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Present status of DG in Germany: National codes, standards, requirements and rules for grid-interconnection and operation

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Abstract:

This National Report describes in detail the technical background for the connection of distributed generators (DG) to the distribution grid in Germany. The requirements and procedures are extracted from the relevant documents, like the national legislation, the LV grid code, and company recommendations, which are applicable to the grid connection of DG.

Executive summary

The present report on “National codes, standards, requirements and rules for grid-interconnection and operation of DG in Germany” is a contribution to the Task 2.1.1, “Review and of existing standards for grid connection of DG” of the European Project DISPOWER.

In this context the aim of this document is to provide a detailed view on the status and contents of the documents which define at the national level the framework for the connection to distribution grids. The information presented here is based on an in-depth analysis of those documents, which were identified as relevant for DG.

In detail the following technical topics are covered in the analysis:

- Principal requirements of the network, assessment of the connection of DG
- Electrical interconnection requirements
- Power quality issues
- Testing and conformance assessment of DG components
- Commissioning
- Operation and communication

The importance of the DNOs must be highlighted, since they establish the requirements that are not totally defined in the regulatory documents and that must be met by the DG owners. On the other hand, many DG connections are based on particular conditions, in the frame of the legal requirements, but defined case by case.

Furthermore, a brief overview on the status, support mechanisms and legislation governing the German electricity system is given, in order to ease a further understanding of the national situation. Besides this, some clues are given to understand how the various documents are elaborated and which stakeholders and organisations are involved in that process.

1 SCOPE AND METHODOLOGY

Opening of the electricity markets, liberalisation, dedicated support for electricity from renewable sources, incentives for small scale Co-Generation and security of supply concerns have triggered a development resulting in a transition from central generation towards a more decentralised supply, based on RES.

As one of the most important barriers in this context, the lack of adequate standards, technical requirements and procedures for the assessment of the connection and the electrical interconnection itself has been identified by many of the involved stakeholders. Furthermore the limited availability, diverse structure and last but not least language often makes it difficult to get a clear view of the requirements for DG connection in various countries.

In order to overcome these barriers and provide a detailed overview on the status and contents of laws, grid codes, network standards, company recommendations, practises and standards concerning the connection of distributed generation to distribution networks, a survey has been performed in the framework of the WP2.1 of the EU project DISPOWER. The focus of the information collection is on the DISPOWER countries: Austria, Belgium, France, Germany, Italy, Spain and the United Kingdom.

The present report intends to provide not only a detailed analysis of the documents which define the rules for interconnecting distributed generators to the electrical networks in Germany but moreover an in deep view on the procedures applied in practise.

Furthermore, a brief overview on the status, development and legislation governing the German electricity system is given in section 2 in order to allow an understanding of the national background. In addition, the way the various documents are elaborated, the involved stakeholders and organisations are described.

The information provided has been structured according to the various technical topics which have been identified by the DISPOWER Task 2.1 working group as being the most relevant for distributed generation connection to the grid.

Specifically the topics covered are organised as follows

- Principal requirements of the network, assessment of the connection of DG
- Electrical interconnection requirements
- Power quality issues
- Testing and conformance assessment of DG components
- Commissioning
- Operation and communication

In each section the requirements are summarised and the according section in the relevant document is referenced.

2 NATIONAL BACKGROUND

2.1 DG in the national electricity market

The distributed generation especially of regenerative energy sources has experienced a very strong rise during the last years in Germany. One important reason for this is a federal law (Gesetz über den Vorrang erneuerbarer Energien, Act on granting priority to renewable energy sources), which regulates the tariffs of the energy delivered to the grid by environmentally friendly generators.

These favourable conditions lead to a strong rise of wind energy and PV in the public grid. In September 2004 the installed capacity of all wind energy converts was 15.688 MW. These systems supply almost one third of the electrical energy demand of the northern federal states of Germany. Their contribution to the entire electrical energy demand of Germany is 6.2 %.

Compared to these achievements, the share of PV power in the grid is small but nevertheless remarkable. By the end of 2003 more than 400 MW have been connected to grid. This market faces a very dynamic growth resulting in new installed 133 MW in 2003. Most of the PV systems are mounted on rooftops of private housings or office building. They are mostly connected to the low voltage grid and represent a deep embedded and widely dispersed kind of power generation.

Co-generation units becoming popular as well especially if supplied by bio fuels which receive a more favourable funding than units with conventional fuels. Due to the tariffs these systems are mostly used when the operator has a high electrical energy demand. The energy export to the grid is minimized by system design.

Due to the large installed capacity technical measures to guarantee the stable operation of the grid are required. In the case of wind energy concerns are raised regarding cascade failures which could cause outages of the grid. Therefore, the wind energy converters have to deliver their rated current even at very low voltages of the grid. In contrast to this with PV power the problem is seen in unintentional islanding which might pose a danger for electricians working on the grid. To fulfil this requirement the PV system has to disconnect as soon as possible if the grid voltage is outside a narrow band of normal operating parameters.

The requirements for the interconnection to the grid are given in the regulations of the grid operators. In additions to this the national and international safety standards for electrical installations are applicable.

2.2 National standardisation bodies and organisations

DG resources fall into the scope of multiple organisations:

DKE

The DKE "Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE" belongs both to the DIN (Deutsches Institut für Normung e.V.) and the VDE (VERBAND DER ELEKTROTECHNIK ELEKTRONIK INFORMATIONSTECHNIK e.V.). In general this institution is responsible for electrotechnical standardisation. Two of its departments deal with issues touching the scope in question.

Division 1: General electrotechnical engineering, materials for electrotechnical purposes

- K 115 „Grund- und Sicherheitsregeln für die Mensch-Maschine-Schnittstelle, Kennzeichnung“
  German equivalent to:
  IEC/TC 16 „Basic and safety principles for man-machine interface, marking and identification“
  CLC/SR 16

- K 121 „Kurzschluss-Ströme“
  German equivalent to:
  IEC/TC 73 „Short-circuit currents“

- K 122 „Isolationskoordination“
  German equivalent to:
  IEC/TC 28 „Insulation co-ordination“

- K 123 „Isolationskoordination für Niederspannungs-Betriebsmittel“
  German equivalent to:
  IEC/TC 109 „Insulation co-ordination for low-voltage equipment“

Division 2: General safety, installation and operation

The following committees of this department are relevant for DG:

- K 221 Electrical system and protection against electric shock
  Working groups / mirrors:
  CLC/BTTF 95-1 „Inspection of electrical installations in domestic accommodations“
  IEC/TC 64 „Electrical installations and protection against electric shock“
  CLC/TC 64 „Electrical installations and protection against electric shock“

  CLC/BTTF 95-1 AK 221.0.1 International co-operation
  IEC/TC 64 AK 221.0.2 Terms and definitions
  CLC/TC 64 GAK 221.0.4 GAK 221 + 712 - Coordination of the potential equalisation of buildings
  AK 221.0.5 DIN VDE 0100-530 without 534, Selection of residual current protection devices (RCD)

  Subgroup UK 221.1: Protection against electric shock:
  Working groups / mirrors:
  CLC/SC 64A AK 221.1.1 Classification of equipment concerning the protection against electrical shock
  IEC/TC 64 AK 221.1.10 Effects of the electric current on humans and productive livestock
  AK 221.1.2 Protective measures
  AK 221.1.4 Erection of photovoltaic systems according to DIN VDE (Responsible for many standards of the DIN VDE 0100-100 series).

- K 222 „Errichten von Starkstromanlagen über 1 kV und deren Erdung“
  German equivalent to:
  IEC/TC 99 „System engineering and erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and 1,5 kV d.c.“

CLC/TC 99X „Power installations exceeding 1 kV AC (1,5 kV DC)“

Responsible for all aspects related to erection of electrical systems exceeding 1 kV

- K 224 „Betrieb elektrischer Anlagen“
  German equivalent to:
  CLC/BTTF 62-3 „Operation of electrical installations“
  CLC/BTTF 95-1 „Inspection of electrical installations in domestic accommodations“
  Responsible for all aspects related to the operation of electrical systems

- K 261 System aspects of electrical energy supply
  The principal discussion about grid coupling of DG resources takes place in this Committee.
  Mirror to CLC/TC 8X

Division 3: Equipment of power engineering

This department deals with the devices used for energy transformation and for grid connection.

- K 311 „Drehende elektrische Maschinen“
  German equivalent to:
  IEC/SC 2G „Test methods and procedures“
  IEC/TC 2 „Rotating machinery“

- K 321 „Transformatoren“
  German equivalent to:
  CLC/TC 14 „Power transformers“
  IEC/TC 14 „Power transformers“

- K 331: Power electronics
  This committee treats generic issues of power electronic. Because of the importance of power electronics for DG the standards generated in this committee will have an impact on DG, as well.
  Mirrors:
  IEC/TC 22 “Power electronics”
  IEC/SC 22E “Stabilised power supplies”
  IEC/SC 22F “Power electronics for electrical transmission and distribution systems”
  IEC/SC 22H “Uninterruptible Power Systems (UPS)
  CLC/TC 22X “Power electronics”

- K 373: Solar Photovoltaic Energy Systems
  All aspects of photovoltaic systems are discussed in the committee 373. Because PV was one of the first largely applied grid connected DG resources in Germany (e.g. 1000-roof-program) much experience has been gained on this topic and standardisation activities on grid coupling are carried out in this committee, too.
  Mirrors:
  IEC/TC 82 “Solar photovoltaic energy systems”
  CLC/TC 82 “Solar photovoltaic energy systems”

  Relevant subgroup: AK 373.0.9 Bidirectional grid interface.
  The aim of this working group is the definition of a safety grid interface. The work concentrates on device specific topics (e.g. functional safety).

- K 383: Wind Turbines
  Mirrors:
  IEC/TC 88 "Wind turbine systems"
  CLC/TC 88 "Wind turbine systems"

- K 384: Fuel cells
  Up to now there have been no significant activities carried out on grid connection in this committee.
  Relevant subgroup: AK384.0.2 "Stationary fuel cells".
  Mirrors:
  IEC/TC 105 "Fuel cell technologies"
  CLC/BTWG 112-2 "Domestic cogeneration"

Division 7: Information and telecommunication technologies

- K 716 „Elektrische Systemtechnik für Heim und Gebäude (ESHG)"
  German equivalent to:
  CLC/TC 205 „Home and Building Electronic Systems (HBES)"

Division 9: Process measurement and control technologies

- GK 914 „Funktionale Sicherheit elektrischer, elektronischer und programmierbarer elektronischer Systeme (E, E, PES) zum Schutz von Personen und Umwelt"
  German equivalent to:
  IEC/SC 65A „System aspects"

- K 921 „Allgemeine Anforderungen"
  German equivalent to:
  IEC/TC 65 „Industrial-process measurement and control"

- K 952 „Netzleittechnik"
  German equivalent to:
  IEC/TC 57 „Power system control and associated communications"
  CLC/SR 57

VDN

The VDN (Verband der Netzbetreiber - VDN - e.V. beim VDEW) is an organisation of the grid operators. Among its members are 4 operators of transmissions grids, 49 regional and 308 municipal operators of distribution grids and 5 foreign grid operators. A working group of this organisation on grid coupling of DG resources writes the technical connection conditions ("Technische Anschlussbedingungen") for the low and the medium voltage grid. These specifications are a recommendation to the members of the VDN concerning the connection of DG resources.

BGFE

The BGFE ("Berufsgenossenschaft der Feinmechanik und Elektrotechnik") belongs to the 35 commercial professional associations in Germany. This organisation runs the legal accident insurance and is responsible for 2.3 million insurants in approximately 99,000 enterprises. Membership (entrepreneur) and insurance protection (employee) are legally regulated.

The task of the BGFE is to prevent industrial accidents, occupational illnesses and work-caused health dangers. Nevertheless, if an industrial accident happens or if an occupational illness is determined, the BGFE will cover the medical, vocational and social rehabilitation and the financial remuneration of the insurants or their survivors.

The BGFE is involved in all issues of electrical safety. This includes the safety of the personnel working on the grid and on domestic installations. Because of this responsibility the BGFE is involved in requirements on the safety of DG resources.

3 RELEVANT STANDARDS, RULES AND RECOMMENDATIONS

3.1 Overview of relevant documents and covered topics

Description of the Standard / Company recommendation / Law / Other document

Id	Type	Status	Number, code, name and/or title of the document	Date of last revision	Short description of the purpose of the document & the issues relevant for DG	Comments and personal opinion concerning the document
1	CR	F	Eigenerzeugungsanlagen am Niederspannungsnetz, Richtlinie für Anschluß und Parallelbetrieb von Eigenerzeugungsanlagen am Niederspannungsnetz, ISBN 3-8022-0646-0	01/01/2001	Guideline of the VDEW (German Electricity Association, trade association of the electricity supply) for the connection of DG to the LV grid	Main guideline for connecting DG to the low voltage grid, no accessible switch required for small systems with a fail safe automatic disconnection device as specified in DIN VDE0126. Makes reference to: DIN EN 61000 3-2, DIN EN 61000 3-3, DIN EN 61000 3-11, DIN EN 61000 3-12
2	CR	F	Eigenerzeugungsanlagen am Mittelspannungsnetz, Richtlinie für Anschluß und Parallelbetrieb von Eigenerzeugungsanlagen am Mittelspannungsnetz, ISBN 3-8022-0584-7	01/01/1998	Guideline of the VDEW (German Electricity Association, trade association of the electricity supply) for the connection of DG to the MV grid	
3	NS	Rev	**DIN VDE0126** Selbsttätige Freischaltstelle für Photovoltaikanlagen einer Nennleistung <= 4,6 kVA und einphasiger Paralleleinspeisung über Wechselrichter in das Netz der öffentlichen Versorgung	01/04/1999	Requirements on the disconnection unit between the DG system and the grid. According to (1) with this device an accessible disconnection-switch is not needed.	Definition of a fail safe disconnection device for grid connected PV systems; in contrast to the title used for other DG, as well. Detection of unintended islanding using the impedance of the grid as a criteria. Is being revised to enhance European compatibility.
4	CR	F	Technische Anschlußbedingungen für den Anschluß an das Niederspannungsnetz "**TAB 2000**", ISBN 3-8022-0627-4	01/2000	General technical requirements for connecting loads and generators to the grid. For DG this regulation refers to (1). Published by VDEW (German Electricity Association, trade association of the electricity supply)	The master copy of this regulation has been published by the VDEW. Individual grid operators are free to use modified versions of this text.For DG this standard makes a reference to (1) which in references DIN VDE0126
5	NS	F	**DIN VDE 0100-551**, Elektrische Anlagen von Gebäuden - Teil 5: Auswahl und Errichtung elektrischer Betriebsmittel; Kapitel 55: Andere Betriebsmittel; Hauptabschnitt 551: Niederspannungs-Stromversorgungsanlagen	08/1997	General rules for sizing and construction of power suppy systems connected to the low voltage grid	The VDE0100 series can be regarded as a "law".
6	CR?	F	**DistributionCode 2003** Regeln für den Zugang zu Verteilungsnetzen	08/2003	Regulation for the general access to the MV and LV grid, published by "Verband der Netzbetreiber - VDN - e.V. beim VDEW	
7	CR?	F	**TransmissionCode 2003** Netz- und Systemregeln der deutschen Übertragungsnetzbetreiber	08/2003	Regulation for the access to the HV grid, published by "Verband der Netzbetreiber – VDN – e.V. beim VDEW"	
8	CR	F	Bau und Betrieb von Übergabestationen zur Versorgung von Kunden aus dem Mittelspannungsnetz	06/2003	General technical requirements for building coupling stations connecting loads and generators to the MV grid. Guideline of the VDEW.	This standard is referenced by (2)
9	CR	Pr	Dezentrale Erzeugungsanlagen, Richtlinie für den Anschluss und Parallelbetrieb von dezentralen Erzeugungsanlagen am Hochspannungsnetz	2004?	Guideline of the VDEW for the connection of DG to the HV grid. Under consideration	

Id	DG Resource: Wind power	Solar power	Cogeneration, CHP	Not specific	Generation Technology: Synchronous gen.	Asynchronous gen.	Static Inverters	Not specific	DG rated Power / Capacity addressed: from	to	Grid Voltage level: LV	MV	HV	Grid topologies: Interconnected grids	Isolated grids
1				X				X			X			X	
2				X				X				X		X	
3		X					X		0	30kW	X			X	
4				X				X			X			X	
5				X				X			X				
6				X				X			X	X		X	
7				X				X					X	X	
8				X				X				X		X	
9				X				X					X	X	

Topics covered in the document – Connection of DG units

Id	Principal requirements Network: Max. DG power	Short circuit capacity	Stability	Other	Electrical interconnection requirements: Installation	Protection issues	Sizing rules	Measurements	Synchronisation	Accessible disconnection-switch
1	X	X			X	X	X	X	X	X
2		X			X	X	X	X	X	X
3						X				
4					X	X				
5					X		X			
6										
7			X			X				
8					X	X				
9	X				X	X	X	X	X	X

Id	Power Quality issues: Power factor / Compensation	Harmonics	Interharmonics Mains signalling	Flicker	Voltage increase	Voltage variations	Unbalance	Behaviour during fault conditions in the grid: Loss Of Mains (LOM - Islanding)	Temporary overvoltages	Transient over-voltages	Autoreclosures	Short circuits	Lightning protection	DC-injection	Other
1	X	X	X	X	X	X	X	X	X		X				
2	X	X	X	X	X	X	X		X		X				
3								X	X					X	
4														X	
5															
6															
7															
8															
9	X	X	X	X	X	X	X	X	X		X	X			

Id	Com-missioning: Basic requirements	Procedures	Other	Operation and Communication: Information exchange DG - Grid Operator	Monitoring Power and Voltage (metering)	Maintenance requirements
1	X				X	
2	X				X	
3	X					
4	X					
5						
6				X		
7						
8	X					
9	X	X	X	X	X	

Legend

- **Type**: **NS** – National Standard; **IS** – International Standard; **L** – Law; **CR** – Company Recommendation; **O** – Other
- **Status**: **F** – Final Document; **Pr** - Preliminary document; **Rev** – Document under revision

3.2 Document details

3.2.1 Laws and decrees

Document title	Last revision	Abstract	Issued by/responsible TC

3.2.2 National grid-code or similar documents

Document title	Last revision	Abstract	Issued by/responsible TC
Distribution Code **Ref: [4]**	08/2003	Regulation for the access to the grid	Verband der Netzbetreiber –VDN-e.V. beim VDEW

3.2.3 International standards

Document title	Last revision	Abstract	Issued by/responsible TC

3.2.4 National standards

Document title	Last revision	Abstract	Issued by/responsible TC
DIN VDE 0126, Selbsttätige Freischaltstelle für Photovoltaikanlagen einer Nennleistung <= 4,6 kVA und einphasiger Paralleleinspeisung über Wechselrichter in das Netz der öffentlichen Versorgung **Ref: [3]**	1999	Requirements on the disconnection unit between the DG system and the grid. According to (1) with this device an accessible disconnection-switch is not needed.	

3.2.5 Company recommendations

Document title	Last revision	Abstract	Issued by/responsible TC
Eigenerzeugungsanlagen am Niederspannungsnetz, Richtlinie für Anschluß und Parallelbetrieb von Eigenerzeugungsanlagen am Niederspannungsnetz, ISBN 3-8022-0646-0 **Ref [1]**	2001	Guideline for the connection of DG to the LV grid	VDEW (German Electricity Association, trade association of the electricity supply)
Eigenerzeugungsanlagen am Mittelspannungsnetz, Richtlinie für Anschluß und Parallelbetrieb von Eigenerzeugungsanlagen am Mittelspannungsnetz, ISBN 3-8022-0584-7 **Ref [2]**	1998	Guideline for the connection of DG to the MV grid	VDEW (German Electricity Association, trade association of the electricity supply)

3.2.6 Other documents

Document title	Last revision	Abstract	Issued by/responsible TC

4 ANALYSIS OF NATIONAL RECOMMENDATIONS AND REQUIREMENTS BY TOPICS

National documents are usually structured in a variety of ways, depending on their scope, the intended target groups and their evolution. All these factors make an evaluation of the national framework in different countries very difficult and are important barriers for future harmonisation.

In order to overcome these barriers, a structured analysis (Figure 1) of the national documents was performed, based on the topics which have been identified as being the most crucial for the interconnection of DG with distribution networks.

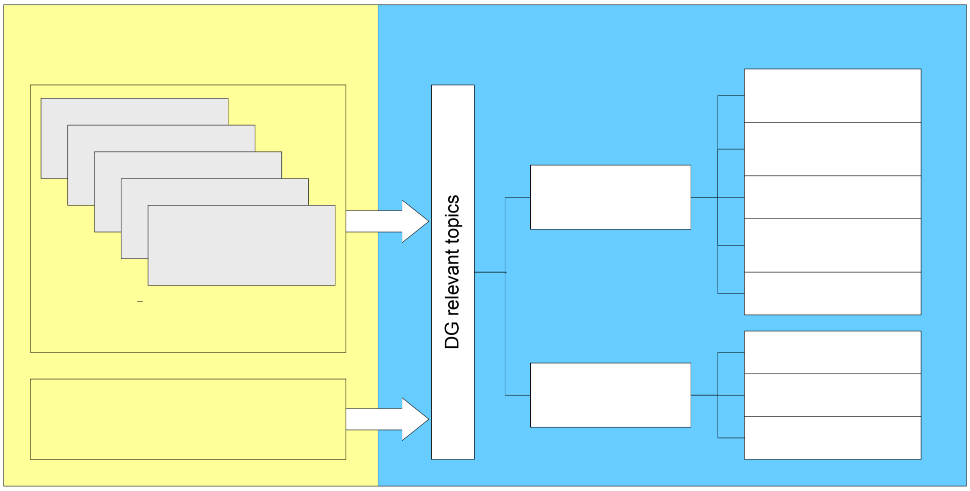

Figure 1. *Analysis of the national recommendations and requirements*

The aim of this analysis was to transform the contents of the national documents into a common structure, in order to allow a comparison of requirements in different countries, the identification of gaps and opportunities for harmonisation. These tasks will be performed in the course of the project.

The following subsections present the results of the analysis for the German framework:

- *General network requirements*, independent of the DG technology used. Here, the principal requirements of the network, the maximum DG capacity which may be connected to a certain network, short-circuit related and stability issues are described.
- *Electrical interconnection requirements* describe all the issues related to the electrical connection such as installation, earthing, protection, synchronisation, disconnection switches, etc.
- *Power quality* focuses on the acceptable impacts of DG on the quality of the network, specifically on reactive power compensation, harmonics, flicker, voltage variation and control, unbalance and others.
- *Requirements for the behaviour of DG under fault conditions* cover islanding, short circuits and earth faults, lightning and over voltage protection and so on.
- *Testing* and conformance assessment procedures for DG components
- *Commissioning* describes suggested procedures for the commissioning and initial start-up of generators
- *Operation and communication* describes the way of exchanging information between grid and DG operators, as well as metering and maintenance requirements.

Information collectior

4.1 General Requirements

See chapter 3 for referred documents.

4.1.1 Principal Requirements of the Network

4.1.1.1 Maximum DG Power

[1][2] The PCC of DG installations in *low and medium voltage* grids has to be defined under consideration of the given grid conditions (impedance of the grid at the PCC), the capacity (rated power) and the operating method of the DG system, as well as the legitimate interest of the DNO. This is to assure that the DG system can be operated without disturbing the grid and the supply of other customers.

DG systems might increase the load of the wires, transformers and other operating devices. Hence, a verification of fulfilling the permitted load limits of those operating devices after the connection of the DG systems is required, according to the corresponding rating rules. Contrary to ordinary customers the DG systems are calculated with steady load meaning that they are considered to deliver rated power all the time.

With most DG systems it is possible to use the agreed apparent power for calculating the thermal load of the operational equipment of the grid. This is also true for *wind energy* systems where the maximum apparent power for 10 minute intervals can be used for the calculations.

4.1.1.2 Short circuit capacity

[1][2] The short-circuit current of the grid is increased by the short-circuit current of DG systems, in particular near the PCC. When the short-circuit current of the DG is not known, the following estimates of its RMS value can be used (in multiples of rated current):

- Systems with synchronous generators: 8
- Systems with asynchronous generators: 6
- Systems with converters: 1

For a detailed calculation, the impedances between generator and PCC must be taken into consideration.

If the DG system causes a rise of the short-circuit current in the grid above the rated value, appropriate systems which limit the short-circuit current from the DG system are to be agreed between operator of the DG system and the DNO and implemented.

4.1.1.3 Stability

Not addressed in the documents.

4.1.2 Electrical Interconnection Requirements

4.1.2.1 Installation

[1] In *low voltage grids*, the compliance to DIN VDE 0100-551 (Elektrische Anlagen von Gebäuden - Teil 5: Auswahl und Errichtung elektrischer Betriebsmittel; Kapitel 55: Andere Betriebsmittel; Hauptabschnitt 551: Niederspannungs-Stromversorgungsanlagen) is required. This is the modified international standard IEC 60364-5-51 "Electrical installations of buildings - Part 5-51: Selection and erection of electrical equipment - Common rules".

[2] In *medium voltage grids*, it is required to comply with "Bau und Betrieb von Übergabestationen zur Versorgung von Kunden aus dem Mittelspannungsnetz". These are general installation requirements which apply to loads, as well. See (German language) document "RichtlinieTrafoMittelspannung2003.pdf" which lists standards on the last pages. This is a rather long list of standards and requirements which can not be summarised to a short comprehensive text.

4.1.2.2 Protection issues

[1][2] In *low and medium voltage*, protection against overvoltage and undervoltage and protection against over- and underfrequency are required. Settings:

- Undervoltage: 0,7 – 1,0 of rated voltage
- Overvoltage: 1,0 – 1,15 or rated voltage
- Underfrequency: 47 – 50 Hz
- Overfrequency: 50 – 52 Hz

[3] If no accessible disconnection switch is provided anti islanding protection by means of impedance monitoring is required.

The German Association of Power Supply Companies (VDEW) sets a strict regulation concerning the connection of DG to the public low voltage (LV) grid. In accordance with this guideline each DG connected to the public LV grid must have an accessible switch, which can be switched by maintenance personnel of the grid operator at any time of the day in case of a failure in the grid. Alternatively, an automatically triggered switch that disconnects the generator in case of a failure in the public grid will be accepted. This device is called "ENS" conforms to VDE0126 and is widely used in Germany for DG units designed for operation in LV grids. In inverter coupled DG (eg. PV), ENS is already implemented in the inverter by the manufacturer. Similar forms of "loss of mains" protection are required in other countries.

To detect a failure in the public grid the ENS device observes the RMS voltage and the frequency. If the continuously measured values are out of the ranges shown in the table below then the switch disconnects the DG unit automatically:

Function	Tolerable Range
Protection in case of voltage drop (phase to neutral)	0.80 U_n, 184 V
Protection in case of voltage rise (phase to neutral)	1.15 U_n, 264.5 V
Protection in case of frequency drop	49.8 Hz
Protection in case of frequency rise	50.2 Hz

In inverter coupled DG the frequency is not monitored. The time delay between detecting a failure and switching of the ENS is 200 ms.

4.1.2.3 Sizing rules

[1][2] Reference to general standards, no difference from regulations for loads (see above).

4.1.2.4 Measurements

[1][2] In *LV and MV*, metering systems must not count in both directions meaning that separate meters are installed for energy generation and consumption. Only calibrated meters are allowed. Measures to monitor the maximum allowed power delivered to the grid might be necessary.

[4] Compliance to "Technische Richtlinie Abrechnungszählung und Datenbereitstellung" as well as "Metering Code" is required.

[2] In *medium voltage* systems, more advanced meters are used measuring not only energy consumption / generation over a time period of one year but the average power consumption / generation in 10 minute intervals. These meters are often connected to a public telephone line or a GSM modem for remote control.

4.1.2.5 Synchronisation

[1][2] Manual synchronisation is allowed, in *low and medium voltage* systems, but automatic synchronisation is preferred. If only course synchronisation is available an inductor is required as an impulse current limiter.

4.1.2.6 Accessible disconnection switch

[1][2] In *LV* and *MV* an accessible all pole circuit breaker with galvanic isolation is required.

[1] For *low voltage* single-phase systems, an automatic disconnection unit based on three phase voltage monitoring can be used instead of the accessible switch. A further alternative for *PV systems* below 30 kW is a fail safe disconnection device according to **[3]** based on, among others, impedance monitoring. Please refer also to chapter 4.1.2.2.

[2] In *medium voltage,* the customer has the choice if the disconnection switch can switch the complete electrical system of the customer or only the DG unit.

4.1.3 Power Quality

The evaluation of the allowable DG system perturbation is referenced, in general, to the normal state of the grid. In case of circuit modification, due to works and/or faults for example, it can be temporarily required to reduce the capacity of the DG systems or to disconnect them from the grid.

4.1.3.1 Power factor

[1] In *low voltage grids*, DG units up to 4,6 kVA per phase do not need compensation: a power factor from 0,9 leading to 0,8 lagging is tolerated for the complete electrical system of the customer.

[4] The “distribution grid code” requires a power factor from 1,0 to 0,9 lagging which is more strict than the above mentioned requirement for low voltage DG systems.

[1][2] In *low and medium voltage grids*, generators with strongly fluctuating reactive power need an automatic compensation system. The capacitors must not be connected to the grid before the generator and have to be disconnected with it. Measures to avoid interference with a ripple control system are required.

4.1.3.2 Harmonics

[1] *In low voltage grids*, the requirements of the EN61000-3-2 or EN61000-3-12 standards must be met. As an alternative the maximum values specified in the table below must not be exceeded.

[2] For *medium voltage grids* the maximum values specified in the table below must not be exceeded:

$$I_{\nu zul} = i_{\nu zul} \cdot S_{kV}$$

$I_{\nu zul}$:maximum current at ν th harmonic

$i_{\nu zul}$: relative maximum current at at ν th harmonic

S_{kV} : maximum apparent power at the PCC

Ordinal number ν	$i_{\nu\ zul}$ [A/MVA] (1)	Ordinal number ν	$i_{\nu\ zul}$ [A/MVA] (2)	
3	4		10 kV	20 kV
5	2,5	5	0,115	0,058
7	2	7	0,082	0,041
9	0,7	11	0,052	0,026
11	1,3	13	0,038	0,019
13	1	17	0,022	0,011
17	0,55	19	0,018	0,009
19	0,45	23	0,012	0,006
23	0,3	25	0,01	0,005
25	0,25	>25 or even	0,06/ν	0,03/ν
>25	0,25 · 25/ν	μ < 40	0,06/ν	0,03/ν
ν νεϖε	1,5/ν	μ > 40	0,18/ν	0,09/ν
ν < 40	1,5/ν			
ν > 40	4,5/ν			

4.1.3.3 Interharmonics

[1][2] In *low and medium voltage grids*, ripple control systems are usually operated between 100 and 1500 Hz. The local frequency has to be asked for at the DNO. The transmission level ranges usually from 1 % to 4 % of the grid voltage. Mains signalling systems are dimensioned for a load, which corresponds to the 50 Hz rated power of the public grid in which the feeding-in of the control voltage occurs.

DG units present an additional load to this signalling system:

- via the DG system itself
- via the higher load which can be connected to the grid because of DG system

This interference may cause inadmissible disturbance of the mains signalling at the PCC. The transmission level at the PCC may not be lowered by more than 10 to 20 % (dependent on the particular conditions as signalling frequency, the kind of the grid, the kind of the receiver and so on), whereas loads and generating units have to be considered according to their impedance.

Besides the limitation of the level decrease, inadmissible interference voltage can not be generated. In detail:

- The interference voltage caused by a DG unit, whose frequency is close to the one used for ripple control, may not exceed the value of 0,1 % Un.
- The interference voltage caused by a DG unit, whose frequency lies on the neighbouring frequencies of +/-100 Hz towards the local used ripple control frequency or lies with it in immediate vicinity, may not add up to more than 0,3 % Un at the PCC.

These limit values, as well as qualified details, can be gathered from “Tonfrequenz-Rundsteuerung – Empfehlungen zur Vermeidung unzulässiger Rückwirkungen, 3. Ausgabe, 1997, Editor: VDEW”.

In the case that a DG unit affects the operation of the mains signalling system due to exceeding the limits, the operator of the DG unit has to agree on arrangements for the settlement together with the DNO. This applies even if the interference has been noticed on a later point in time.

4.1.3.4 Flicker

[1] In *low voltage grids*, requirements of EN61000-3-3 or EN61000-3-11 must be met.

[2] In *medium voltage grids* the maximum values for long term flicker are the following:

- A_{lt}: 0,1
- P_{lt}: 0,46

4.1.3.5 Voltage rise and voltage variation

Voltage rise

[1][2] In *low and medium voltage grids*, the rise of the voltage with DG units may not exceed the value of 2 % at the worst case PCC, compared to the voltage without DG supply.**[1]** In *low voltage grids*, because of the requirement to comply with the limits of supply voltage in the grid (DIN IEC 60038), the DNO may ask for a voltage rise lower than 2 %.

[1][2] With only one PCC, this condition is to be evaluated using the short-circuit capacity relationship:

$$k_{kl} = \frac{S_{kv}}{\sum S_{A\max}} \geq 50$$

S_{kv}: short-circuit power at the PCC
S_{Amax}: Maximum apparent power of all given or planed DG units which are connected to that point.

For the calculation of S_{Amax} of *wind energy* converters, the maximum apparent output for one minute has to be used. If a DG unit has a special power limitation, this has to be taken into account. For a precise calculation of the voltage rise at the PCC the complex impedance of the grid, with its phase angle, has to be provided. With meshed networks and/or for the operating of multiple DG units which are dispersed in the grid, the rise of the voltage is to be determined usually with the aid of complex load flow calculation. When operating all DG units, the voltage rise has to be below 2 % at the worst case PCC.

Voltage variation

The operation of a DG unit is acceptable if it is verified that the system complies with the standards EN 61000-3-3 or EN 61000-3-11. If this proof is not available, the variations of voltage caused by hooking up and turning off are acceptable, if the values in the following table are not exceeded at the PCC.

	Max. Voltage Variation	Max. frequency: once in
[1] Low Voltage	3%	5 min.
[2] Medium Voltage	2%	1,5 min.

If there are only few operating cycles, for example one per day, the DNO may allow a higher variation of voltage. The voltage variation can be estimated via:

$$\Delta u_{\max} = k_{i,\max} \cdot \frac{S_{nE}}{S_{kV}}$$

$k_{i,max}$: maximum inrush current in relation to the nominal current
S_{kv}: Short-circuit power at the PCC
S_{nE}: Nominal apparent power of the DG unit that is to be connected

This calculation gives an upper assessment and is basically a safe bet.

[1] In *low voltage grids*, the value for the factor $k_{i,max}$ is given in the manuals of the DG units respectively with wind energy systems in the inspection report.

[2] In *medium voltage grids* the following estimates apply for the factor $k_{i,max}$:

- synchronous generator: 1
- asynchronous generator connected to the grid within +/-5% of synchronous rotational speed: 4
- asynchronous generator started as motors via the grid (if inrush current is not specified): 8

Even by switching asynchronous machines with approximately synchronous rotational speed to the grid, very short time voltage variations may occur because of internal transients. Such variations may reach up to twice the acceptable value (**[1]** 6% in LV, **[2]** 4% in MV), when they last not longer than two periods and when the following variation of voltage does not exceed (**[1]** 3 % in LV, **[2]** 2 % in MV] of the output voltage before connecting up the asynchronous machine. As a consequence with asynchronous machines the short time disturbance of the grid voltage may be higher than the "standard" value.

A simultaneous switching operation of several generators at the PCC leads to multiplying the effect caused by one generator. This should be avoided (**[1]** in LV, only if the maximum change of voltage exceeds 3% in the total). A technical possibility for this is the time grading of the individual switching operations. Here, the time between two switching operations is selected in accordance with the amplitude of the caused voltage variation and has to be at least 5 min. in *low voltage grids* (**[1]**) and 1,5 min. in *medium voltage grids* (**[2]**), with the maximum acceptable apparent power conditions of the DG unit. A period of 40 seconds (**[1],** *LV*) and 12 seconds (**[2],** *MV*) is acceptable with an apparent power of the DG unit lower than half of the acceptable value.

4.1.3.6 Unbalance

[1] In *low voltage grids,* to limit unbalance, DG units may only be connected to one phase up to a capacity of 4,6 kVA (with *photovoltaic* systems up to 5 kWp). Where several single-phase systems are connected to one PCC, a balanced distribution of the supplied power in the three phases has to be aimed.

4.1.4 Behaviour during Fault Conditions in the Grid

4.1.4.1 Unintentional Islanding

[1] In *low voltage*, three phase voltage monitoring for single phase systems of fail safe interface must be provided according to the following paragraph.

[3] In *low voltage PV* systems, a "ENS" Fail safe interface device must be provided, for systems up to 30 kVA monitoring voltage, frequency and impedance of the grid.

Please refer also to chapter 4.1.2.2.

4.1.4.2 Overvoltages

[1][2][3] In both low and medium voltage grids disconnection is required if maximum voltage is exceeded (see chapter 4.1.2.2)

No specific recommendations on the behaviour of generators during overvoltages are provided in the documents

4.1.4.3 Autoreclosures

[1] In *low voltage grids*, for larger systems ("large" defined by DNO) and systems with a synchronous generator without inverter the disconnection time of the protection unit must be shorter than the reclosure time. As an alternative protective measures for the reclosure must be provided.

[2] In *medium voltage grids*, the operator of DG unit has to take care that the DG unit can not be damaged by an auto reclosure.

4.1.4.4 Short circuits

If the DG unit leads to a short circuit current of the grid higher than the rated short circuit current, the short circuit of the distributed generator has to be limited.

4.1.4.5 DC – injection

[3] In *low voltage grids PV* installations, DC currents due to a fault in the inverter must lead to disconnection within 0,2 s. A DC current of max. 1 A is the criterion for disconnecting.

4.1.5 Testing and Conformance Assessment

[3] Tests for impedance measurement of the grid, residual currents and dc injection are provided for *low voltage PV* installations.

4.1.6 Commissioning

4.1.6.1 Basic requirements

[1][2] For both *low and medium voltage grids*, in the proposal for the start-up the builder of the system has to confirm that the design of the DG unit fulfils the relevant standards and complies with all guidelines.

The first-time parallel operation is to be adjusted with the DNO the following procedure applies:

- Inspection of the system.
- Comparison of the built system with the design specification.
- Check-up of the accessibility and operation of the disconnection device, which has to be accessible any time (does not apply for systems with ENS).
- Comparison of the design of the metering device with the contractual and technical instructions.
- In *low voltage grids* only: start-up control of the meters for supply and delivery. **[1]**

In addition to this, an inspection of the operation of the disconnection unit has to be undertaken. It has to be verified that:

- the disconnection unit is activated by the required set points.
- the disconnection times are met.

If the disconnection unit is a type tested device and a test report is available (with wind energy systems for example complying with "Technische Richtlinien für Windenergieanlagen – Teil 3: Bestimmung der elektrischen Eigenschaften, Editor: Fördergesellschaft Windenergie e.V., Kiel") the inspection effort can be reduced.

[1] In *low voltage grids*, with DG units having an "ENS", the system builder verifies the disconnection function following these simplified steps:

- During grid parallel operation the phase conductor is disconnected at a convenient point, after having bypassed this point with a resistor of 0.5 Ohm. Even with a three-phase ENS a single-phase inspection is sufficient.
- It has to be checked if the switch is opening and the ENS displays a grid failure.

[1][2] The DNO may seal the protection device or secure it, or let it secure otherwise, to avoid unintentional changes (for example protection of the code word).

4.1.6.2 Procedures

[1][2] There is a standard form for report on commissioning available for both *medium and low voltage grid* connected DG. This form has to be sent to the DNO.

4.1.7 Operation and Communication

4.1.7.1 Information Exchange DG/Grid Operator

[1][2] In *low and medium voltage grids*, there is a form to register the DG unit with the DNO, plan of the site, technical data of the system, circuit diagram of the system, description of the protection measures, short circuit capability.

4.1.7.2 Monitoring power and voltage (metering)

See chapter 4.1.2.4. (Measurements)

4.1.7.3 Maintenance requirements

[1] In *low voltage grids*, regular checks by a skilled person are required, proof via protocol. The exception are systems with fail safe interface ("ENS"), they do not need regular checks.

[2] In *medium voltage grids*, regular checks by a skilled person are required, proof via protocol.

5 OUTLOOK

5.1 New developments

A further rise especially of wind and PV is expected. Limiting factors are good locations for wind parks and the limited amount of PV modules on the market. An important aspects of standardisation in this area is to harmonise the requirements on the grid connection for different energy sources. For historical reasons (1000 roof program) this has been done by the PV committee for the low power range. With the advent especially of domestic co-generation a joint and preferably European standardisation strategy should be followed. The emerging standard for domestic generation (prEN 50438:200X - Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks prEN50438) could be used for a common grid interface in this power range.

6 CONCLUSIONS

Federal laws to promote the use of regenerative energy for electricity generation by regulating the tariffs has lead to beneficial conditions for this kind of decentralised generators. Because of the strong rise of especially wind and PV generators standards for grid connection were highly needed. Today we have a mixture of national and international standards as well as regulation of the grid operators dealing with power quality, EMC and safety.

Because of the history of PV (1000 roof programme) the standard for connecting small power embedded generators has been written especially for PV. The future task is to harmonise the requirements for all kind of embedded generation on a national and European level.

7 DISCLAIMER

The national reports only describe the current state of the documents which define the framework and rules for grid interconnection of DG in the respective country. Since the situation in Europe's electricity sector undergoes fundamental changes at the moment, the authors can not warrant or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of the information provided.

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8 REFERENCES

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[2] Eigenerzeugungsanlagen am Mittelspannungsnetz, Richtlinie für Anschluß und Parallelbetrieb von Eigenerzeugungsanlagen am Mittelspannungsnetz, ISBN 3-8022-0584-7

[3] DIN VDE 0126, Selbsttätige Freischaltstelle für Photovoltaikanlagen einer Nennleistung <= 4,6 kVA und einphasiger Paralleleinspeisung über Wechselrichter in das Netz der öffentlichen Versorgung

[4] "DistributionCode 2003, published by "Verband der Netzbetreiber – VDN – e.V. beim VDEW"

9 GLOSSARY

- BGFE: deals with safety standards in Germany
- DC: Direct Current
- DG: Distributed Generation
- DIN: Deutsches Institute für Normung e.V. – Standardisation Institute
- DKE: Responsible of electrotechnical standardisation in Germany (Belongs to VDE and DIN)
- DNO: Distribution Network Operator
- ENS special MSD device using mechanical switching and impedance monitoring required according to German Standard Draft DIN E-VDE0126
- HV: High Voltage
- IEC: International Electrotechnical Commission
- LV: Low Voltage
- MV: Medium Voltage
- MW: Megawatt
- PCC: Point of Common Coupling
- PV: Photovoltaic
- RCD: Residual Current protection Devices
- RES: Renewable Energy Resources
- VDE: Verband der Elektrotechnik Elecktronik Informationstechnik e.V.
- VDEW: German Association of Power Supply Companies
- VDN: Organisation of the grid operators in Germany