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Compliance with Technical Codes turns into Precondition for Support and System Services Bonus for Wind Power Plants in Germany

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***Abstract*-- When amending the Renewable Energy Sources Act (EEG) in June 2008 the German government acknowledged the importance of enhanced technical requirements. From now on, for wind power plants, full grid code-compliance will become a necessary precondition for privileged network access, receipt of feed-in tariff, and extra payments (system services bonus). Thus, the amended EEG ensures further development of renewable energy sources in line with targets without compromising security of supply. The technical basis for the technical requirements in the EEG has been determined by the recently revised technical code for dispersed generators in German distribution networks (Medium Voltage Directive 2008) and the TransmissionCode 2007 respectively. However, the latter needed careful review and some clarifying specifications were proposed. The new technical requirements and their implications for renewable energy sources generators, with special regard to wind power plants, are presented in this paper.**

***Index Terms*—Ancillary services, Dispersed storage and generation, Frequency control, Large-scale integration, Power system faults, Reactive power, Voltage control, Wind power generation.**

I. Introduction

As part of its climate policies the German government takes ambitious aims at electricity generation based on renewable sources (RES-E): by 2020 a RES-E share of more than 30% has to be achieved [1]. In 2020 the installed capacity of wind power onshore will be in the range of 25 GW, corresponding to about 60% of the national minimum load and complemented by other renewable generation (biomass, PV, hydro, etc) plus wind power offshore. The vast majority of RES-E will be connected to distribution networks. These developments imply fundamental changes in power system as well as power generation sources operation. They introduce new challenges, not at least related to power quality and security of supply.

Aiming at maintaining power quality and secure network operation, the utility association of those days issued the first dedicated technical codes for the connection of DG to the medium voltage (MV) distribution networks in the 1990s [2].

The more DG were connected to high voltage networks, the higher became the influence on the overall system's security of supply. In the following, individual grid operators issued respective technical codes for the connection to their high and extra-high voltage (HV/EHV) networks; these technical codes already included requirements for DG's dynamic behaviour during faults as well as for steady-state reactive power supply.

From the number of technical codes for HV/EHV networks from individual grid operators the German Association of Network Operators (VDN[1]) developed a guideline for the connection of DG to the HV/EHV networks in Germany in 2004 (*HV/EHV-Guideline 2004*) [3]; however, this guideline had an advising character only. Finally, in 2007, the VDN included the most important requirements of this guideline into the *TransmissionCode 2007* what turned them into nation wide technical requirements [4]; since then, this technical code describes conditions for connecting both conventional and RES-E generators (e.g. wind farms) to the transmission system in Germany.

In order to streamline the technical codes for distribution systems with the ones for transmission system, in June 2008 the BDEW[2] (successor organisation of VDN) published a revision of the technical code for the connection of DG to MV networks *(MV-Directive 2008)*.

The mentioned guidelines form the basis for the grid connection agreement between grid operators and RES-E operators. But in the past it was common practice to deviate from these guidelines on a case by case basis. When amending the Renewable Energy Sources Act (EEG) in June 2008 [1] the German government acknowledged the importance of enhanced technical requirements. After June 2010, for wind power plants, compliance with specific technical requirements will become a necessary precondition for privileged network access, receipt of feed-in tariff, and extra payments (system services bonus).

The EEG additionally stimulates upgrades of existing capacity on some key issues (e.g. fault-ride-through,

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[1] VDN: Verband der Netzbetreiber e.V (German Association of Network Operators, since beginning of 2008 part of BDEW)

[2] BDEW: Bundesverband der Energie- und Wasserwirtschaft e.V (German Association of Energy and Water Industry)

frequency support). Thereby, the amended law aims at ensuring further RES-E development in line with targets without compromising security of supply.

The draft specific technical requirements have been presented by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in March 2009 [5]. The technical basis for the technical requirements in the EEG has been determined by the above mentioned BDEW *MV-Directive 2008* and the *TransmissionCode 2007* respectively. How to transform the requirements from these guidelines into legally binding requirements was analysed by part of the authors of this paper in [6]. There, it has also been shown that especially the *TransmissionCode 2007* needed careful review and some clarifying specifications were eventually proposed.

The new technical requirements and their implications for renewable energy sources generators, with special regard to wind power plants, are presented in the following sections: In section II a general overview on the specific technical requirements is given. In section III the main requirements on the behaviour of generating plants (e.g. wind power plants) connected to the HV/EHV networks according to the *TransmissionCode 2007* are presented. In section IV these requirements as adapted by the *MV-Directive 2008* to MV networks are discussed. In section V amendments to these requirements according to [5] are proposed. Finally, conclusions are given in section VI.

II. Overview Specific Technical Requirements

According to the draft specific technical requirements [5] all wind power plants in Germany that are put into operation after June 2010 have to comply with the following technical guidelines:

- If connected to a MV network
  ➔ *MV-Directive 2008*
- If connected to a HV/EHV network
  ➔ *TransmissionCode 2007* plus amendments

All requirements defined have to be met at wind power plant level at the point of common coupling (PCC). This can be achieved by appropriate capabilities of individual units (e.g. wind turbines) and/or by (additional) dedicated measures at wind power plant level (e.g. FACTS etc.).

The compliance with the above mentioned technical guidelines (and amendments if applicable) is going to become the precondition for privileged network access, receipt of feed-in tariff, and extra payments (system services bonus) for all wind power plants put into operation after June 2010. In other words, if these technical requirements are not met, the wind power plant operator does not receive the support of the feed-in tariff, nor privileged network access and neither the system services bonus. Wind power plants that are going to be put into operation between January 2009 and June 2010 can comply with these technical requirements on a voluntary basis and will then be also eligible to receive the system services bonus.

The system services bonus equals 0.5 €cents/kWh and is paid to the wind power plant operator over the so-called initial payment period (typically 16 years). It is only paid during a transitional period until the end of 2013, because the system services bonus is meant to cover extra costs resulting from the advanced technical requirements. No system services bonus will be paid to operators whose wind power plants are put into operation after the year 2013.

The operator must verify the compliance with the specific technical requirements by presentation of unit certificates for all wind turbine types used in the wind power plant and an expert report that verifies the compliance at the PCC. After the publication of a detailed certification procedure by the German government, the compliance at the PCC must be verified with so-called project certificates.

The following sections present the most important technical requirements of the *MV-Directive 2008* and the *TransmissionCode 2007* with its respective amendments.

III. The TransmissionCode 2007

The *TransmissionCode 2007* [4] defines in its chapter three "connection conditions" the technical requirements for the connection and operation of all kind of power plants connected to HV/EHV networks. These technical requirements cover:

- Reactive power provision and control,
- Active power control, and
- Behaviour of power plants during network faults.

In the following subsections, the original technical requirements are presented. Section V will present amendments to these requirements according to [5].

A. Reactive power provision and control

With active power output, it must be possible to operate the generating plant in "any operating point" with a reactive power output corresponding to one of the variants 1-3 shown in

Fig. 1. The standard requirement is a slow control of reactive power within a couple of minutes. The setting value is either

- a fixed active factor cos φ or
- a active factor cos φ (P) or
- a fixed reactive power in MVar or
- a reactive power/voltage characteristic Q(U).

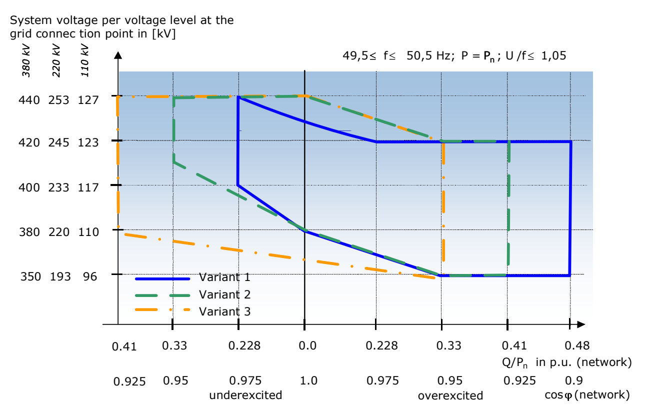

Fig. 1 Basic requirement of reactive power from generating plant at the PCC (Variants 1-3) according to *TransmissionCode 2007* [4]

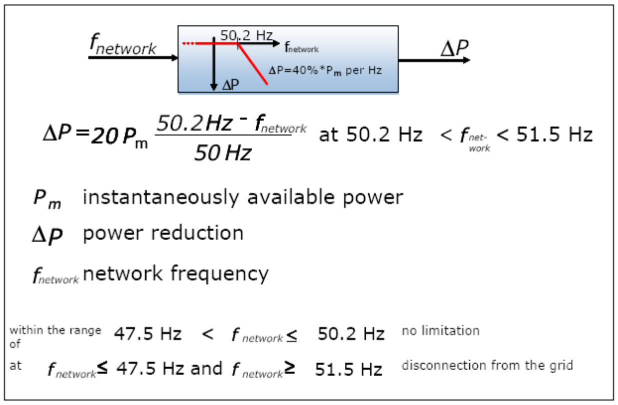

Fig. 2 Active power reduction of generating units in the case of over-frequency [4]

B. Active power control

The generating plants must be capable of reducing their active power at steps of maximally 10 % of the agreed active connection power. A reduction down to the target value 10 % must be possible without automatic disconnection from the network; below 10 % of the agreed active connection power P_{AV}, the generating facility may disconnect from the network. The reduction of the power output to the respective target value must be realized without delay, but within one minute, at the most.

All generating units must reduce, while in operation, at a frequency of more than 50.2 Hz the instantaneous active power with a gradient of 40 % of the generator's instantaneously available power per Hertz as shown in Fig. 2.

C. Behaviour of power plants during network faults

According to the *TransmissionCode 2007* all plants connected to the HV/EHV networks have to be able to ride through grid faults ("fault ride through" - FRT).

A distinction is made between type-1 and type-2 generating plants with regard to their behavior in the event of network disturbances. A type-1 generating unit exists if a synchronous generator is directly (only through the generator transformer) connected to the network. All other plants are type-2 generating units.

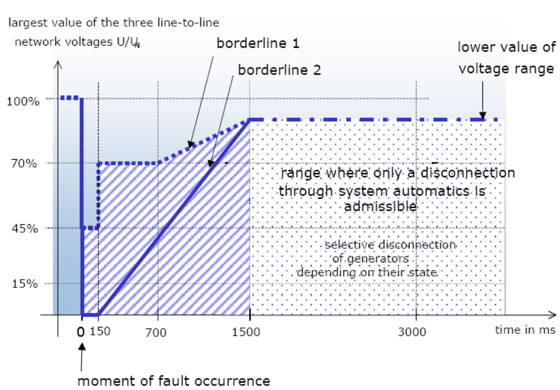

Fig. 3 Fault ride through limiting curves of voltage at the PCC for a generating plant connected to HV/EHV networks according to *TransmissionCode 2007* [4]

The focus will be put on type-2 generating plants for that the following conditions according to Fig. 3 and Fig. 5 apply:

1. If the voltage drops to values above the borderline 1 (area ① in Fig. 5):
   - This must not lead to instability or to the disconnection of the generating plant from the network.
   - Feed-in of a reactive current is to be supplied to the network by the generating facility, currently according to Fig. 4 but preferably according to Fig. 8.
2. If the voltage drops to values below the borderline 1 and above the borderline 2 (area ② in Fig. 5):
   - Generating units shall pass through the fault without disconnecting from the network.
   - In consultation with the network operator, it is permissible to shift the borderline 2 if the generating plant's connection concept requires doing so. Also in consultation with the network operator, a short-time disconnection from the network is permissible if the generating plant can be resynchronized within 2 seconds, at the latest, after the beginning of the short-time disconnection.
   - Feed-in of a reactive current is desired (but not obligatory) to be supplied to the network by the generating facility, currently according to Fig. 4 but preferably according to Fig. 8.
3. If the voltage drops to values below the borderline 2 (area ③ in Fig. 5):
   - A short-time disconnection of the generating plant may be carried out in any case.
   - A feed-in of a reactive current is not required.
4. If the voltage remains more than 1.500 ms below 90 % of the nominal voltage U_N (area ④ in Fig. 5):
   - A stepwise tripping by the safeguard II protection after 1.5 … 2.4 s is allowed/required.

The principle of the reactive current supply to the network aiming at grid voltage support during faults is shown in Fig. 4. However, the revision in Fig. 8, section V should be noted.

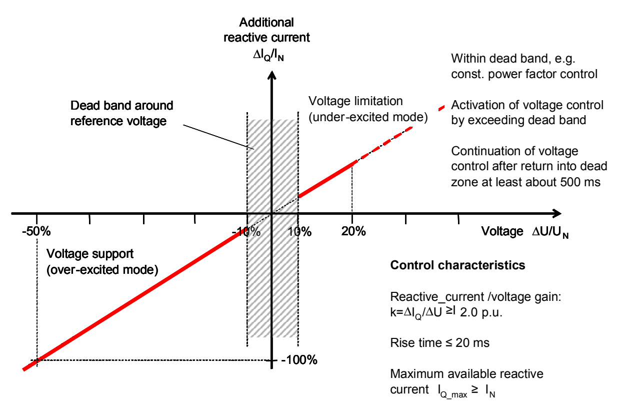

Fig. 4 Current figure for voltage support during faults by reactive current feed based on [4] and [7]

IV. The new MV-Directive 2008

The *MV-Directive 2008* substantially extends the requirements for the connection of DG defined in earlier technical codes from the 1990s. The revisions apply many of the previously described requirements from the *TransmissionCode 2007* to the MV level. Table I highlights some important changes.

The changes altogether are related to the behaviour of generating plants connected to the network. Therefore, the focus in this section will be put on:

- Steady-state voltage control
- Dynamic network support
- Active power output
- Reactive power

Not included in the following presentation but with reference to [8] are requirements for:

- Determination of the network connection point
- Dimensioning of network equipment
- Admissible voltage changes
- Network disturbances, including
  - Sudden voltage changes
  - Long-term flickers
  - Harmonics and inter-harmonics
  - Commutation notches
  - Audio-frequency centralized ripple-control

For the detailed and binding technical requirements, it is generally referred to [7] and [5].

A. Behaviour of generating plants connected to the network

During network feed-in, generating plants must be capable of participating in voltage control. Steady-state voltage control and dynamic network support are distinguished.

1) Steady-state voltage control

Steady-state voltage control means voltage control within the MV network under normal operating conditions, where slow voltage changes in the distribution network are kept in acceptable limits. This control is closely related to the reactive power limits of the generating units.

2) Dynamic network support

Dynamic network support means voltage control in the event of voltage drops, especially within the HV/EHV network with a view to avoiding unintentional disconnections of large feed-in power, and thus network collapse.

TABLE I
COMPARISON OF NEW AND PAST TECHNICAL DISTRIBUTION CODE

MV-Directive 2008	MV-Directive 1998
FRT capability and simultaneous support of grid voltage (see Fig. 5)	Immediate disconnection in case of voltage disturbance ($V < 80\% \ V_{nominal}$)
Proportional active power reduction for frequency exceeding 50.2 Hz (see Fig. 2)	Immediate disconnection in case of frequency disturbance
Reactive power control at PCC of up to cos(φ) = 0.95 lagging and leading	Unity power factor at PCC

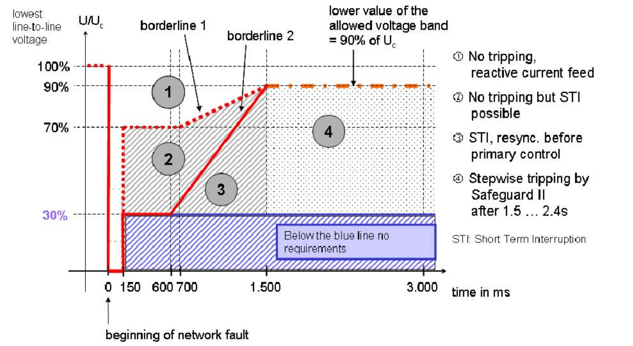

Fig. 5 Fault ride through limiting curves of voltage at PCC for a generating plant connected to MV networks according to *MS-Directive 2008 [7]*

The requirements for dynamic network support are in principle the same as the requirements for FRT in the *TransmissionCode 2007*. However, two differences can be noted:

- Instead of the limiting curves of voltage at PCC according to Fig. 3, the curves according to Fig. 5 apply. Thus, the borderline 1 is as low as zero voltage during the first 150 ms after the beginning of the network fault.
- Instead of the largest value of the three line-to-line voltages as shown in Fig. 3, the curves in Fig. 5 refer to the lowest line-to-line voltage at the PCC.

As a result, generating plants connected to the HV/EHV networks must even be able to run through unsymmetrical network faults for that one or two line-to-line voltages can stay very low (e.g. close to zero voltage) while at least one line-to-line voltage remains above the borderline 1 or 2 150 ms after the beginning of the fault. In contrast, generating plants connected to the MV networks are allowed to disconnect (in short term) when one or two line-to-line voltages stay longer than 150 ms below borderline 1 or 2 during a network fault. However, in both cases a (short term) disconnection in case of an unsymmetrical network fault during that one or two line-to-line voltages drop to nearly zero voltage in the first 150 ms after beginning of the fault is not allowed.

In other words, during the first 150 ms both guidelines require FRT for symmetrical and unsymmetrical faults whereas only the *TransmissionCode 2007* requires FRT for unsymmetrical faults longer than 150 ms.

Active power output

The requirements are identical to the ones defined in the *TransmissionCode 2007*.

Reactive power

The reactive power requirements of the *MV-Directive 2008* are weaker than the requirements of the *TransmissionCode 2007*. This applies especially to generating plants operating at partial load: only limits for the cos φ are defined.

$$\cos\varphi = 0.95_{lagging} \text{ to } 0.95_{leading}$$

The setting values are similar to the requirements in the *TransmissionCode 2007*.

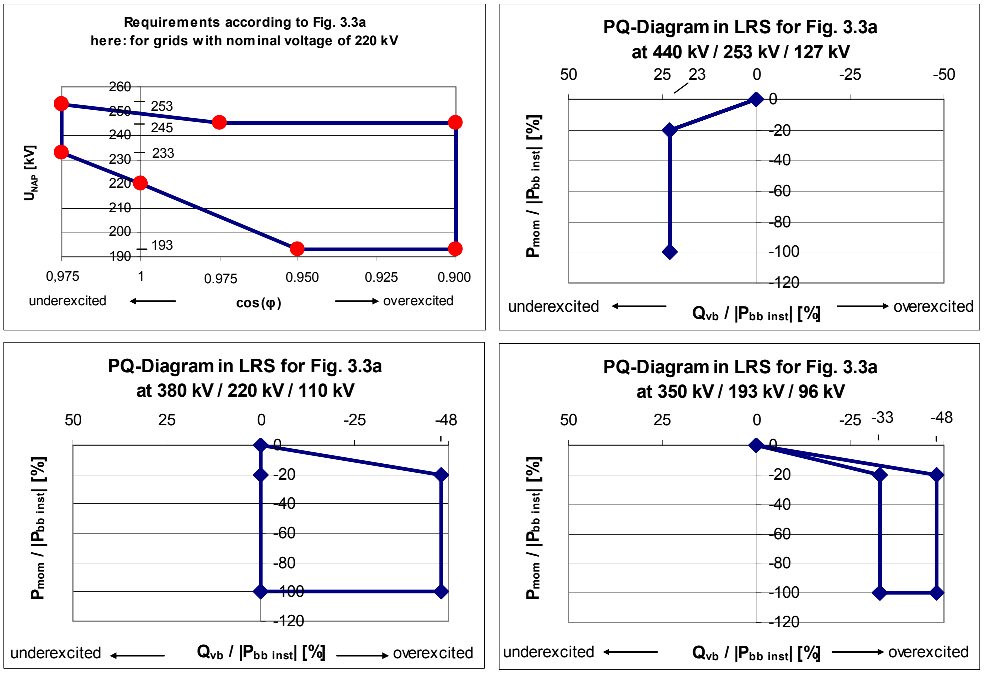

Fig. 6 Example for proposed clarifying figure showing the steady-state reactive power provision at partial load for extreme voltages at PCC (here for variant 1). LRS = load reference system

V. Proposed Clarifying Specifications for the TransmissionCode 2007

The analysis of the requirements defined by the *TransmissionCode 2007* showed that a couple of clarifying specifications should be incorporated in future versions of the document [6]. The main purpose of these specifications was to take into account the inherent characteristics power plants based on RES-E, e. g. their fluctuating power production and their specific generator technologies. In the following, a selection of proposed specifications is presented.

A. Reactive power provision and control

The *TransmissionCode 2007* only indirectly defines by cross-reference to [3] that the steady-state reactive power provision is meant to be a discrete and slow reactive power control with time constants of "several" minutes. Therefore, it was regarded as necessary to explicitly clarify this fact and it was also proposed to sharpen the dynamic performance according to which the respective reactive power should be reached within "up to ten minutes".

Moreover, as shown in Fig. 1, the *TransmissionCode 2007* only defines the steady-state reactive power provision for operation of the generating units at nominal power in an explicit way. But also for partial load it should be made clear what reactive power limits (instead of only cos φ limits as in the case of the *MV-Directive 2008*) are required. It was proposed that for any operation with instantaneously available power P_{mom} between 20 % and 100 % of available installed power $P_{bb\ inst}$ the reactive power limits shown in Fig. 1 should also apply (for variant 1 refer to Fig. 7). Note that the presented PQ-diagrams use the load reference system (LRS) so that reactive power "consumption" becomes positive and reactive power "supply" becomes negative.

The implications resulting from PCC voltage dependency of the steady-state reactive power provision requirements should also be illustrated for the partial load operation of the power plant (see Fig. 6).

B. Behaviour during network faults

In the respective section of the *TransmissionCode 2007* only to symmetrical faults an explicit reference is given. The reason may be that 3-phase faults have the highest impact on power system stability. However, as described in section IV of this paper, the remark in Fig. 3 that refers to the "largest value of the three line-to-line network voltages U/U_N") indicates that generating plants connected to the HV/EHV networks must also run through any unsymmetrical faults during that at least one of the three phase voltages remains above borderline 1 or 2. Therefore, it was proposed to explicitly refer to unsymmetrical faults in the respective lines.

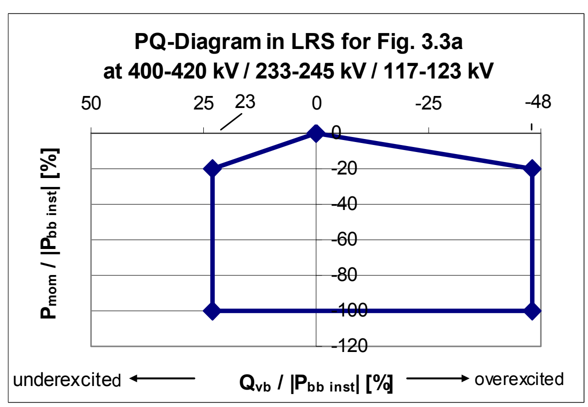

Fig. 7 Example for proposed clarifying figure showing the steady-state reactive power provision at partial load for the typical voltage range at the PCC (here for variant 1). LRS = load reference system

Finally, fundamental revisions of the principle for the reactive current supply to the network, which aims at grid voltage support during faults, are proposed. Recent investigations showed some drawbacks of the present functionality as shown in Fig. 4, e.g.:

- The reactive current / voltage characteristic passes the origin (0 % voltage deviation, 0 % additional reactive current) instead of starting from the boundaries of the voltage deadband – this defines an additional reactive current of a minimum of 20 % of the nominal current that must be feed-in when the voltage exceeds the voltage deadband.
- No upper limit for the reactive current is defined when the voltage control is activated – this allows instantaneously switching to a reactive current equal to nominal current and that may cause detrimental effects for the grid voltage and the generating plant's stability.
- An additional rule that requires a continuation of the voltage control for a period of 500 ms after the voltage returns into the boundaries of the deadband is defined – mainly in order to smooth the additional reactive current feed-in during voltage restoration because it would otherwise jump back to zero value.

Based on this analysis, an improved functionality of feed-in of a reactive current during network faults is proposed according to Fig. 8 based on [5] and described in further detail below.

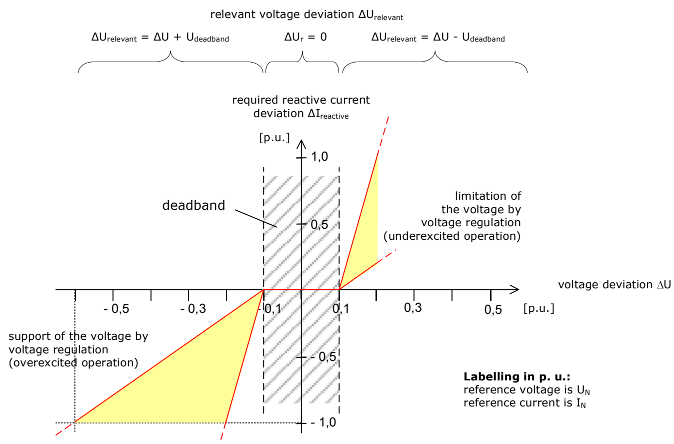

Fig. 8 Proposed specified figure for voltage support during faults by reactive current feed based on [5]

The feed-in of a reactive current should preferably be realised according to Fig. 8 as follows:

1. Basic requirements
   - For any *Significant voltage deviations* the generating units must support the voltage by adaptation (increase or decrease) of the *Reactive current* $I_{reactive}$.
   - The *Reactive current deviation* ($\Delta I_{reactive}$) of the generating units must be proportional to the *Relevant voltage deviation* ΔU_r ($\Delta I_{reactive} / I_{reactive\ nominal} = K * \Delta U_r / U_{nominal}$) and must be within the range indicated in Fig. 8 (defined by $2 \leq K \leq 10$).
   - The constant K must be adjustable within 0 … 10.
   - The variation of the measured reactive current that results from the chosen reactive current / voltage characteristic must be within a tolerance range of -10 % to +20 % of the nominal current.
   - The absolute value of the total *Reactive current* $I_{reactive}$ must comply with these requirements:
     – 3-phase faults: The absolute value of the total *Reactive current* $I_{reactive}$ must reach at minimum 100 % of the nominal current.
     – 1,2-phase faults: Generating units must be technically able to feed-in a *Reactive current* $I_{reactive}$ of a minimum of 40 % of the nominal current. The feed-in of the reactive current must not impede the compliance with the fault ride through requirements.
   - For any *Significant voltage deviations* U_s the *Active current* I_{active} must be decreased for the benefit of the reactive current feed-in and for securing the stability of the generating unit.
2. Performance requirements
   - The dynamic behaviour of the reactive current feed-in is characterised by the *Step response of the reactive current* as it appears with approximation as a consequence of network faults.
   - For any *Significant voltage deviations* the *Step response of the reactive current* must comply with the following requirements (see Fig. 9):
     – *Response time*: 30 ms
     – *Settling time*: 60 ms
   - During the voltage recovery the function of the reactive current must not show any steps that are not defined by the reactive current / voltage characteristic as shown in Fig. 8 and that may have a negative impact on the quality of supply. This applies especially for the transition between the operation during *Voltage deviations* ΔU within the *Deadband* $U_{deadband}$ and the operation for *Significant voltage deviations* U_s.

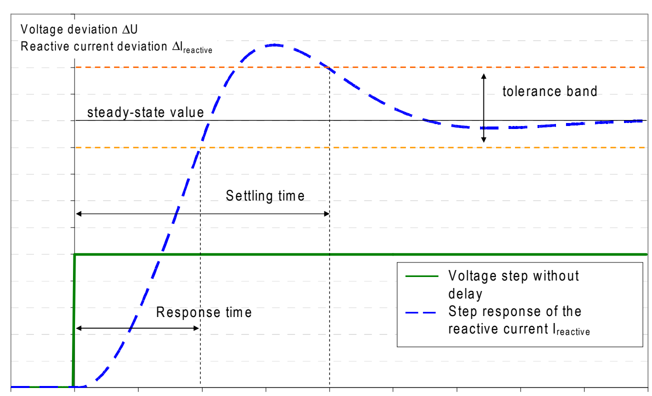

Fig. 9 Step response of the reactive current and definition of performance parameters based on [5]

VI. Verification of Compliance

It is recommended introducing a verification procedure using the so-called wind power "project certificates". These would be based on so-called "unit certificates" as well as stationary and dynamic grid calculations of the wind farm at their interface with the grid into which the power would be fed. The verification by unit certificates would be provided to the grid operator when the request to connect a new wind farm to the grid is lodged. The project certificate for the whole wind farm would be made available when the wind power facility becomes active, at latest. These certificates will be issued by accredited and licensed certification bodies.

The recommendations follow existing guidelines including the *TransmissionCode 2007*, the *MV-Directive 2008* and the *VDN Guideline 2004*.

VII. Conclusions

When amending the EEG in June 2008 the German government acknowledged the importance of enhanced technical requirements. Compliance with specific technical requirements is becoming a necessary precondition for privileged network access, receipt of feed-in tariff, and extra payments (system service bonus) for any wind power plant put into operation after June 2010. The system services bonus is only paid during a transitional period to any operators that put their wind power plant into operation until the end of 2013. The bonus is meant to cover extra costs resulting from the advanced technical requirements; it equals 0.5 €cents/kWh and is paid to the wind power plant operator over the so-called initial payment period.

The EEG additionally stimulates upgrades of existing capacity on some key issues (e.g. FRT, frequency support) but that was not discussed in this paper.

The present paper presented a proposal for how the technical codes should be used to define the technical requirements in the EEG and it was shown that the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety to very large extent is following this proposal. The proposal included reasonable revisions of the *TransmissionCode 2007* and it would be desirable to include these revisions in future versions of the TransmissionCode.

VIII. Acknowledgment

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- Dr.-Ing. Markus Pöller, DIgSILENT GmbH, Gomaringen, Germany
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IX. Definitions

- „*Response time*" is a characteristic value of the step response: time between the instantaneous appearance of a *Significant voltage deviation* U_s and the first moment when the *Reactive current* $I_{reactive}$ reaches the tolerance band around the *Steady-state value*. The *Response time* includes the time to identify a *Significant voltage deviation* and the rise time of the reactive current control.
- „*Reactive current* $I_{reactive}$" is the total reactive current that is calculated from the positive sequence components (indices "1") of the fundamental frequency of current and voltage at the low-voltage side of the generator transformer, $I_{reactive} = \frac{Q_1}{\sqrt{3} \cdot U_1}$ with $Q_1 = \mathrm{Im}\{\underline{U}_1 \cdot \underline{I}_1^*\}$; <u>underlined:</u> complex value; „*": conjugant complex value.
- „*Reactive current deviation* ΔI_B" is the deviation of the *Reactive current* $I_{reactive}$ from its 1-minute mean value.
- „*Settling time*" is a characteristic value of the step response: time between the instantaneous appearance of a *Significant voltage deviation* U_s and the moment at which the oscillation has decreased so much that the *Reactive current* $I_{reactive}$ remains in the tolerance band around the *Steady-state value*.
- „*Relevant voltage deviation* (ΔU_r)" is the part of the *Voltage deviation* ΔU by that the *Voltage* U_1 exceeds the boundaries of the *Voltage deadband* $U_{deadband}$. Within the *Voltage deadband* $U_{deadband}$ the *Relevant voltage deviation* (ΔU_r) equals zero:
  - If $\Delta U > U_{deadband}$ then $\Delta U_r = \Delta U - U_{deadband}$
  - If $\Delta U < -U_{deadband}$ then $\Delta U_r = \Delta U + U_{deadband}$
  - Else $\Delta U_r = 0$
- „*Significant voltage deviation* ΔU_s" is a *Voltage deviation* ΔU with an absolute value larger than the *Voltage deadband* $U_{deadband}$.
- „*Voltage* U_1" is the voltage that that is calculated from the positive sequence components (indices "1") of the fundamental frequency of current and voltage at the low-voltage side of the generator transformer.
- „*Voltage deviation* ΔU" is the deviation of the *Voltage* U_1 from its 1-minute mean value. A *Voltage deviation* ΔU with negative value represents a voltage decrease. A *Voltage deviation* ΔU with positive value represents a voltage increase.

- „*Voltage deadband* $U_{deadband}$ “ equals usually 10 % of the nominal voltage but can be set to zero if the grid operator agrees, e.g. for the realisation of a continuous voltage regulation.
- „*Step response of the reactive current* $I_{reactive}$“ is the function of the *Reactive current* $I_{reactive}$ as a consequence of an instantaneous change of the *Voltage* U_1.
- „*Steady-state value*“ of the *Reactive current* $I_{reactive}$ is the value of the *Reactive current* $I_{reactive}$ as a function of the *Voltage* U_1 in steady-state operation.
- „*Current* I_1“ is the positive-sequence component of line current at the low-voltage side of the generator transformer.
- „*Active current* I_{active}“ is the total active current that is calculated from the positive sequence components (indices “1”) of the fundamental frequency of current and voltage at the low-voltage side of the generator transformer, $I_{active} = \frac{P_1}{\sqrt{3} \cdot U_1}$ with $P_1 = \text{Re}\{\underline{U}_1 \cdot \underline{I}_1^{\,*}\}$; underlined: complex value; „*“: conjugant complex value.

X. References

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XI. Biographies

Jens Bömer received his Dipl.-Ing. in Electrical Engineering from Technical University of Dortmund (Germany) in 2005. He specialised on power systems and renewable energies. In 2006-2007 he advised as an independent consultant the German Environment Ministry on policies for improved grid integration of wind turbines and other renewable energy resources. Since September 2007 he works as a Consultant in the Power Systems and Markets Group at the Ecofys office in Berlin. Parallel to his employment at Ecofys, Mr Bömer is Ph.D.-candidate with the Department of Electrical Power Engineering, Delft University of Technology, The Netherlands.

Dr.-Ing. Karsten Burges combines a PhD in electrical engineering from the Technical University of Magdeburg (Germany) with a Masters degree in Environmental Management from the University of Amsterdam (The Netherlands). Since joining the renewable energy consultant Ecofys in 1992, Dr. Burges has been focusing on integration of renewable energy sources and technologies in electrical power systems.

Dr.-Ing. Thomas Kumm has studied electrical engineering at Technical University of Berlin (Germany) focusing electrical power transmission and distribution. He received a PhD on High Voltage cable diagnostics. Dr. Kumm joined the Association of German Network Operators (VDN) in 2006, since June of 2008 he works as technical manager at the Network Technology and Operation Forum of VDE (FNN). He deals with technical codes aimed to a sure and reliable grid operation.