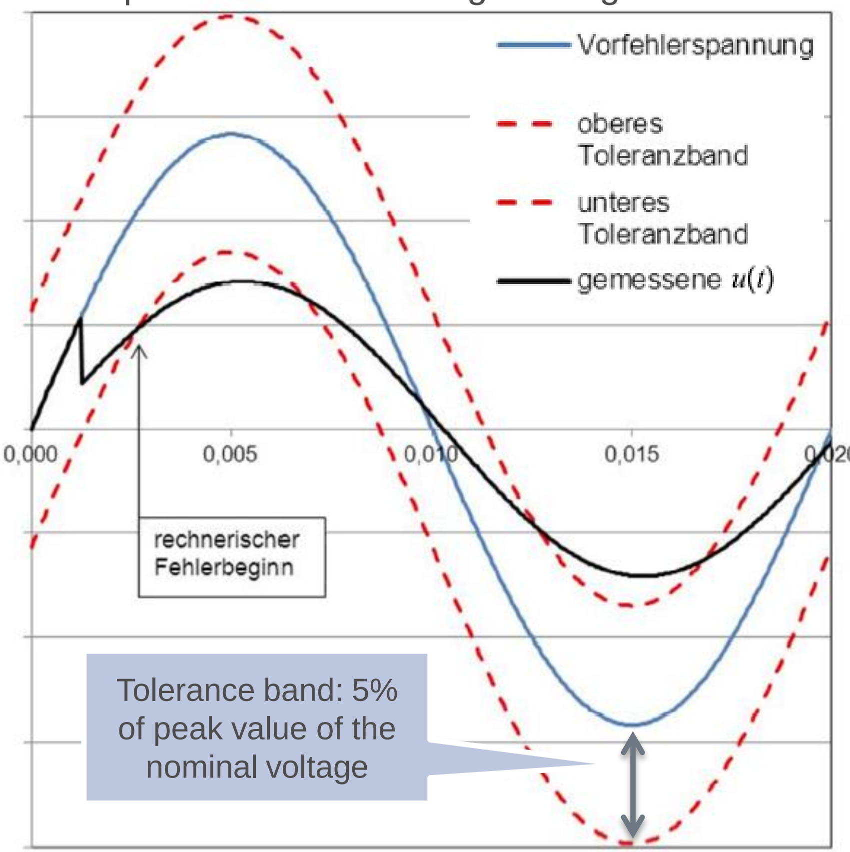
## Section 10.2.3.3

# Dynamic Grid Support for Type 2 modules

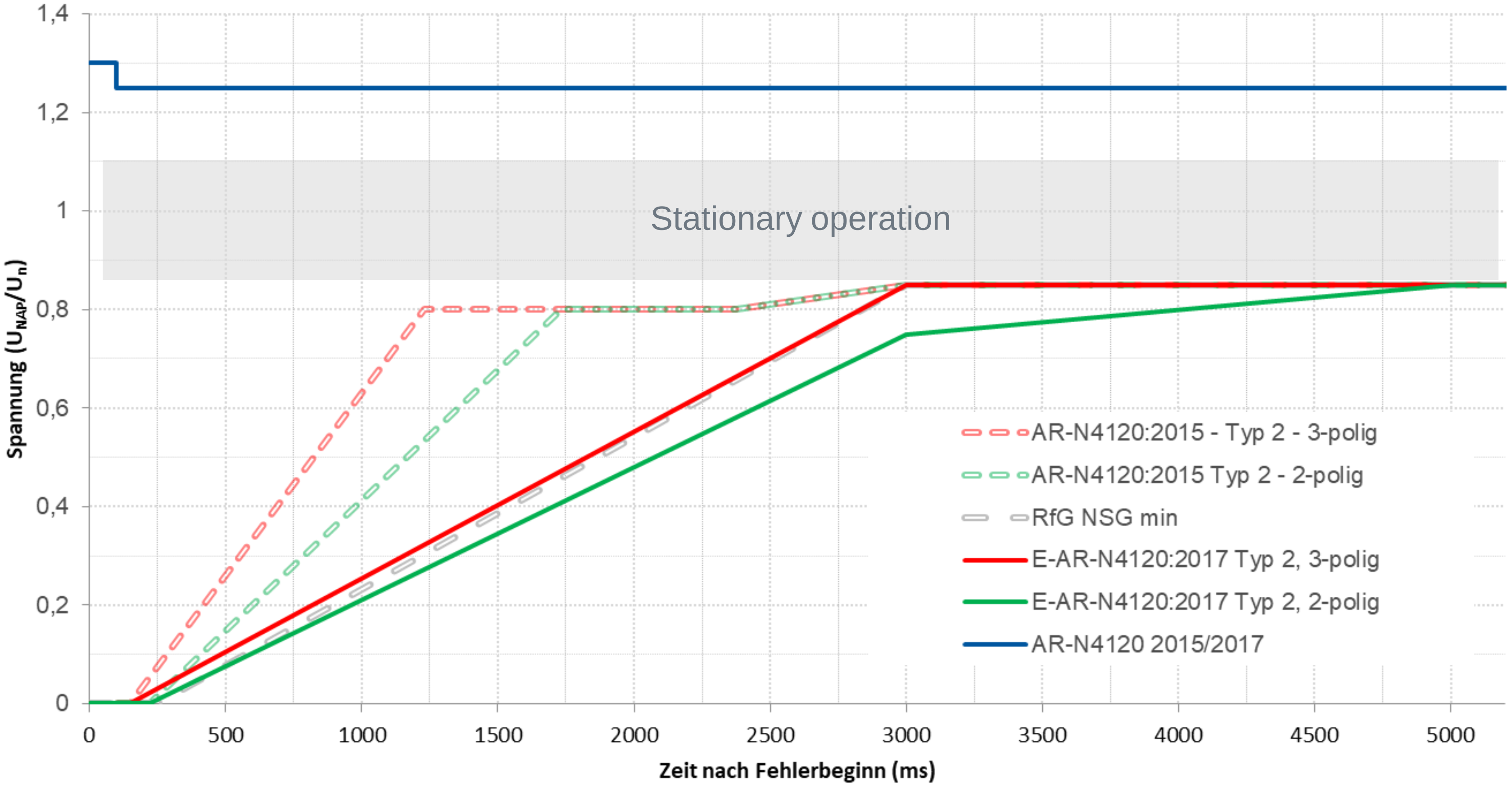
# Type 2 modules: Fault start and end

- Criteria for fault start:
  - sudden voltage changes compared to 50 pre-fault voltage periods
  - Voltages > 1.1 $U_{MS}$ or < 0.9 $U_{MS}$
    $U_{MS}$: controller's target voltage for the plant''s medium voltage
- Criteria for fault end:
  - 5s after fault start
  - Restoration of all L-L voltages in the range of 0.9 $U_{MS}$< U <1.1 $U_{MS}$
- New faults, as soon as a criterion for fault end was completed
- These are calculated criteria, in order to make behavior verifiable

Example of a sudden voltage change



# Type 2 modules: Time constraints



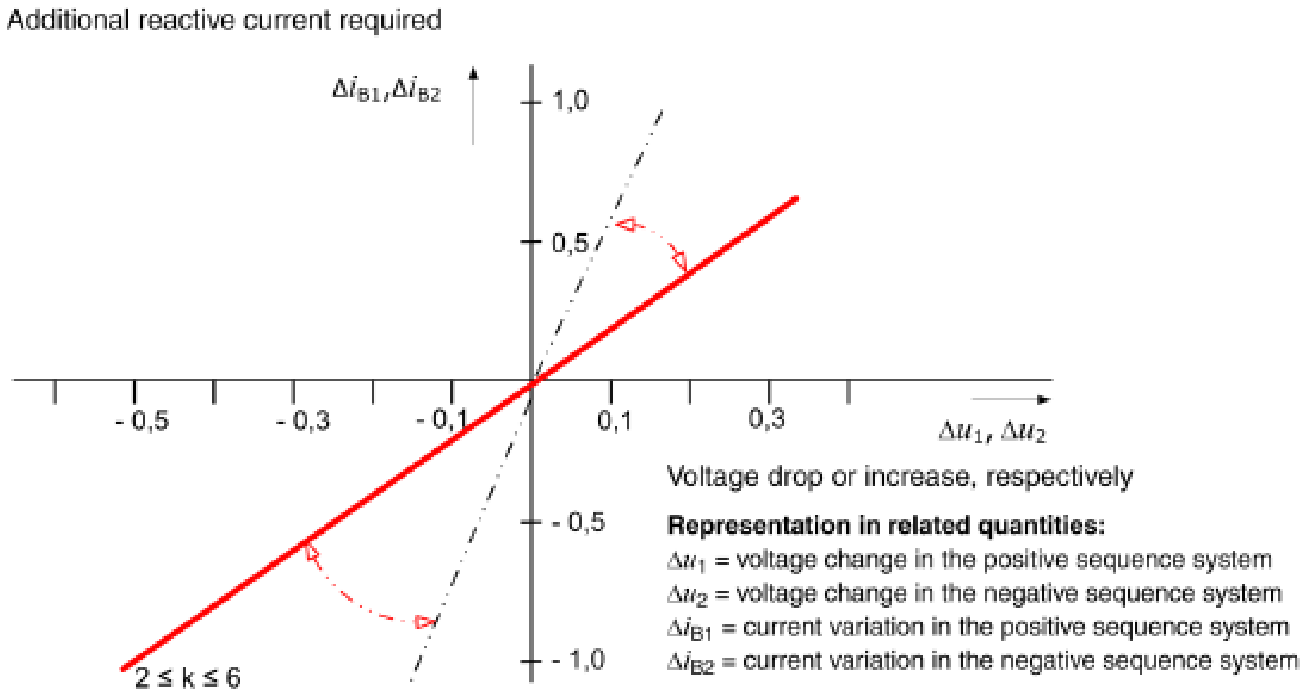

- Requirements of Type 2 modules **expanded**, to conform with RfG limit curve
- **Two-phase** faults: often a more profound issue, usually non-critical for PGM (green curve)
- Requirements for riding through **surges** (upper limit curve) unchanged compared to AR-N-4120-2015

# Type 2 modules: Comprehensive Dynamic Grid Support

- Supply of additional reactive current from fault start
- Objective: Optimum grid support for symmetrical and unsymmetrical faults
- Minimization of surges in non-faulty phases → grid support in positive and negative sequence
- Voltage measurement and provision of additional reactive current at the PGU
- Reactive current is prioritized; setpoint arises continually from the curve; active current is continually readjusted
- After fault end:
  - Increase in active current to pre-fault value within maximum one second (response time)
  - Transition to static voltage stability

# Type 2 modules: Comprehensive Dynamic Grid Support

- Context: 1-min mean value of the grid voltage (here: L-L values); $U_2 \rightarrow 0$ → unchanged reference for the whole duration of the fault
-
$$\Delta u_1 = \frac{\left|\underline{U_1}\right| - U_{1min}}{U_n}$$
$$\Delta u_2 = \frac{U_2}{U_n}$$
- zus. Blindstrom:
$$\Delta i_{B1,2} = k \cdot \Delta u_{1,2}$$
- Dynamik:
$$T_{an_{90}\%} \leq 30\text{ ms}$$
$$T_{ein\_\Delta x} \leq 60\text{ ms}$$

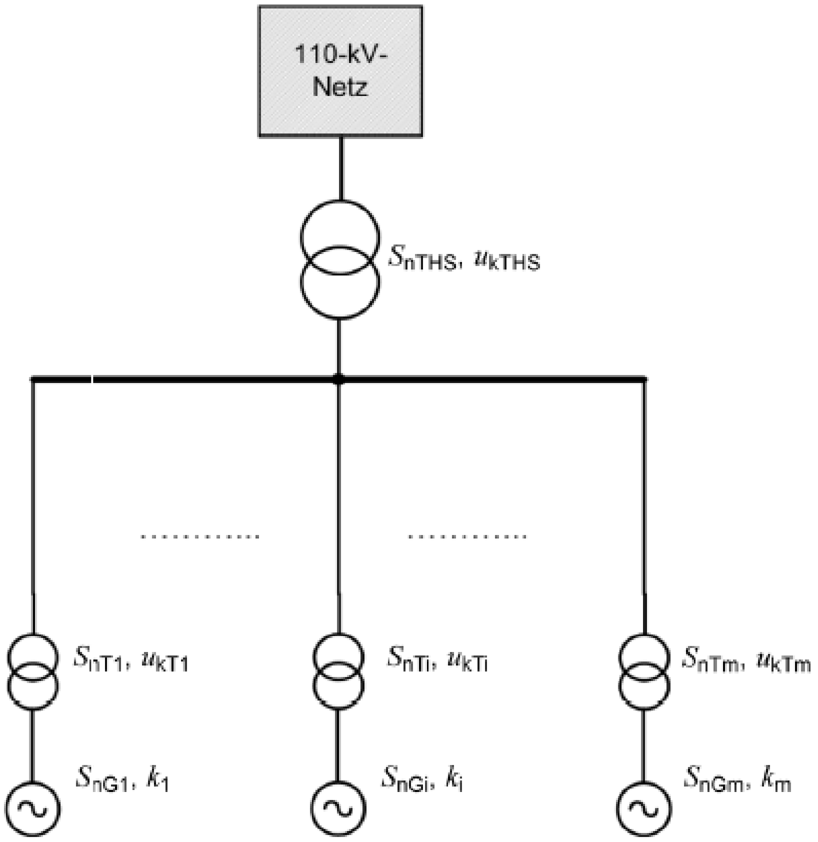


# Calculation of k-Factor at grid connection point

- Internal plant impedances impacting the effective k-Factor
- Formula for calculating the k-Factor value:

$$k_i = \frac{c_K}{\frac{1}{k_{soll}} - u_{kTi} \cdot \frac{S_{nGi}}{S_{nTi}} - u_{kTHS} \cdot \frac{\sum_1^m S_{nGi}}{S_{nTHS}}}$$

- Example:
  Plant with $S_{nTHS}$ = 30MVA; $u_{kTHS}$ = 12%;
  15 PGU each with 2MVA, $S_T$=$S_{nG}$; $u_{kTi}$=6%
- $k_{soll}$ = 2 → $k_i \approx 3$



# Multiple faults

- It must be possible to ride through an arbitrary sequence of grid faults
- With some plant types there may be limitations
  → Requirement is limited to an energy of $P_{Emax} \cdot 2s$ dissipated or not supplied to the grid as a result of grid fault effects
- between multiple grid fault sequences, a time of 30min is estimated
- Verification through test sequence:

| Netzereignis | Residualspannung bezogen auf $U_{1min}$ | Dauer [ms] | Pausenzeit |
|---|---|---|---|
| Doppelfehler | 0,2 – 0,3 | 140 ms – 160 ms | 0,3 s – 2 s |
| | 0,2 – 0,3 | 550 ms – 600 ms | 20 s – 30 s |
| Standardfehler | 0,2 – 0,3 | 950 ms – 1050 ms | 20 s – 30 s |
| Doppelfehler | 0,2 – 0,3 | 140 ms – 160 ms | 0,3 s – 2 s |
| | 0,2 – 0,3 | 950 ms – 1050 ms | 20 s – 30 s |

# Summary and Dynamic Grid Support

- The requirements in the draft AR-N 4120 for dynamic grid support were revised compared to AR-N 4120:2015-1 and aligned with the RfG framework
- The required conduct was specifically revised regarding
  - time requirements
  - sudden voltage changes
  - conduct after the fault
  - multiple faults
  - verification procedures

Section 10.2.4

# Active Power Supply

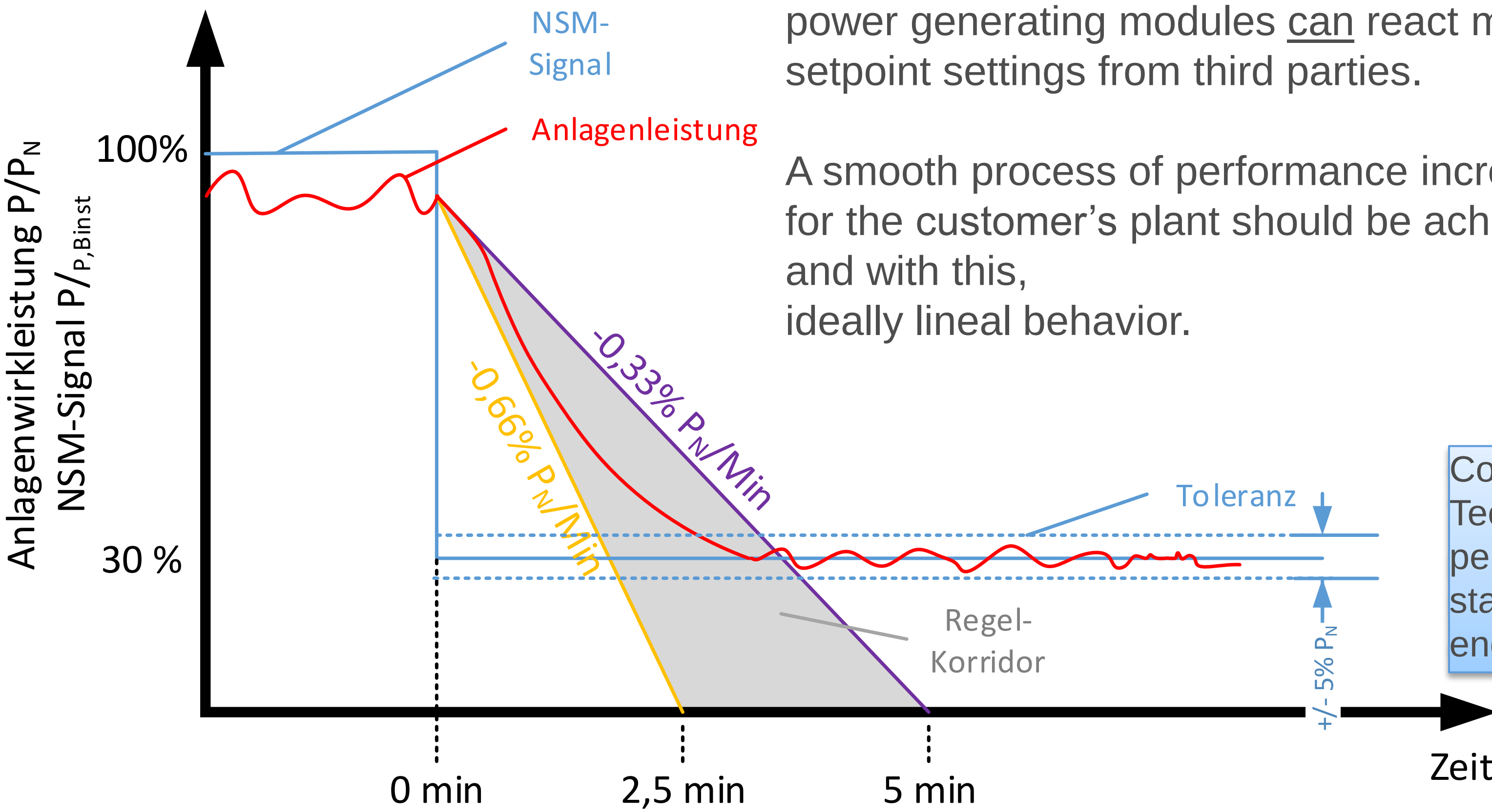
# Requirements for power generating modules – active power supply

- **10.2.4.1 Overview**
  - Speed restrictions
  - Prioritisation
- **10.2.4.2 Grid security management**
  - DSO requirements
- **10.2.4.3 Active power supply for over and under frequency**
  - Requirements of grid retention
  - P-f curves

# PGM – active power supply / overview

- **Challenges:**
  - increasing number of plants participate in direct marketing
  - higher power gradients up to 15 min change as a result
  - sudden power changes are always dangerous
  - synchronized plant behavior potentially critical
  - in future, controllable demand facilities are also likely

# PGM – active power supply / limitation of gradients




Limitation of performance gradients are for increasing and reducing active power supply and active power usage

– no faster than in 2.5 min (0.66 % $P_N$ per second);

– no slower than in 5 min (0.33 % $P_N$ per second).

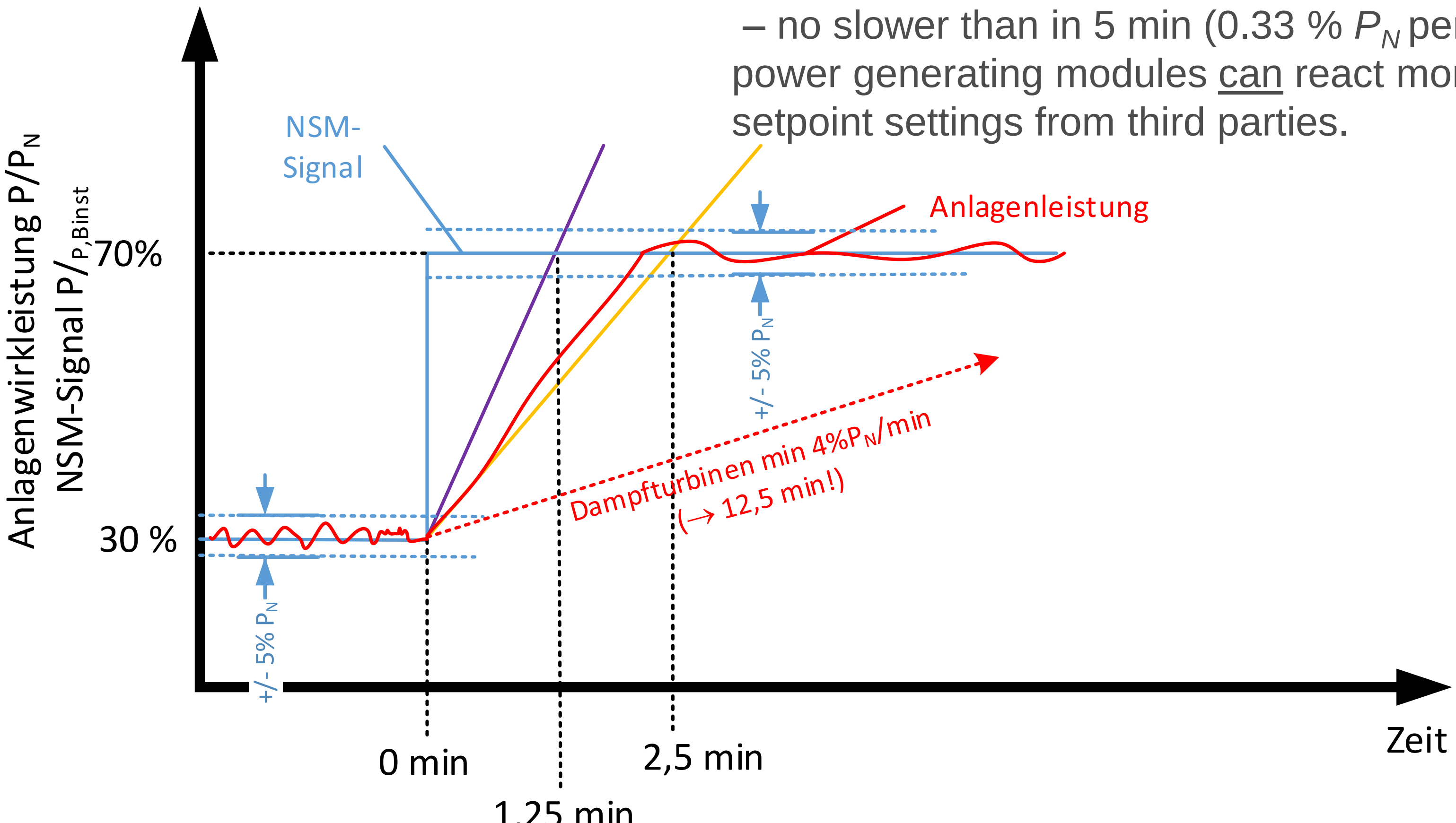
power generating modules <u>can</u> react more slowly to setpoint settings from third parties.

A smooth process of performance increase or reduction for the customer's plant should be achieved, and with this, ideally lineal behavior.

Comments:
Techn. minimum performance stated for combustion engines

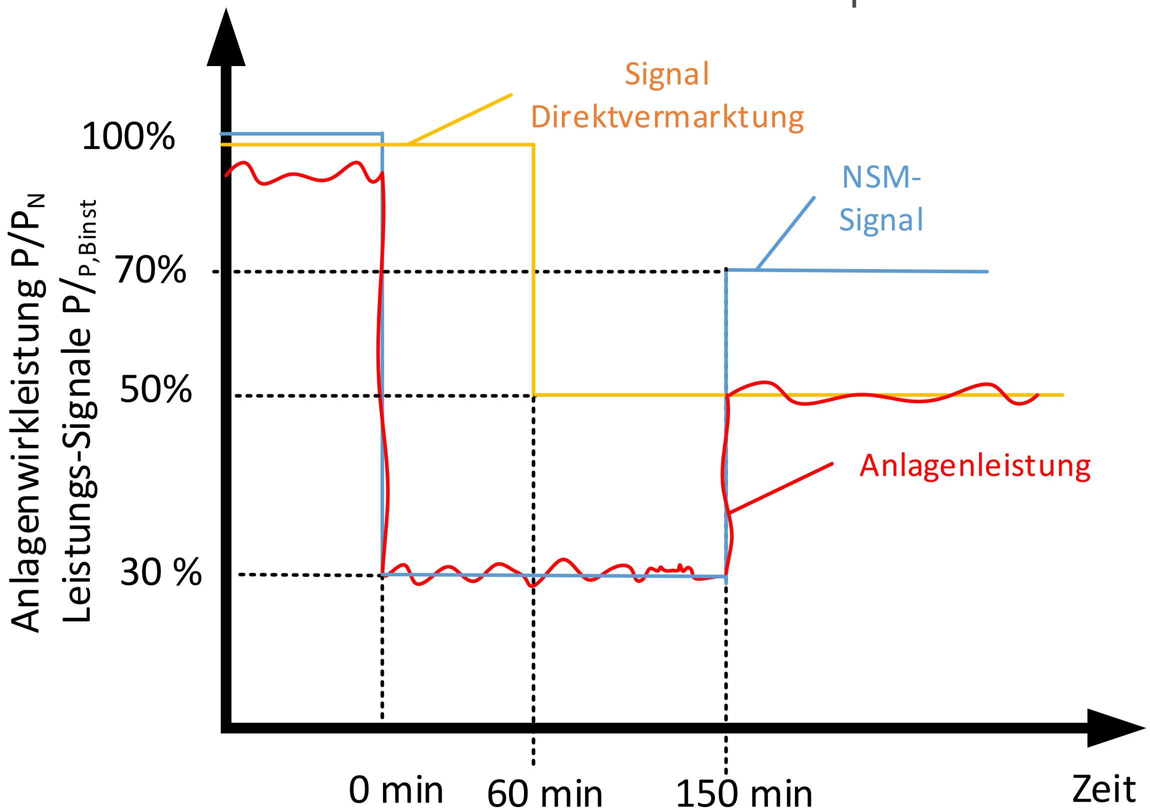
# PGM – active power supply / performance increase

Limitation of performance gradients are for increasing and reducing active power supply and active power usage
– no faster than in 2.5 min (0.66 % $P_N$ per second);
– no slower than in 5 min (0.33 % $P_N$ per second).
power generating modules can react more slowly to setpoint settings from third parties.

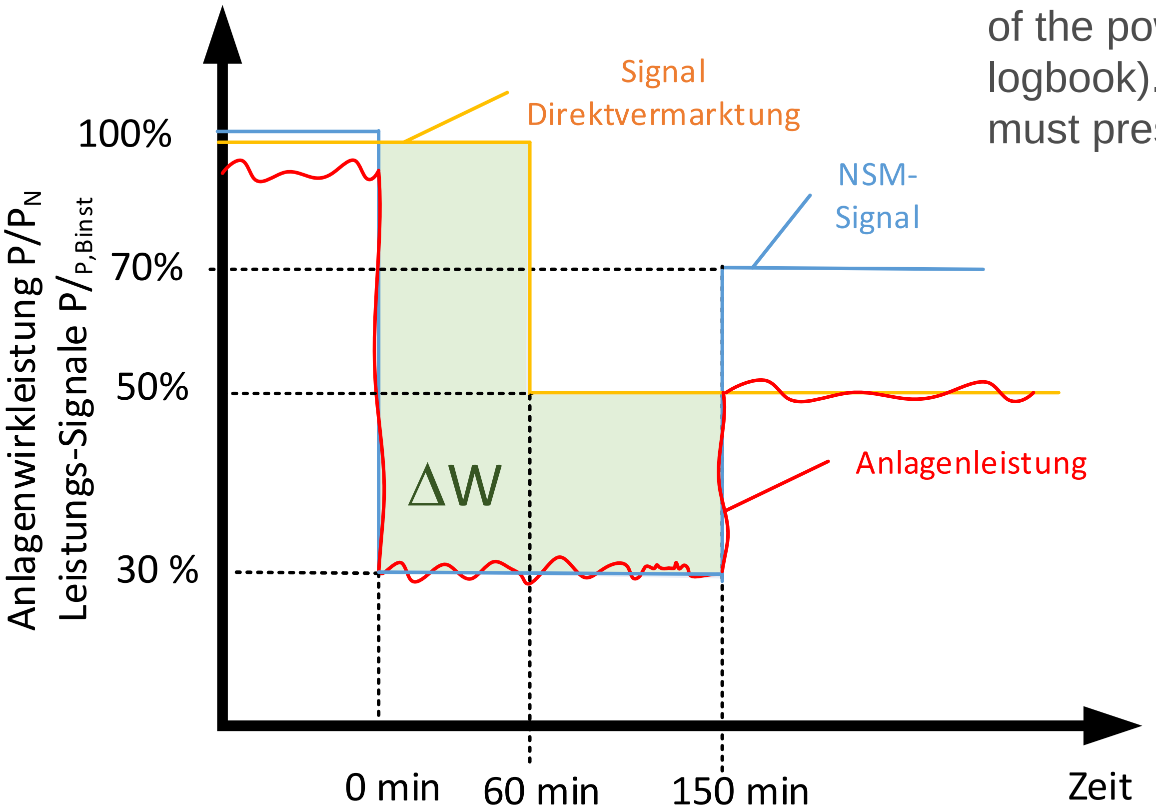


# PGM – active power supply / priority regulations

With temporally overlapping active power specifications of grid operators (grid security management) and third parties (market specifications, personal requirement improvements etc.), smaller services always matter



# PGM – active power supply / logbook




The plant operator must always retain evidence for the prior 12 months of power regulation for grid security management and interference by third parties during operation of the power generating module (e.g. in a logbook). Upon demand, the grid operator must present this evidence.

# Active power supply during frequency deviations **Fundamentals**

Most recently: 2006

- if f <49.8 Hz or f>50.2 Hz then: System is at risk
  - P-changes have priority over market (complies with EnWG Art.13)
  - P-changes do not have priority over NSM

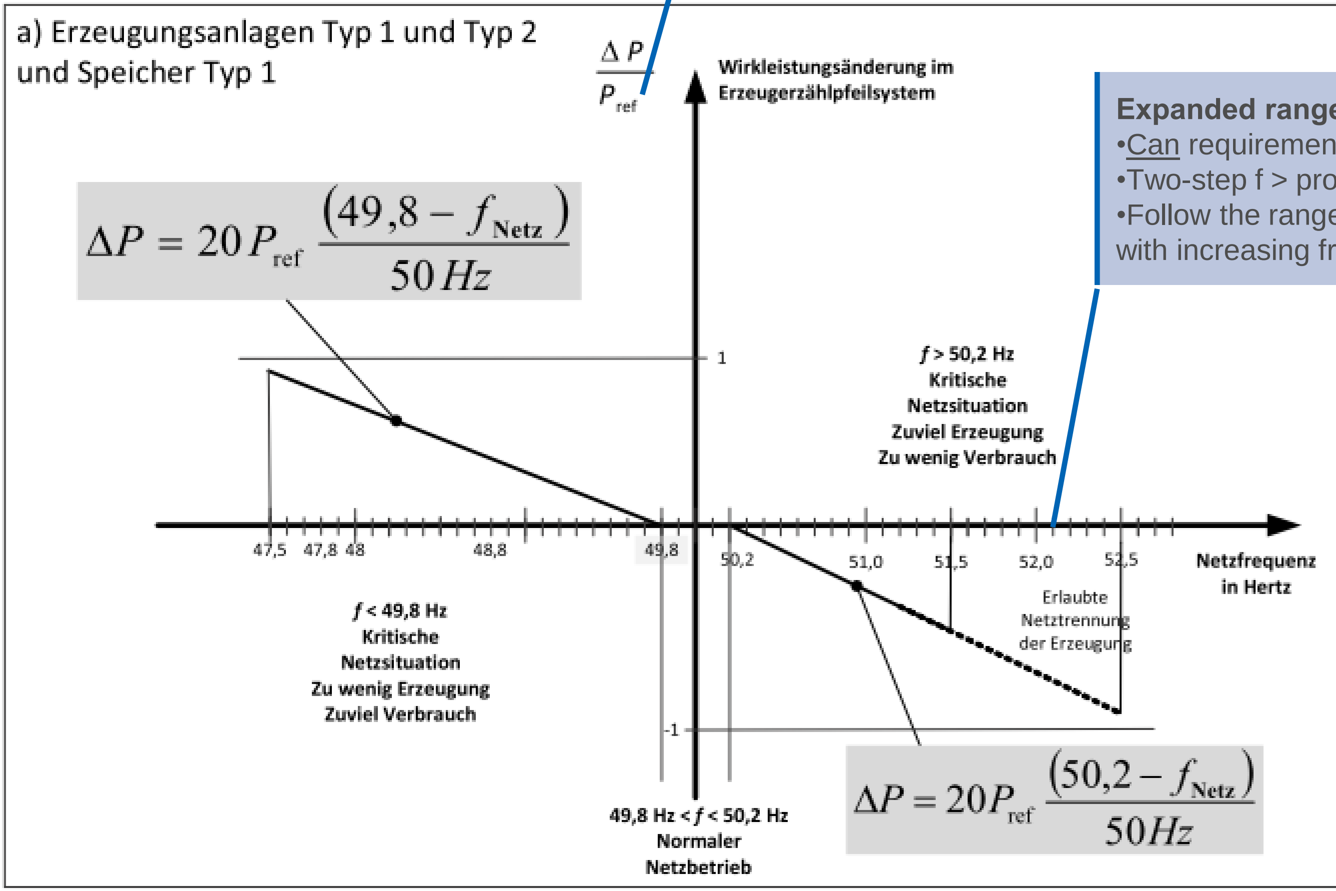
    Reason: if NSM was used, the grid is close to 100% capacity at the MV level; additional capacity increase risks tripping protection and loss of the entire production.

- When does that cease?
  - If 49.8 Hz < f <50.2 Hz → generally OK;
  - But please slowly return to “Normal status”!
  - If f in “Range”: Active power changes of a maximum of 10 % $P_N$ /min
  - if f over 10 min long within the tolerance range → normal grid operation

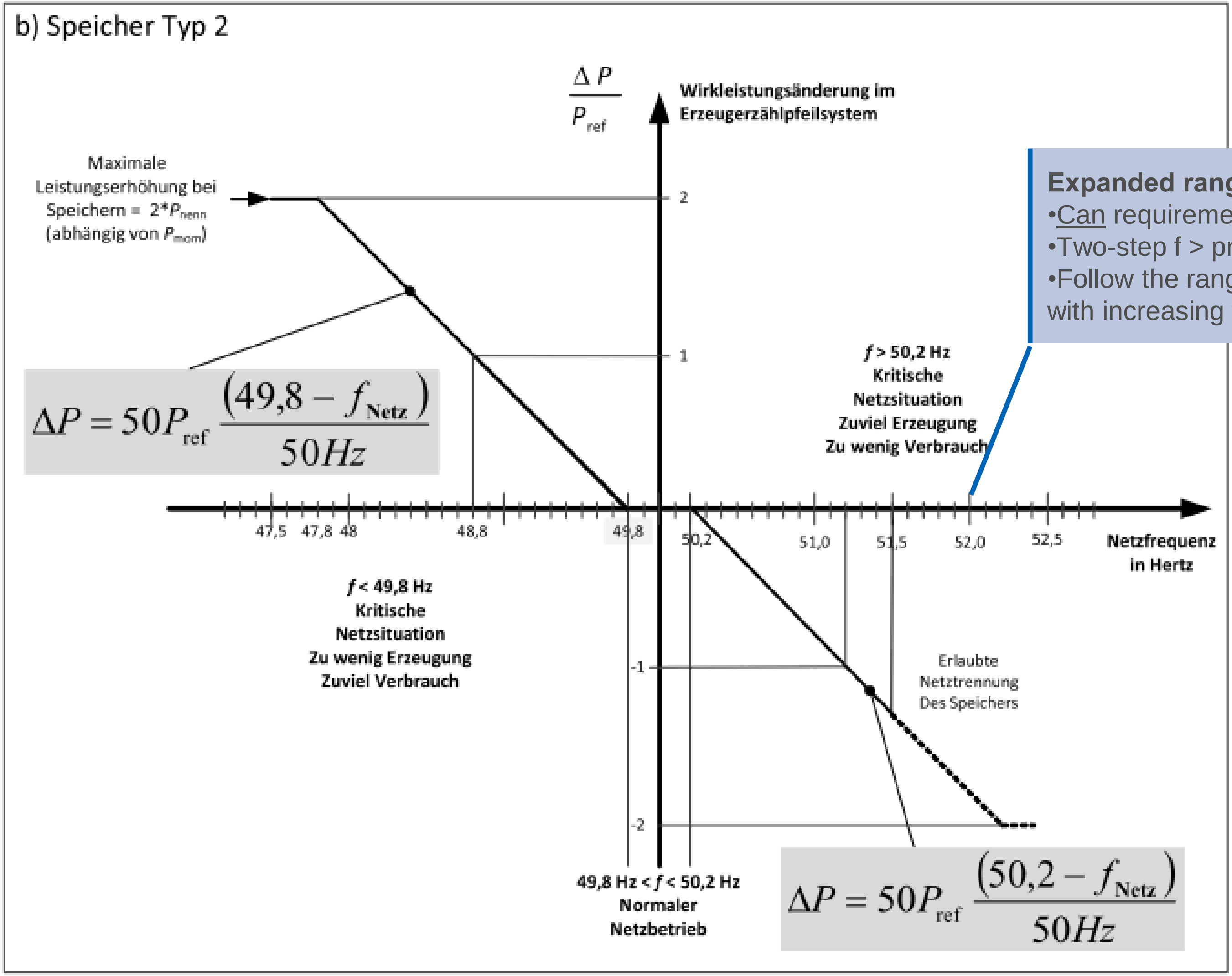
# PGM – active power supply at over or under-frequency for PGM Type 1 and 2 and storage Type 1

$P_{ref}$=$P_{MOM}$ for Type 2: → No change (remains locked at f=50.2 or f=49.8)
$P_{ref}$ = $P_N$ for Type 1: → RfG (fixed curve slope)

**Expanded range for overshots" by 5 s**
- Can requirement
- Two-step f > protection
- Follow the range curve where possible; no increase with increasing frequency



# PGM – active power supply at over or under-frequency for storage Type 2




**Expanded range for overshots" by 5 s**
- Can requirement
- Two-step f > protection
- Follow the range curve where possible; no increase with increasing frequency

# PGM – active power supply at over or under-frequency
# Control times

| | | Type 1 | Type 2 | |
|---|---|---|---|---|
| | | Generation units and storage | Generation units | Storage |
| **Power increase** | Step response time when decreasing frequency in the range of 49.8 Hz – 47.5 Hz | ≤ 5 min for a Δf of up to 0.5 Hz | ≤ 10 s | ≤ 1 s |
| | Step response time when decreasing frequency in the range of 51.5 Hz - 50.2 Hz | ≤ 5 min for a Δf of up to 0.5 Hz | ≤ 5 s for a Δf of up to 0.5 Hz | |
| | Settling time | ≤ 6 min | ≤ 30 s | ≤ 10 s |
| **Power reduction** | Step response time when increasing frequency in the range of 50.2 Hz - 51.5 Hz | ≤ 8 s for a Δf of up to 1.3 Hz | ≤ 2 s for a Δf of up to 1.3 Hz | ≤ 1 s |
| | Step response time when increasing frequency in the range of 47.5 Hz – 49.8 Hz | | | |
| | Settling time | ≤ 30 s | ≤ 20 s | ≤ 10 s |

# PGM – active power supply at over or under-frequency
# Control times

**Limited requirements due to technical restrictions**

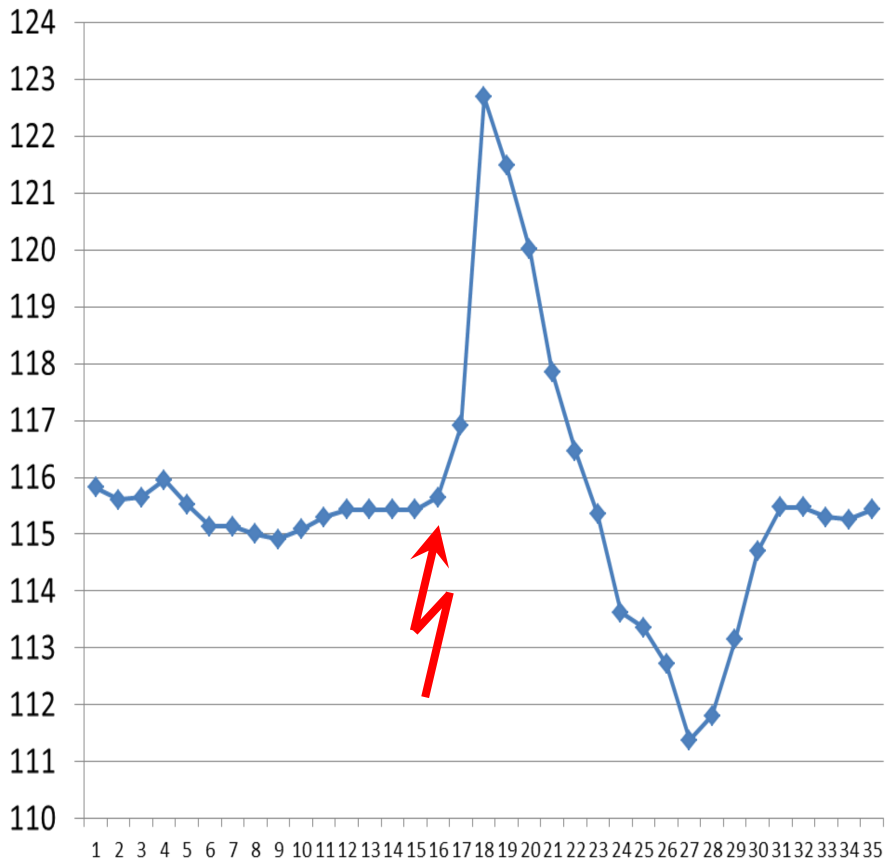
- Wind (active power increase): if wind > 50% $P_N$ response time of 5 s (at a frequency change of 0.5 Hz) if wind < 50% $P_N$ no requirements for control times
- Combustion engines or gas turbines:
  - ≤ 2 MW minimum 66 % $P_n$ per minute
  - > 2 MW minimum 20 % $P_n$ per minute
- Increase through steam turbines; minimum 4 % $P_n$ /min
- For hydroelectric power plants (incl. pumped storage), the response and settling times must be agreed for each specific project with the grid operator

## Section 10.3

# Protection systems and protection settings - experiences gained from grid faults with voltage protection systems

# Case 1) short circuit in 110kV grid

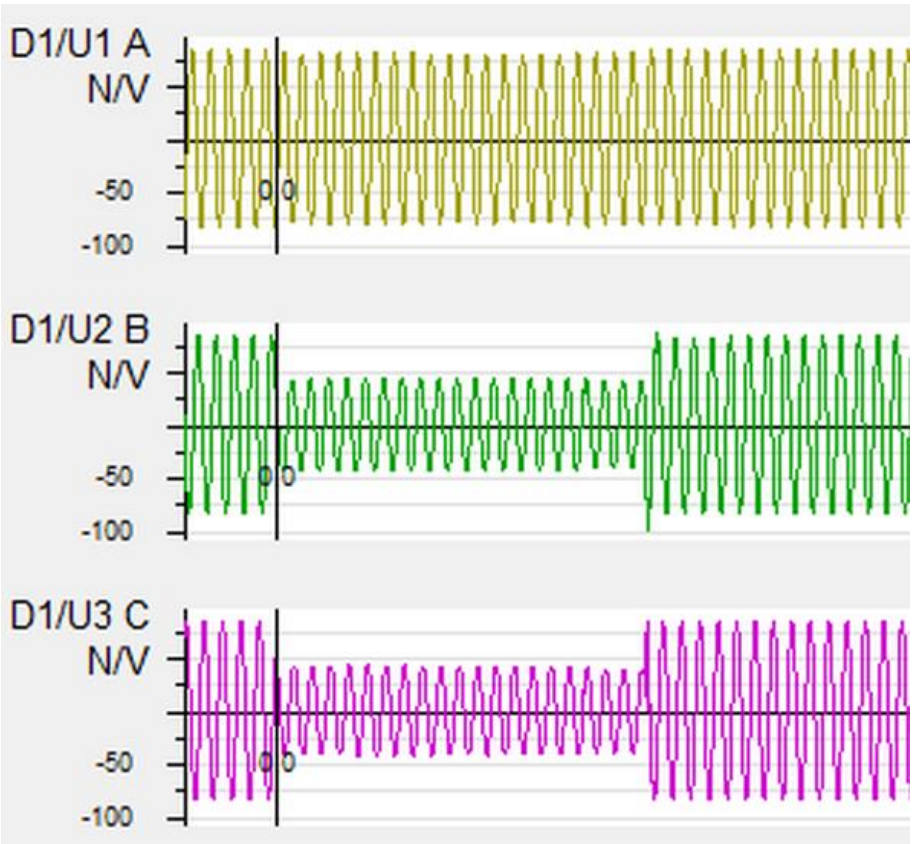
L-L voltage in kV (minute values)

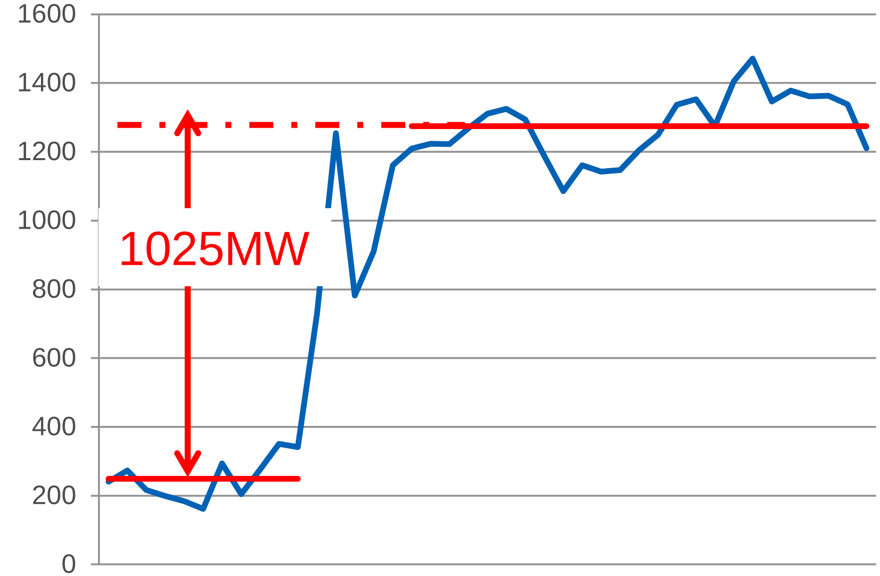



- Two-phase short circuit 110kV
- fault clearing time 90ms
- Loss of generation capacity >900MW
- Suspected cause: Response by surge protection systems

*) source: Effects of grid disruption on energy balance and voltage maintenance, T. Henning, U. Welz, H. Kühn SuL 2014

# Case 2) Two-phase short circuit in 380kV grid

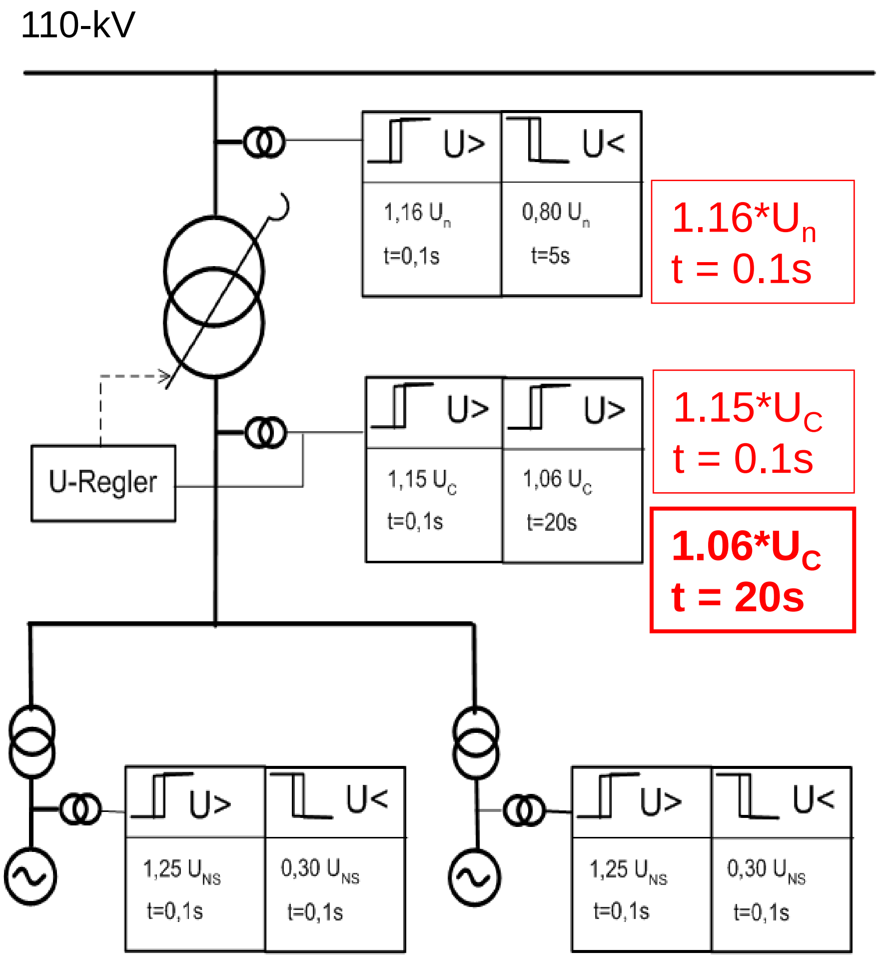



- Two-phase short circuit 380kV
- fault clearing time approx. 400ms
- Loss of over 1000 MW
- Suspected cause: Response by surge protection systems

*) source: Effects of grid disruption on energy balance and voltage maintenance, T. Henning, U. Welz, H. Kühn SuL 2014

# Suspected cause for the loss of generation capacity




- Example formulation of voltage relay
  VDN guidelines from 2004

*) source: Effects of grid disruption on energy balance and voltage maintenance, T. Henning, U. Welz, H. Kühn SuL 2014

| | VDN 2004 | | 4120 (old) TAB HV | | VDE-AR-N 4120 (new) | |
|---|---|---|---|---|---|---|
| **Function - GCP** | | | | | | |
| Voltage increase U> | 1,16 $U_N$ | 0,1s | 1,25 $U_n$ | 0,5 s | 1,25 $U_n$ | 0,5 s |
| Voltage decrease U< | 0,80 $U_N$ | 5 s | 0,80 $U_n$ | 5,0 s | 0,80 $U_n$ | 5,0 s |
| QU protection Q→&U< | ./. | ./. | 0,85 $U_n$ | 0,5 s | 0,85 $U_n$ | 0,5 s |
| **Function – MV side (optional)** | | | | | | |
| Voltage increase U>> | 1,15 $U_C$ | 0,1s | 1,20 $U_{MS}$ | 0,3 s | 1,20 $U_{MS}$ | 0,3 s |
| Voltage increase U> | 1,06 $U_C$ | 20s | 1,10 $U_{MS}$ | 180 s | 1,10 $U_{MS}$ | 180 s |
| **Function – PGU** | | | | | | |
| Voltage increase U>> | 1,25$U_{NS}$ | 0,1s | 1,25 $U_{NS}$ | 0,1 s | 1,25 $U_{NS}$ | 0,1 s |
| Voltage decrease U << | 0,30$U_{NS}$ | 0,1s | 0,30 $U_{NS}$ | 0,8 s | 0,30 $U_{NS}$ | 0,8 s |
| Voltage decrease U< | ./. | ./. | 0,80 $U_{NS}$ | 1,5-2,4s | 0,80 $U_{NS}$ | 1,5-2,4s |

Important – Important – Important – Important – Important – Important

# Requirements for voltage relays (Ch. 10.3.4.2)

- resetting ratio voltage increase ≤ 1,02
- resetting ratio voltage drop ≥ 0.98
- measurement error ≤ 1%
- analysis of fundamental oscillation root mean square

## Section 10.3

# Protection systems and protection settings - Frequency protection systems and protection overviews

# Frequency protection systems

| VDE-AR-N 4120 (old) | |
|---|---|
| ≤ 47.5 Hz | isolation from grid |
| 47.5–51.5 Hz | isolation not permitted |
| ≥ 51.5 Hz | isolation from grid |

| VDE-AR-N 4120 (new) | |
|---|---|
| ≤ 47.5 Hz | isolation from grid |
| 47.5–51.5 Hz | isolation not permitted |
| 51.5-52.5 Hz | isolation permitted |
| 52.5 Hz | isolation from grid |

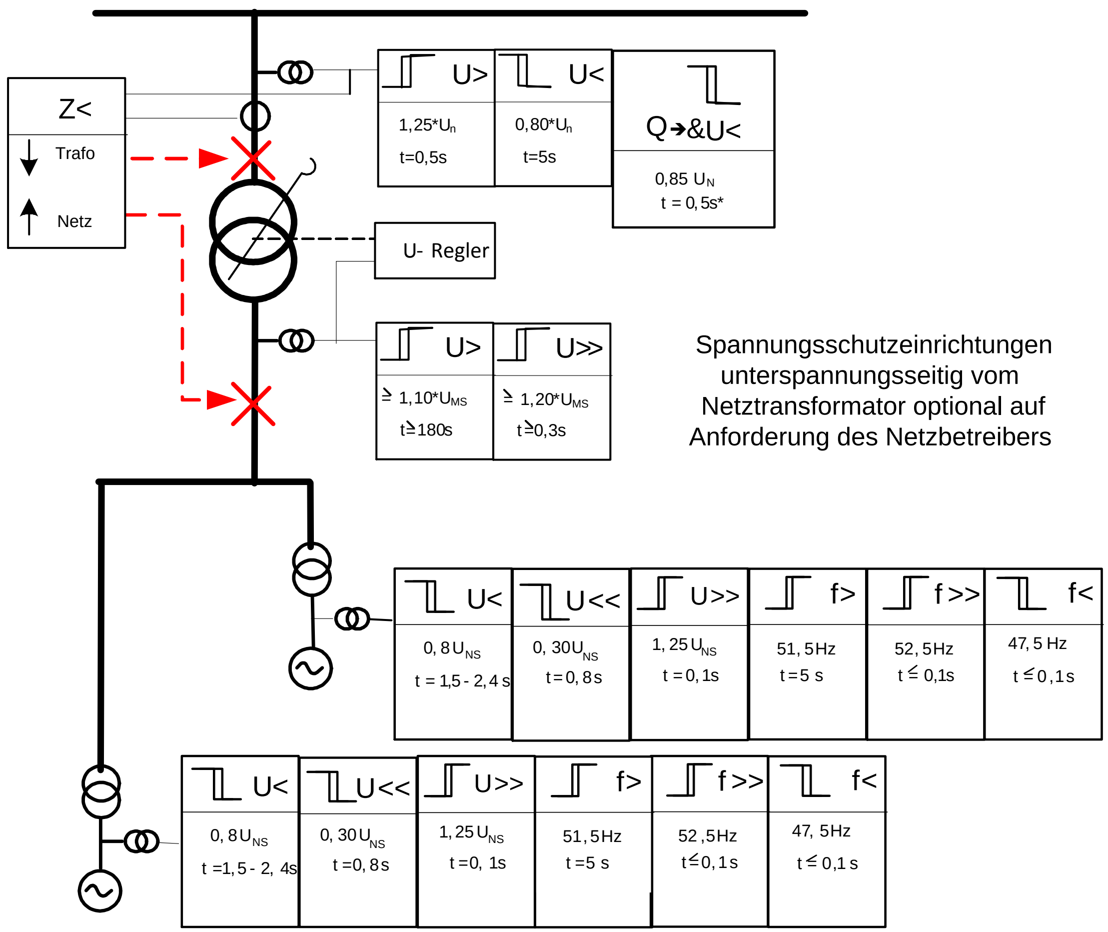
**PGU frequency protection systems**

| | | | |
|---|---|---|---|
| Frequency decrease | f< | 47.5 Hz | 0.1 s * |
| Frequency increase | f> | 51.5 Hz | ≤ 5 s ** |
| Frequency increase | f>> | 52.5 Hz | 0.1 s * |

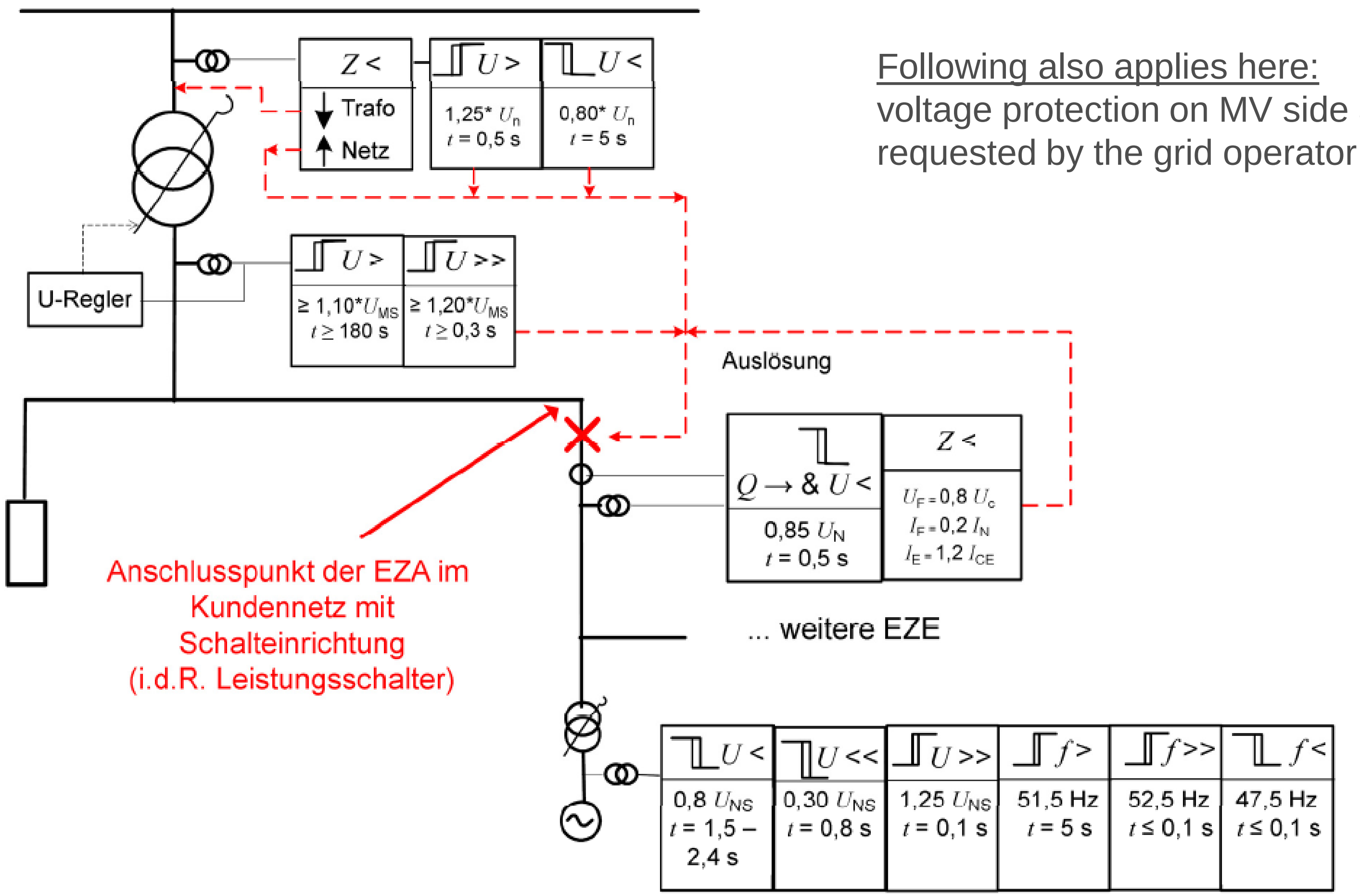
* better: 5 repeat measurements

** according to PGU property

# Protection overview: Connection of a power generating module



# Protection overview: Connection of combined facilities with generation/demand/storage (Ch. 10.3.6 new)




<u>Following also applies here:</u>
voltage protection on MV side as requested by the grid operator

Section 10.4

# Connection conditions and synchronization

# New formulations - re-connection

## TAB HV (old) – Ch. 10.3.2

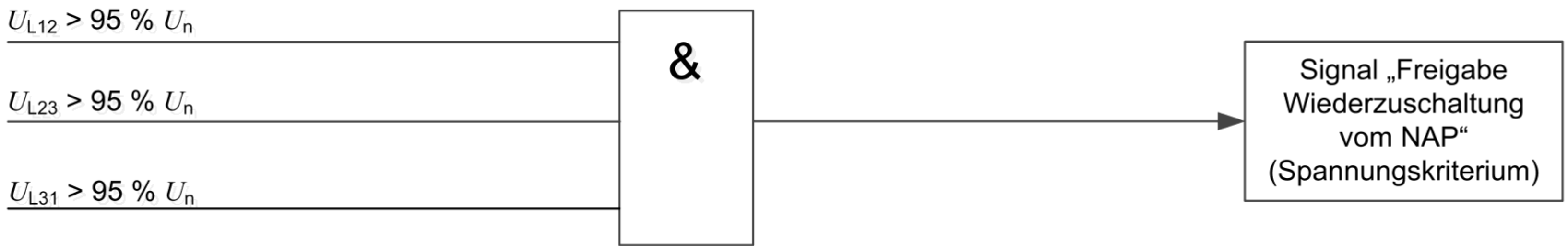
Following the disconnection of a power generating module from the grid through a cut-out of the 110 kV circuit breaker, due to tripping by short circuit or decoupling protective devices (over-frequency, under-frequency, overvoltage, undervoltage, reactive power-undervoltage protection), an automatic reconnection is not permitted. Reconnection will be carried out pending approval by the responsible grid control center.

## TAR HV (new) – Ch. 10.3.2

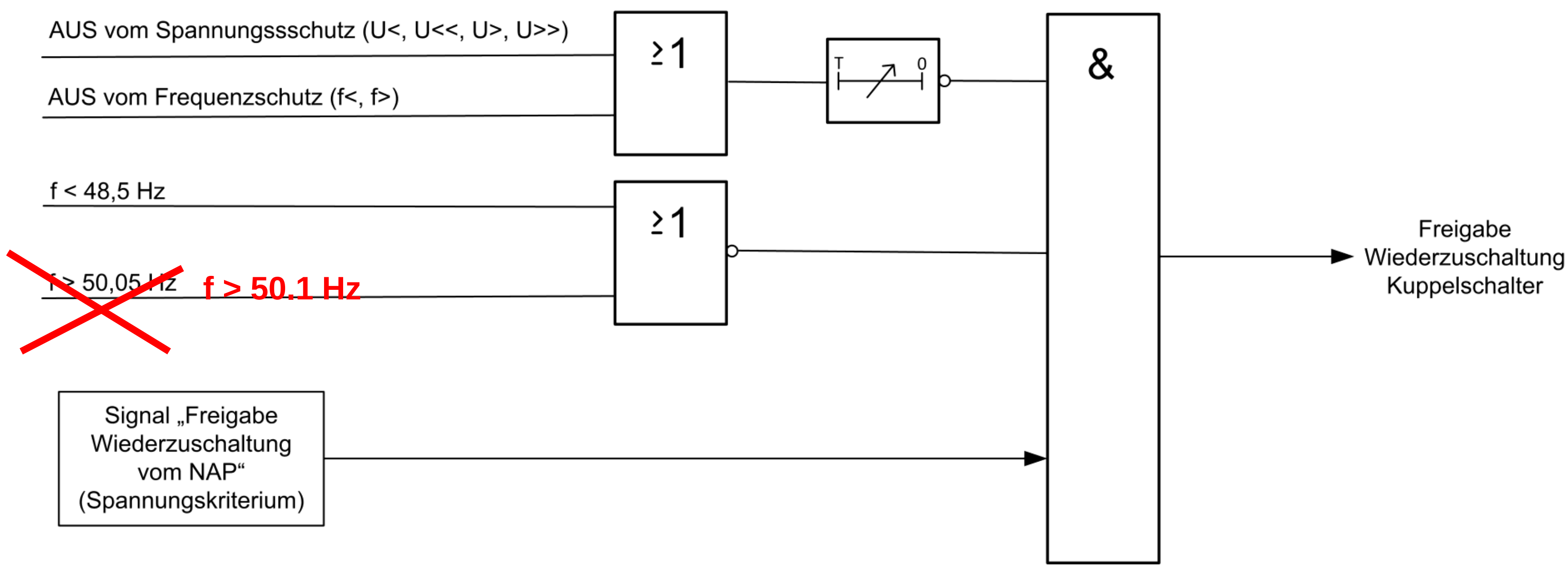
Paragraph removed, replaced by the following, newly added in Ch. 10.4.2

## TAR HV (new) – Ch. 10.4.2 Connection after tripping by safety systems

Unless the grid operator specifies otherwise (grid management agreement), an automatic reconnection is not permitted following disconnection of a power generating module from the grid through a cut-out of the 110 kV circuit breaker, due to tripping by short circuit or decoupling protective devices (over-frequency, under-frequency, overvoltage, undervoltage, reactive power-undervoltage protection). Reconnection is carried out after approval by the relevant grid control center.



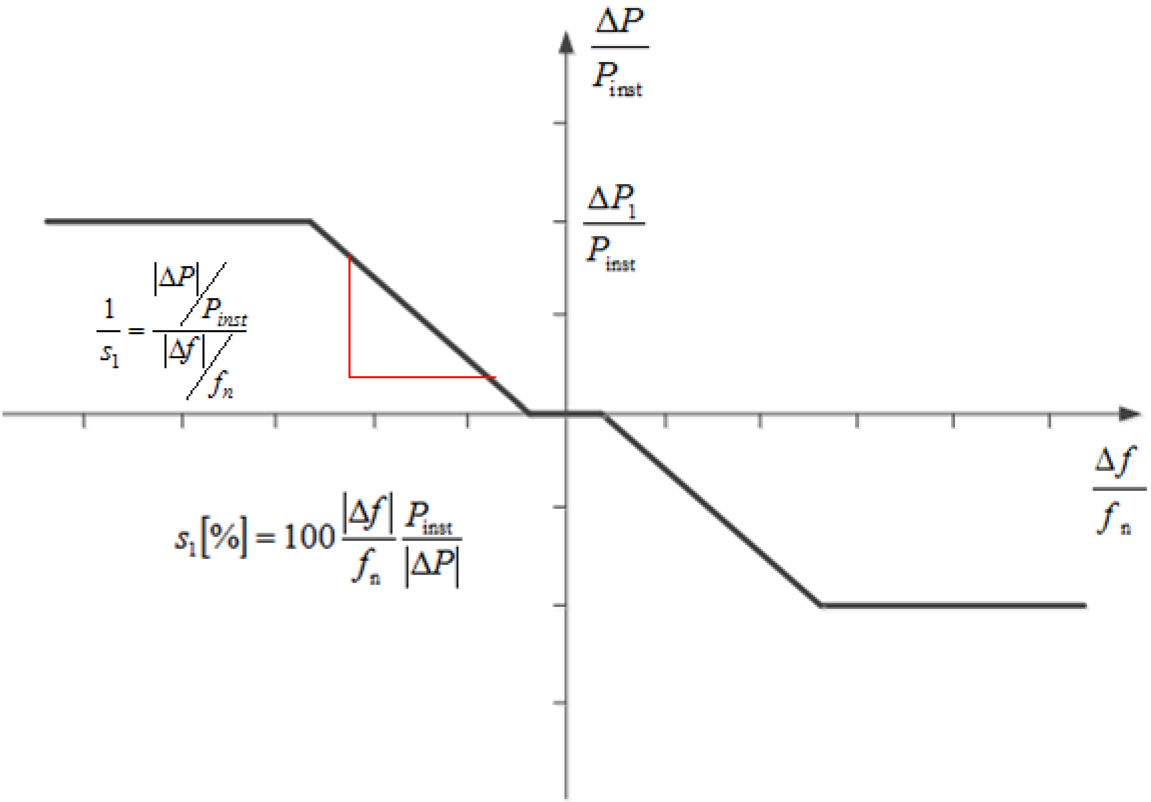

TAR HV – Ch. 10.4.2 Figure 19



Section 10.5

# Additional requirements for power generating modules

VDE



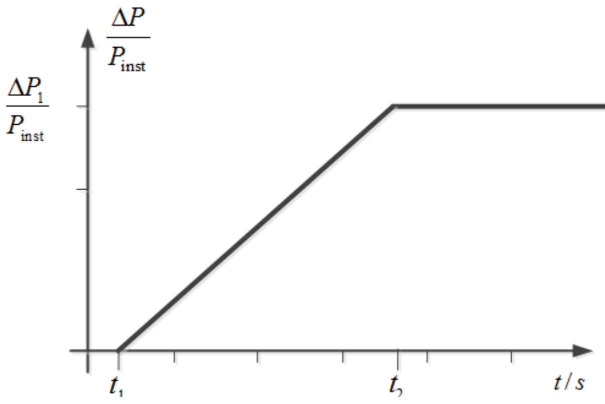

Primary control power

- available min. 2% $P_{inst}$
- max. insensitivity ≤ 10mHz
- measuring tolerance ≤ 10mHz
- deadband 0 – **10** – 200mHz
- static for PGM and pumped storage

  2% - 12“
- static for other storage

  0.4% - 12%

- maximum delay time of activation $t_1$ = 1s
- maximum time to complete activation $t_2$ = 30s



# FNN Frequency restoration control

VDE

| Parameters | Secondary control | Minute reserve |
| --- | --- | --- |
| Minimum control band (not simultaneous) | Type 1: +/- 5 % $P_{AV}$<br>Type 2: +/- 10 % $P_{AV}$ | Type 1: +/- 10 % $P_{AV}$<br>Type 2: +/- 20 % $P_{AV}$ |
| maximum delay time of activation | 30 s | 7,5 min |
| maximum time to complete activation | 2 min – 7,5 min | 7,5 min – 15 min |