Summary of the draft VDE-AR-N 4110:2017-02

The following summary:
- does not cover all parts of the VDE-AR-N 4110 and is therefore not exhaustive;
- mainly covers the technical requirements for customer installations;
- and is purely informative.

February 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 5 and 10.2.2

Static Voltage Stability
Requirements for

- power generating modules and power generating units
- combined facilities of generation/demand/storage
- Storage

For combined facilities of generation/demand/storage it is important to note the

- Protection concept (10.3)
- Use of emergency generators (8.9)
- Frequency-dependent active power response (10.2.4.3)
- Dynamic grid support (10.2.3)
- Active power demand by the grid operator (reduction) (10.2.4.2)
- Static voltage stability (10.2.2)
- Evidence of electrical properties (11)
10.2 Behavior of the power generating module connected to the grid during steady-state operation
10.2 Behavior of the power generating module connected to the grid during steady-state operation

Definition of steady-state operation

- Voltage gradient < 5 % \( U_c \text{ min}^{-1} \)
- Frequency gradient < 0.5 % \( f_n \text{ min}^{-1} \)

Power generating modules must remain on the grid in steady-state operation, as per Figure 4
10.2 Behavior of the power generating module connected to the grid during steady-state operation

- In the voltage range from 90 % \(U_c\) to 110 % \(U_c\) voltage gradients of greater than 5% \(U_c\) min\(^{-1}\) can occur.

- For voltages outside the voltage range 90 % \(U_c\) to 110 % \(U_c\) the active power and the reactive power supply can be reduced to protect the power generating module.
10.2 Behavior of the power generating module connected to the grid: Rotating or grid oscillation, subnetwork operability and Black Start capability

- Oscillations in the continental European grid with frequencies of 0.15 – 1.5 Hz
  - With this, the voltage can lie outside Figure 4 for a few seconds
  - For this reason, do not isolate supply from power generating modules when there is a symmetrical voltage curve in operation at 0.8 $U_c$ – 1.2 $U_c$ for 5 sec.
  - During grid oscillation, the active power can be reduced to avoid overloading
- If a loss of stability occurs, the generation units must be isolated from the grid
- Subnetwork operability, Black Start capability, Isolated network and Black Start capability are not minimum requirements
10.2.2 Static voltage stability/ reactive power supply

Bild 5 – Anforderungen an Erzeugungsanlagen an die Blindleistungsbereitstellung am Netzanschlusspunkt
10.2.2 Static voltage stability/ idle power supply

- Supply of reactive power in the power generating module to maintain voltage when slow (steady-state) voltage changes
- Requirements for the grid connection point
- Active power reduction of max. 10 % $P_{b \text{ inst}}$ permitted outside the shaded area in Figure 5

Note: The reactive power area in the design is not yet fully complete in the project group (see introduction)
10.2.2 Static voltage stability/ reactive power capability below $P_{b \ inst}$

Mindestanforderung der Blindleistungs-Stellfähigkeit

$$\frac{Q_{vb}}{P_{b \ inst}}$$

$+ 0.48$

$- 1.0$

$\cos (\phi) = 0.9$

$- 0.05$

$- 0.48$

Bild 6 – $P/Q$-Diagramm der Erzeugungsanlage am Netzanschlusspunkt im Verbraucherzählpfeilsystem
10.2.2 Static voltage stability/ reactive power supply less than \( P_{b\ inst} \)

- Requirements for the reactive power capability at partial load \( P_{mom} \)
- \((0.05 < P_{mom} / P_{b\ inst} < 1)\) at grid connection point
- Maximum residual deviation \(\pm 2.0\%\) with regard to \( P_{inst} \), for power generating modules < 300 kVA maximum \(\pm 4.0\%\) with regard to \( P_{inst} \).
- Reactive power in range \( 0 \leq P_{mom} / P_{b\ inst} < 0.05 \) no more than 5% of sum of stipulated active power supply \( P_{AV, E} \).
### 10.2.2 Static voltage stability: Procedure for reactive power supply at the grid connection point

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Formula</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>a) Q (U)</td>
<td>a) fixed displacement factor cos φ</td>
<td></td>
</tr>
<tr>
<td>b) Q (P)</td>
<td>b) cos φ (P)</td>
<td></td>
</tr>
<tr>
<td>c) Reactive power kvar</td>
<td>c) fixed reactive power MVar</td>
<td></td>
</tr>
<tr>
<td>d) displacement factor cos φ</td>
<td>d) Q (U)</td>
<td></td>
</tr>
</tbody>
</table>

- Control behavior of reactive power qualitatively according to PT1 – behavior for procedure a), b) and c)
- Specification of fixed setpoint or variable setpoint via remote control system (or other control technology)
- Reactive power adjustment of power generating module in range 6 s – 60 s (for 95 % of set point jumps)

Note: Testing of adjustment times by the working group pending
10.2.2 Static voltage stability set point jump overall

Funktion der Sprungantwort (wenn die Sprunghöhe bekannt ist)

\[ a(t) = K(1 - e^{-\frac{t}{T}}) \]

Differentialgleichung:

\[ T \cdot \dot{y}(t) + y(t) = K \cdot u(t) \]

Bild 7 – Beispiel des Regelverhaltens bei einem Sollwertsprung mit der Höhe 1 (normiert) und einer Zeitvorgabe (3 Tau) von 10 s
10.2.2 Static voltage stability set point jump with tolerances relevant to analysis

Bild C.3 – Veranschaulichung bei 3 Tau = 10 s
a) Reactive power – voltage curve Q (U)
a) Reactive power - voltage curve Q (U)

- The curve values are preset (in the course of planning)
- Curve adjustment by grid operator only within reference voltage $U_{Q0} / U_C$ by remote control technology. I.e. horizontal parallel shift of the curve in 0.5 % $U_C$ increments.
- Enabling/disabling of Q (U) – curves – control via remote control technology or manually.
b) Reactive power curve as function of performance Q (P)

$Q(P)$-Beispielkennlinie

Bild 9 – Beispiel für eine $Q(P)$-Kennlinie
b) Idle power curve as function of performance Q (P)

- Supply of reactive power depending on the current active power supply
  \[ Q = f(P_{mom}) \]
- Curve adjustment via remote control is not foreseen. It will be defined over max. 10 grid points that can be set manually.
- Enabling and disabling of Q (P) – curve by remote control technology (disabled cos φ ~ 1)
c) Reactive power

- Supply of reactive power independent of active power supply
- Setpoint in relation to agreed active connection power \( Q_{EA, soll} / P_{b \, \text{inst}} [\%] \) termination max. 1% \( P_{b \, \text{inst}} \).
- Setpoints are in range shown by P/Q – diagram (Figure 6)
- Should remote control technology fail (> 1 min), the default – setpoint of 0 % should be applied, if no value is given by the grid operator.
d) Displacement factor $\cos \varphi$

- Supply of reactive power to the grid with a constant ratio of active and apparent power.
- Specification of setpoint with minimum steps of $\Delta \cos \varphi = 0.005$.
- Maximum fault tolerance of reactive current supply calculated from the fault tolerance of $\pm 2\%$ or $\pm 4\%$ in regard to $P_{b \text{inst}}$.
- Grid operator provides setpoint (not provided $\cos \varphi = 1$)
- Specification of setpoint possible via remote control technology.
- Reaction time max. 1 min for changes to setpoint.
10.2.2.6 Special requirements for combined facilities of generation/demand/storage with demand facilities

- Requirements for the static voltage stability/ reactive power supply for power generating modules and storage must be maintained at the grid connection point.
- Impact of loads is not taken into account
- For reactive power supply $Q(U); Q(P); \text{kvar}; \cos \phi$, a simplified solution can be implemented if
  - $P_{\text{inst}}$, installed active power of the power generating module $\leq 50 \%$ of the agreed reference power $P_{AV,B}$ of the combined facility of generation/demand/storage
  - Agreement of the grid operator
10.2.2.6 Special requirements for combined facilities of generation/demand/storage with demand facilities

Simplified solution

- for $Q(P)$; kvar; $\cos \varphi$, the measurement of reactive and active power can be undertaken at the generation unit (with computed correction)
- For $Q(U)$, the voltage measurement must be taken at the voltage level of the grid connection point. Shift of the measuring point within the voltage level is possible if $\Delta U \leq 0.2 \% U_C$.
- Measurement of reactive power supply at the generation unit.
Section 10.2.3

Dynamic Grid Support
Outline

- Introduction and brief review of BDEW medium voltage directive
- Draft AR-N 4110 - overview
- Type 1-modules
  - Time constraints
  - Other requirements
  - Multiple faults
- Type 2-modules
  - Fault start / fault end
  - Time constraints
  - Comprehensive and Restricted Dynamic Grid Support
  - Multiple faults
- Behavior after fault end (Type 1 and Type 2)
Introduction with review
Motivation

- Example: Two-phase faults in high voltage grid
- Max. changes to voltage:
  - Positive sequence: 20%
  - Negative sequence: 21%
- Unsymmetrical faults far more frequent than symmetrical
- Also incorporate fault-remote systems in the voltage support
- Support after the fault, to maintain reactive power allowance
Status Quo: dyn. grid support in the BDEW medium voltage directive

- Riding through grid faults with defined timed limits
- Supply of a short-circuit current with agreement of the grid operator, in accordance with TransmissionCode 2007 (TC2007)
- Increase in voltage should be limited in non-faulty phases
- Type-2 modules: Temporary disconnection allowed in principle if necessary upon agreement with the grid operator
- Grid support also in the case of repeated Automatic Restart (AR)
- Active power re-establishment min. 10% $P_n/s$
VDE-AR-N 4110

Entwurf  März 2017

Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung)

Entwurf

Amwendungswarnvermerk

Dieser VDE-Anwendungsregel-Entwurf mit Erstehungsdatum 2017-02-17 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

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Gesamtumfang 251 Seiten

VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V.
Dynamic Grid Support for AR-N-4110 - Fundamentals

- 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 (half-frequency oscillation RMS).
- Dynamic reactive current support in the positive and negative sequence.
- Multiple faults must also be ridden through.
- Voltage surges within the FRT curves must not lead to tipping.
Type 1 modules
(directly linked synchronous generators)
Type 1 modules: Time constraints

- LVRT requirements were **slightly adjusted** (RfG curve for **symmetrical faults**)
- **Two-phase faults**: often more profound issue, usually non-critical for PGM (green curve)
- New: Requirements for riding through **surges** (HVRT)
Other / general requirements Type 1 modules

- Voltage drops within the a.m. limit curve should be ridden through if $S_k$ is $> 5 S_{A,Ges}$ after end of fault in the relevant grid.
- Voltage regulator settings and software status must be defined and traceable.
- Maximum voltage increase in the functioning external conductors maximum $5\% U_C$ compared to pre-fault voltages.

- Behavior after fault end
  - Increase in 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
- Tipping permitted, if these thermal limits are exceeded due to multiple faults
Type 2 modules
generators that do not comply with Type 1
Type 2 modules: Fault start and end

- **Criteria for fault start:**
  - sudden voltage changes compared to 50 pre-fault voltage periods
  - Voltages $> 1.1 \ U_C$ [max. $1.15 \ U_C$] or $< 0.9 \ U_C$
    $U_C$: Agreed supply voltage, usually equals $U_n$

- **Criteria for fault end:**
  - 5s after fault start
  - Restoration of all L-voltages in the range of $0.9 \ U_C < U < 1.1 \ U_C$

- **New faults**, as soon as a criterion for fault end is completed

Example of a sudden voltage change
Type 2 modules: Time constraints

- Requirements of Type 2 modules **expanded**, to conform to RfG limit curve
- **Two-phase faults**: often more profound issue, usually non-critical for EZA (green curve)
- **New**: Requirements for riding through **surges** (HVRT)
Type 2 modules: Comprehensive Dynamic Grid Support

- Supply of an additional reactive current from fault start (standard configuration, if not explicitly stated otherwise)
- 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
- After *fault end*: Increase in active current to pre-fault value within maximum one second (response time)
Type 2 modules: Comprehensive Dynamic Grid Support

- Context: 1 min mean value for the grid voltage \((U_2 \to 0)\)
  - unchanged reference for the whole duration of the fault

\[
\Delta u_1 = \frac{U_1 - U_{1\text{min}}}{U_C}
\]

\[
\Delta u_2 = \frac{U_2}{U_C}
\]

- zus. Blindstrom:

\[
\Delta i_{B1,2} = k \cdot \Delta u_{1,2}
\]

- Dynamik:

\[
T_{an\_90\%} \leq 30 \text{ ms}
\]

\[
T_{ein\_\Delta x} \leq 60 \text{ ms}
\]
Intermediate supply to the grid through comprehensive dynamic grid support can limit the effectiveness of an Automatic Restart (AR).

Therefore: Grid operator can request that grid faults are ridden through without current supply.

Criterion for fault start: $U < 0.8 \ U_C$

For voltage surges above this limit: undertake comprehensive dynamic grid support.
Multiple faults

- It must be possible to ride through an **arbitrary sequence** of grid faults
- For some plant types, limitation is possible (e.g. thermal limits with the use of choppers)
  → Requirement is limited to the energy to be removed or not supplied to the grid of PE_{max} \cdot 2s
- between multiple grid fault sequences, a time of **30min** is estimated
Behavior after fault end (Type 1 and Type 2)
Conduct between fault endings and stage. Plant (Type 1 & 2)

- after fault end, the grid voltage is possibly still outside the range $U_C \pm 10\%$ until the HV/MV transformers stepping switch re-adjusts
- modules may still have to supply a reactive current, to prevent a triggering of the protection mechanisms
- possible support through adaptation of active power
Summary

- Requirements of AR-N 4110 for dynamic grid support are more extensive than previously and were aligned with the RfG framework.
- The required conduct was specifically defined regarding:
  - unsymmetrical faults
  - definition of fault start / end for Type 2 modules
  - conduct after the fault
  - dynamic
  - Multiple faults
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
  - Implementation for combined facilities of generation/demand/storage

- **10.2.4.3 Active power supply for over or under frequency**
  - Requirements of grid retention
  - P-f curve
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
- with system performance, “many cooks” are increasingly involved.
- also for surface circuits by DSO (cascade), a greater change to performance is required.
- 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 can 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.
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 \( \frac{P_N}{P} \) per second);
- no slower than in 5 min (0.33 \( \frac{P_N}{P} \) 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.
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.
PGM – active power supply / combined facilities of generation/demand/storage

Reference value NSM is $P_{\text{binst}}$ → Signal independent of instantaneous power → Can be directly switched to PGU/PGM. (simple standard case)

Could an (appropriate) load setting instead of a “reduction” also occur?

→ Technically OK; providing “grid power” at GCP is guaranteed.

Problem: Evidence management → Requirement that $\Delta P$ must be metrologically traceable
PGM – Active power supply for over/under frequency

- **Frequency: Primary value**
  - (integrated grid / SYSTEM / Cross-Border Issue)
  - entso-e values must be observed
    (Rfg: generator > 0.8 kW = Significant Grid User)
  - 50.2 Hz problem & P-f curve known (Basis)

**Questions:**
- Turbines & combustion engines reduce output with lower revolutions.
  - Can they do that?
  - Why do we immediately switch off in MV at 51.5 Hz?
  - How quickly do the modules operate on the curve?
  - What does storage actually do at under frequency?
  - What do we do with market or already NSM limited modules (e.g. marketing) at f< 49.8 Hz?
Active power supply during frequency deviations

**Fundamentals**

- 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 a 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 $f$ is in “Range”: Active power changes of a maximum of 10% $P_N/\text{min}$
  - if $f$ over 10 min long within the tolerance range → normal grid operation
Active power supply at over-frequency

Expanded range for “overshots” by 5 sec.
→ Two-step f > protection
→ Follow the range curve where possible
→ Requirements not (yet) compulsory

Control times according to Entso-e
Rfg:
“As fast as technically feasible”
→ As fast as possible
→ Precision comes second

Response time: 2s
Settling time 20s
Measuring tolerance < 10 mHz
P deviation +/- 10%P_N

\[
\frac{\Delta P}{P_{ref}} = \frac{(50,2-f)}{50 s^{-1}} \cdot 100 s \quad \text{mit } s = 5\%
\]

49.8 Hz < f < 50.2 Hz
Normaler Netzbetrieb

\[P_{ref} = \begin{cases} P_{MOM} & \text{for Type 2: } \rightarrow \text{No change (remains locked at } f=50.2 \text{ or } f=49.8) \\ P_N & \text{for Type 1: } \rightarrow \text{RfG (fixed curve slope)} \end{cases}\]
Active power supply at underfrequency

**Example 1:**
\[ \Delta P = -200\% \]
Storage no longer discharges; P=-100%

**Example 2:**

- \( \Delta P = 100\% \)
  Storage charges; P=-20%
- \( \Delta P = 100\% \)
  Storage no longer discharges; P=-100%
- \( \Delta P = 80\% \)
  Storage no longer discharges; P=0%
- Storage charges at 80%

**Caution!**
Different axis scaling!
DP refers to the NOMINAL output
ΔP requirement! (Direction change is always correct)
Applies to generators (with storage capacity $W > P_N \times 30s$)
Applies to applications according to Art. 14 EnWG with electronic control (e.g. load applications for storage or electronically controlled electro-thermal applications)
required in reference direction, providing there is no risk to people and plants. These demand facilities or combined facilities of generation/demand/storage should lower the reference power with under frequency or increase it with increasing frequency, as shown in Figure 17.
P-f requirements - control times

**Limited requirements due to technical restrictions**

- **Wind:** Increase only when wind > 50\% $P_N$
- **Combustion engines:**
  - ≤ 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,** a response time of 15 s and a settling time of 30 s is necessary.
- **Evidence management in and response times relating to $\Delta f = 500$ mHz**

(still) no firm requirements for the $f\leq$ range with PGM:
The more who participate now, the sooner it will be possible to make exceptions later

-> The fewer who participate now, the stricter the subsequent directive will be

Control times according to Entso-e Rfg:
“As fast as technically feasible”

-> as fast as possible
-> precision comes second

Storage:
Response time: 2s
Settling time 20s
Measuring tolerance < 10 mHz
$P$ deviation +/- 10\%$P_N$
Ch. 6.3.3 Protection technology (general)

For purchasers and for power generating modules
Applies to demand facilities and to power generating modules, i.e. for
- grid protection systems
- the subscriber’s short-circuit protection systems and
- disconnection protection systems (for power generating modules)

Responsibility lies with the respective owner

The grid operator can request the installation of a frequency relay and provide the settings for this

Regular protection inspections are mandatory

For this, at least one testing terminal bar must be installed

In justified cases, disturbance recorders must be installed at the grid connection point (e.g., if no metrological evidence of compliance with grid support is available)

All information necessary for fault investigation must be exchanged between the grid operator and the subscriber.
Ch. 10.3 Protection systems and protection settings (for power generating modules)

Experience gained from grid faults with voltage protection systems
Case 1) short circuit in 110kV grid

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

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

Suspected cause for the loss of generation capacity

- Example formulation of voltage relay
  VDN guidelines from 2004

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<thead>
<tr>
<th>Function - GCP</th>
<th>BDEW 2008</th>
<th>VDE-AR-N 4110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage increase U&gt;&gt;</td>
<td>Can be omitted by connection to MV grid, if no dynamic grid support is required</td>
<td>Always available</td>
</tr>
<tr>
<td>Voltage increase U&gt;</td>
<td>1,15 (U_C) (0,1\ s)</td>
<td>1,20 (U_{MS}) (0,3\ s)</td>
</tr>
<tr>
<td>Voltage decrease U&lt;</td>
<td>1,08 (U_C) (60\ s)</td>
<td>1,10 (U_{MS}) (180\ s)</td>
</tr>
<tr>
<td>QU protection Q→&amp;U&lt;</td>
<td>0,80 (U_C) (2,7\ s)</td>
<td>0,80 (U_N) (2,7\ s)</td>
</tr>
<tr>
<td>Voltage increase U&lt;&lt;</td>
<td>0,85 (U_C) (0,5\ s)</td>
<td>0,85 (U_N) (0,5\ s)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function – PGU</th>
<th>Connection to busbars</th>
<th>Connection to busbars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage increase U&gt;&gt;</td>
<td>1,20 (U_C) (0,1\ s)</td>
<td>1,25 (U_{MS}) (0,1\ s)</td>
</tr>
<tr>
<td>Voltage decrease U&lt;</td>
<td>0,80 (U_{NS}) (1,5-2,4\ s)</td>
<td>0,80 (U_{NS}) (1,5-2,4s)</td>
</tr>
<tr>
<td>Voltage increase U&lt;&lt;</td>
<td>0,45 (U_C) (0,3\ s)</td>
<td>0,3 (U_{MS}) (0,8\ s)</td>
</tr>
</tbody>
</table>

| Connection to MV grid         |                                                                           | Connection to MV grid             |
|-------------------------------|                                                                           |                                   |
| Voltage increase U>>          | 1,15 \(U_{NS}\) \(0,1s\)                                                 | 1,25 \(U_{NS}\) \(0,1\ s\)       |
| Voltage decrease U<           | 0,80 \(U_{NS}\) \(1,0s\)                                                 | 0,80 \(U_{NS}\) \(1,0\ s\)       |
| Voltage decrease U <<          | 0,45 \(U_{NS}\) \(0,3\ s\)                                               | 0,45 \(U_{NS}\) \(0,3\ s\)       |
Requirements for voltage relays (Ch. 10.3.1)

- Resetting ratio voltage increase \( \leq 1.02 \)
- Resetting ratio voltage drop \( \geq 0.98 \)
- Measurement error \( \leq 1\% \)
- Analysis of fundamental oscillation root mean square
Ch. 10.3 Protection systems and protection settings (for power generating modules)

Frequency Protection Systems
Frequency protection systems

<table>
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<tr>
<th>BDEW 2008</th>
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<tbody>
<tr>
<td>≤ 47.5 Hz isolation from grid</td>
<td>≤ 47.5 Hz isolation from grid</td>
</tr>
<tr>
<td>47.5–51.5 Hz isolation not permitted</td>
<td>47.5–51.5 Hz isolation not permitted</td>
</tr>
<tr>
<td>≥ 51.5 Hz isolation from grid</td>
<td>51.5–52.5 Hz isolation permitted</td>
</tr>
<tr>
<td></td>
<td>52.5 Hz isolation from grid</td>
</tr>
</tbody>
</table>

* better: 5 repeat measurements
** according to PGU property

### PGU frequency protection systems

<table>
<thead>
<tr>
<th>Frequency decrease</th>
<th>f&lt;</th>
<th>47.5 Hz</th>
<th>0.1 s *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency increase</td>
<td>f&gt;</td>
<td>51.5 Hz</td>
<td>≤ 5 s **</td>
</tr>
<tr>
<td>Frequency increase</td>
<td>f&gt;&gt;</td>
<td>52.5 Hz</td>
<td>0.1 s *</td>
</tr>
</tbody>
</table>
Ch. 10.3 Protection systems and protection settings (for power generating modules)

Protection overviews
Connection to the busbar of an UW

$U_{c}$ - vereinbarte Versorgungsspannung
$U_{NS} = U_{c}/\ddot{u}$ mit $\ddot{u}$ = Übersetzungsverhältnis der Maschinentransformatoren

Schutzfunktion ist konzeptionell zu berücksichtigen und nach NB-Vorgabe zu realisieren

*) Mitnahmeschaltung nur bei im Stich angeschlossenen UW
**) Auslösung LS am Netzanschlusspunkt nach 0,5 s

New: Distance relay with U/I-stimulus required
IOR not permitted

Curzschlusssschutz und übergeordneter Entkupplungsschutz

<table>
<thead>
<tr>
<th>$U_{&gt;&gt;}$</th>
<th>$U_{&gt;}$</th>
<th>$U_{&lt;}$</th>
<th>$f_{&gt;}$</th>
<th>$f_{&lt;}$</th>
<th>$Z_{&lt;}$</th>
<th>$Q \rightarrow &amp; U_{&lt;&lt;}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,20 $U_{c}$ $t = 0,3 \text{ s}$</td>
<td>1,10 $U_{c}$ $t = 180 \text{ s}$</td>
<td>0,8 $U_{c}$ $t = 2,7 \text{ s}$</td>
<td>51,5 Hz $t = 5400 \text{ ms}$</td>
<td>47,5 Hz $t = 400 \text{ ms}$</td>
<td>$U_{F} = 0,8 U_{c}$</td>
<td>$I_{F} = 0,2 I_{N}$ $I_{e} \geq 1,2 I_{CE}$ $t = 0,5 \text{ s}$</td>
</tr>
</tbody>
</table>

New: $f_{>}$ and $f_{<}$ optional (according to grid operator)

New: $f_{>>}$

Entkupplungsschutz

<table>
<thead>
<tr>
<th>$U_{&gt;&gt;}$</th>
<th>$U_{&lt;}$</th>
<th>$U_{&lt;&lt;}$</th>
<th>$f_{&gt;}$</th>
<th>$f_{&lt;}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,25 $U_{NS}$ $t = 0,1 \text{ s}$</td>
<td>0,8 $U_{NS}$ $t = 1,5 - 2,4 \text{ s}$</td>
<td>0,3 $U_{NS}$ $t \leq 100 \text{ ms}$</td>
<td>52,5 Hz $t \leq 100 \text{ ms}$</td>
<td>51,5 Hz $t = 5 \text{ s}$</td>
</tr>
</tbody>
</table>

New: $f_{>>}$
Section 10.3

Protection systems and protection settings - Frequency protection systems and protection overviews
Connection to medium voltage grid

- New: always disconnection protection
- New: always disconnection protection
- Upon request by grid operators (e.g. if dynamic grid support activated)
- f> and f< optional (according to grid operator)