PV in Urban Policies- Strategic and Comprehensive Approach for Long-term Expansion

EIE/05/171/SI2.420208

WP4 – Deliverable 4.2:
UTILITIES EXPERIENCE AND PERCEPTION OF PV DISTRIBUTED GENERATION
–
ANNEXES

version: 5

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2 AUSTRIA

2.1 VKW-Netz

CONTACT PERSON: **REINHARD NENNING (Network Planning)**

INTERVIEW DONE BY: **VIENNA UNIVERSITY OF TECHNOLOGY – ENERGY ECONOMICS GROUP**

DATE: **2007-05-10**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by them**	
LV: 0,7 – 1,2 %	MV: ---
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: Yes, so far as accumulation exists. Experience with a 260 kW community PV plant in which electricity meters were destroyed due to harmonics induced by inverters	MV: ---
▪ **Concern about future problem?**	
LV: Yes. Requirements towards inverters should be more restrictive. Consideration of THD_V if there is a large penetration of PV-DG.	MV: ---

▪ **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**	
LV: Of great interest not only in urban areas but also in rural areas	MV: ---
1.2 – VOLTAGE REGULATION	
▪ **Perception of current problem?**	
LV: Immense perception. Noteworthy voltage increase particularly at <4,6 kVA single-phase PV systems	MV: ---
▪ **Voltage regulation systems used by the Distribution company**	
LV: - "Relo Regler" - Manual (fixed) off-load tap changers in MV/LV transformers	MV: - MV-MV transformers - Automatic tap changers on the secondary side of HV/MV transformers
▪ **Are such systems adequate for bidirectional power flows?**	
LV: Yes	MV: Yes
▪ **Maximum overvoltage allowed to PV-DG: [AUSTRIA: Maximum overvoltage allowed is 5% of nominal voltage (2% in MV, 3% in LV); necessary differences are allowed (see below)]** **Are national regulations enough?** No. It's a challenge to put this 5% into the voltage range of +/- 10%. **Are there any requirements set by the Distribution company?** Yes, see below For obtaining a practical overview of the impact of decentralized generation on electricity distribution networks, within the scope of a measurement campaign, coordinated by the Austrian Association of Electricity Companies (VEÖ), ten Austrian DNOs have performed related measurements. These results represent the real demand of Voltage-percents and were set as requirement by the VKW Netz AG. In this Network there is no more space in the voltage range of Un ± 10%. The Regulatory Framework TOR (Technical and Organizational Rules) D2 (Guideline for the assessment of network disturbances) also allows such necessary differences.	

LV: Additional requirements set: - Point of common coupling: 1,5% of nominal voltage level. - Connecting Point: 2,0% of nominal voltage level.	MV: Additional requirements set: - Total: 1,0% of nominal voltage level.
▪ **Concern about future problem?**	
LV: Yes. Case-by-case analysis is needed not only in urban areas, but also in rural areas. Every PV-DG has to be judged by technical guidelines.	MV: Yes (same as in LV).
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: Yes	MV: Yes
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: Yes	MV: Yes
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: Yes	MV: Little known
1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: No	MV: No
▪ **Concern about future problem?**	
LV: No	MV: No

1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	
LV: ---	MV: ---
▪ **Concern about future problem?**	
LV: ---	MV: ---
▪ **Are current technical requirements adequate and sufficient?**	
LV: ---	MV: ---
▪ **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**	
LV: ---	MV: ---

1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ **Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment)?**	
LV: There is a lack of knowledge regarding standards of electromagnetic compability.	MV: ---
▪ **Concern about mutual disturbance of large numbers of inverters (nuisance tripping, low voltage quality) ?**	
LV: Yes	MV: Yes

1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: Automatic switches would be necessary in each PV-DG. The question is: Who should pay for changing present integrated switches (relay) into automatic switches. The cost may be intolerable for owner of PV-DG.	MV: ---

1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: Is momentary being worked out.	MV: Same as in LV

1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: ---	MV: ---
▪ **Have tranformerless inverters shown "noticeable" differences from inverters comprising a transformer?**	
LV: ---	MV: ---

1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: 1/3 of the transport capacity of the LV line / transformer capacity.	MV:
▪ **Are/should penetration limits be different in urban and rural grids?**	
Yes. In urban areas: higher penetration limits. In rural areas: smaller penetration limits.	

1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: Yes. Significant.	MV: Same as in LV
▪ **Are new tools needed?**	
LV: No. Fundamental software for calculation of load flow is sufficient.	MV: Same as in LV

▪ **Potential interest for including PV-DG into load dispatching?** **Are new tools needed?**	
LV: Not in LV level	MV: ---
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: Yes. e.g. transformer (stations) only remain cause of high penetration of PV-DG	MV: ---
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: Marked switchboxes, where PV-DG's are. Highlighting of relevant information where to disconnect.	MV: ---
2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
LV: Accumulation of PV-DG often results in higher voltage levels. At times with few load (weekend) PV-DG are noticable. Often PV-DG in rural areas cause cable connections with disproportionately (big) dimensions at the end of supply network. Just load would not cause this.	MV: ---
▪ **Are the PV plants where regular measurements are done?**	
LV: Not with remote monitoring / measurement.	MV: ---

▪ Incidents with PV-DG over the last 10 years	
LV: Destroyed electric meter because of harmonics	MV: ---
2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ Standards and guidelines used for admission of PV-DG	
LV: Guideline for operating distributed generations connected with LV grid	MV: ---
▪ Are current standards for PV-DG sufficient?	
LV: No	MV: ---
▪ Issues at present not covered by standard, which should be included	
LV: Flicker, harmonics	MV: ---
2.3 – OTHER ISSUES	
▪ Any research/development needs identified?	
---	

3 FRANCE

3.1 Electricité De France

CONTACT PERSON: **CHRISTOPHE DUVAUCHELLE (EDF R&D – "Economic and Technical Analysis of Energy Systems Department")**

INTERVIEW DONE BY: **BRUNO GADDON (HESPUL)**

DATE: **JUNE 2007**

NOTE:

- **THIS INTERVIEW REFLECTS THE EXPERIENCES OF EDF-ERD (ELECRICITÉ DE FRANCE – RÉSEAU DE DISTRIBUTION) AND EDF-SEI (ELECRICITÉ DE FRANCE – SYSTÈMES ÉNERGÉTIQUES INSULAIRES: ENTITY IN CHARGE OF OVERSEAS DEPARTMENT)**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by them**	
LV: ---	MV: ---
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: Yes, we already observed DC current harmonics (H6 and H8) measured during a monitoring campaign on a 6 inverter PV system with 2	MV: ---

transformerless inverters. The origin of the high H6 and H8 current harmonics still need to be determined.	
▪ **Concern about future problem?**	
LV: Yes but harmonics are not considered as the most urgent present issue on which all efforts must be focused.	MV: ---
▪ **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**	
LV: Of great interest not only in urban areas but also in rural areas. But, the main difficulty is to determine the origin of harmonics.	MV: ---
1.2 – VOLTAGE REGULATION	
▪ **Perception of current problem?**	
LV: Yes, although the total power installed in France is low, problems of voltage rise were already identified at the time of connection studies to weak LV grids.	MV: No
▪ **Voltage regulation systems used by the Distribution company**	
LV: Fixed off-load tap changers in MV/LV transformers are used for LV adjustments.	MV: Automatic tap changers on HV/MV transformers are used for voltage regulation and capacitor banks are used for reactive power compensation..
▪ **Are such systems adequate for bidirectional power flows?**	
LV: ---	MV: Yes, voltage regulation is automatic and does not depend on the origin of the voltage rise/drop.
▪ **Maximum overvoltage allowed to PV-DG:** -115 % of nominal voltage for PV systems connected to LV networks and 115 % of average voltage for PV systems connected to MV networks.	

Are national regulations enough? **Are there any requirements set by the Distribution company? -**	
LV: Both EDF French DNOs (ERD for metropolitan network and EDF SEI for overseas networks) refer to the DIN VDE 0126-1-1 standard for PV systems connected to LV networks …	MV: …and to EDF technical requirements for PV systems connected to MV networks.
▪ **Concern about future problem?**	
LV: Yes, especially on weak LV grids	MV: No
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high load conditions)**	
LV: Yes, especially on weak LV grids.	MV: Same as in LV-
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: General cases ▪ Grid disturbances that impacted the continental European transmission grid on 4 November 2006 show that DG are not adapted to support the grid in case of anomalous situation, although it would be of great benefits from distribution grids if PV-DG could participate in the grid stability to prevent a major blackout ▪ Present legal framework and new framework under preparation at European level are supposed to deal with that issue. Due to stability reasons, particular requirements must be taken for systems connected to overseas	MV: Same as in LV

networks: ▪ A limit rate of PV insertion must be set ▪ PV must be able to withstand voltage sags due to HV short circuit.	
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: ---	MV: ---
1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: ---	MV: ---
▪ **Concern about future problem?**	
LV: ---	MV: ---
1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	
LV: At present, voltage and frequency controls are considered enough to prevent islanding conditions. Grid operators allow PV users to disconnect the impedance measurement of the inverter to reduce disturbances generated by PV-DG.	MV: Voltage and frequency controls are considered enough to prevent islanding conditions.
▪ **Concern about future problem?**	
LV: No specifically	MV: Same as in LV

▪ **Are current technical requirements adequate and sufficient?**	
LV: Would like to receive information about islanding in order to take appropriate measures to avoid islanding operations without creating additional disturbances on the grid.	MV: Yes
▪ **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**	
LV: Would like to receive information about islanding in order to take appropriate measures to avoid islanding operations without creating additional disturbances on the grid.	MV: Not concerned.
1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ **Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment)?**	
LV: ---	MV: ---
▪ **Concern about mutual disturbance of large numbers of inverters (nuisance tripping, low voltage quality) ?**	
LV: Yes	MV: Yes
1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: ---	MV: Remote connection/disconnection of PV-DG by means of automatic switches (telecontrol) is considered of great interest, especially for big PV plants connected to the MV non-interconnected network.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: ---	MV: ---

1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: ▪ refer to DIN VDE 0126-1-1 ▪ Information on that subject would be welcome. ▪ Small DC current value measured during a monitoring campaign on a 6 inverter PV system with 2 transformerless inverters. The origin of the measured DC current still need to be determined.	MV: ---
▪ **Have transformerless inverters shown "noticeable" differences from inverters comprising a transformer?**	
LV: ---	MV: ---

1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: There is no legal penetration limits for PV-DG yet. The penetration limits of PV are technical and depend on the grid characteristics and on generator behavior: power installed limited by nominal power of transformer and by voltage rise. Due to stability reasons, particular requirements must be taken for systems connected to overseas networks: ▪ A limit rate of PV insertion must be set ▪ PV must be able to withstand voltage sags due to HV short circuit.	MV: same as in LV

▪ **Are/should penetration limits be different in urban and rural grids?**	
Yes, the penetration limits of PV depend on the grid characteristics and are therefore different for rural grids and urban grids.	
1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: Yes, a technical study is done for each PV system	MV: Same as in LV
▪ **Are new tools needed?**	
LV: No but there is a need to improve existing tools.	MV: No
▪ **Potential interest for including PV-DG into load dispatching?** **Are new tools needed?**	
LV: For non-interconnected networks, interest for more information about power forecasts in order to take PV-DG into account for power consumption forecasts.	MV: Same as in LV
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: ---	MV: ---
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: ---	MV: ---

2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
LV: ▪ No specific concern in France Mainland at present. ▪ In Overseas Departments, concern about the very quick market development due to the incentive feed-in tariff (0,4 Euro/kWh + 0,15 Euro/kWh, if BIPV), incentive tax credits and the good solar irradiation. ▪ Want to take appropriate measures in order to manage properly its network without preventing the PV market.	MV: Same as in LV
▪ **Are the PV plants where regular measurements are done?**	
LV: No but one measurement campaign has done on one PV system to assess the impact on the LV grid	MV: ---
▪ **Incidents with PV-DG over the last 10 years**	
LV: ---	MV: ---
2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: ▪ National framework and ERD / SEI own guidelines ▪ EN 50 160 (Quality of the electricity) ▪ Inverter must comply with DIN VDE 0126-	MV: ▪ National framework and ERD / SEI own guidelines ▪ EN 50 160 (Quality of the electricity)

1-1 (impedance measurement can be switched off) …	
▪ **Are current standards for PV-DG sufficient?**	
LV: Yes but harmonization at European level seems necessary, especially concerning appropriate measures to avoid islanding operations without creating additional disturbances on the grid.	MV: Yes
▪ **Issues at present not covered by standard, which should be included**	
LV: Islanding detection methods	MV: ---

2.3 – OTHER ISSUES
▪ **Any research/development needs identified?**
▪ Apropriate measures to avoid islanding operations without creating additional disturbances on the grid ▪ Theoretical penetration limit of PV-DG in non-interconnected network ▪ Power forecasts in order to take PV-DG into account for power consumption forecasts ▪ EDF R&D is involved in a consortium that submitted a proposal to work on the appropriate characteristics and settings of the disconnection device of PV-DG in order to support the grid in case of anomalous situation so as to avoid the situation that occurred in Europe on 4 November 2006.

4 GERMANY

WP4 – Deliverable 4.2

UTILITIES´ EXPERIENCE AND PERCEPTION OF PV DISTRIBUTED GENERATION IN GERMANY

Authors: Hermann Laukamp, Thomas Erge (Fraunhofer ISE)

Version: 2

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4.1 REGULATORY FRAMEWORK

4.1.1 Market development

Due to favourable provisions in the “EEG” market for PV systems in Germany was growing quickly and is estimated to have reached about 3 000 MWp by mid – 2007.

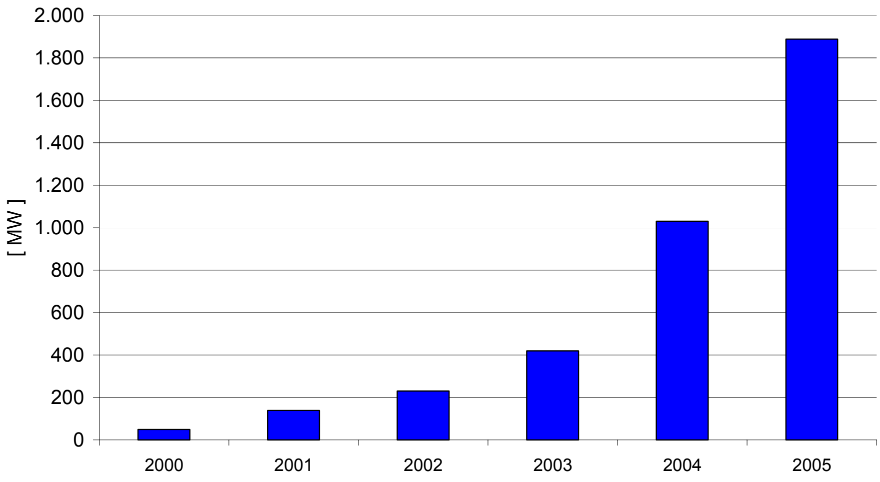

Fig. 1: development of PV market in Germany (source: Photon magazine, November 2006)

This growth concentrates on the southern German states as can be seen for figure 2. Southern Germany receives a slightly higher irradiation than central and northern Germany.

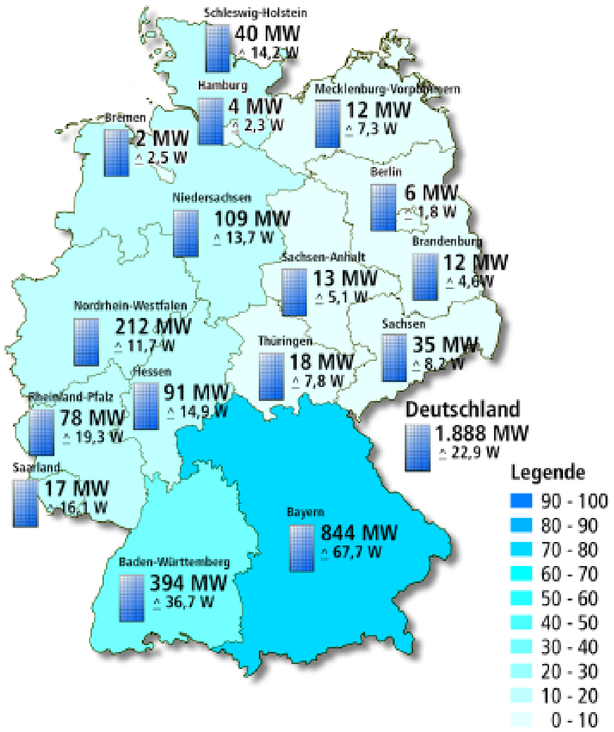

Fig. 2: distribution of market shares among the German states. The second figure indicates the installed PV capacity per capita. (Source: Photon magazine, November 2006).

4.1.2 Electricity companies

The electricity business in Germany is characterised by an oligopolic generation structure. Four big companies own about 80 % of the power generation capacity. However, there is a total of some 800 electricity companies in Germany. Most of them are regional or local network operators (DNO) including small municipal utilities and municipal utilities of large cities. Many of them operate some generation capacity as well.

4.1.3 Legal frame

There are two most important legal documents on grid access for electrical power from RE in Germany: the EEG (Renewable Energy Act, updated in August 2004) and the new Energy Economy Act including the amendments from July 2005.

The EEG set a firm obligation for electricity companies to buy electrical power from Renewable Energy sources and to buy it fixed rates. The Energy Economy Act including lots of amendments introduced central regulation to German electricity market. The responsible authority is called “Bundesnetzagentur”, i.e. “Federal network agency”.

4.1.3.1 Federal network agency (FNA)

Business environment for electricity companies in Germany has changed significantly during the last 10 years due to liberalisation and deregulation. Currently (2007) it is changing from re-regulation from a new regulation authority, the Federal Network Agency FNA (in German BNetzA) /BNA 2007/.

The Federal Network Agency (German: Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen, abbreviation: BNetzA) is the German regulatory office for the telecommunications, postal services, electricity, gas and train markets. In July 2005, the agency had been renamed to Bundesnetzagentur (Federal Network Agency). The regulatory office primary purpose is the regulation of former governmental market segments which have been released into public economy.

All enterprises serving at least 100 000 customers, regardless in which service branch, are subjected to regulation from FNA. That means, about 90 % of the electricity market are ruled by FNA.

4.1.3.2 Renewable energy act (EEG)

PV development in Germany during the last years has been shaped by the “EEG”, the act for feed-in from renewable energy sources. It defines that DG installation operators bear the costs of connection to the next suitable point of the grid, and that grid operators take on the necessary measures and costs for reinforcing the grid. However, they may take these costs into consideration in their charges for use of the grid.

The act guaranties a defined buy-back rate for each kWh generated. The rate is high enough to allow PV systems to be operated profitably with typically some 5 % to 7 % profit rate. Feed-in tariffs depend on mounting – attached to a building or on open land – and system size. The tariff is fixed for the next 20 full calendar years.

Table 1: Feed-in tariffs for systems commissioned in 2007

Attached to buildings	up to 30 kW larger than 30 kW to 100 kW above 100 kW	49,21 Cent/kWh 46,82 Cent/kWh * 46,30 Cent/kWh *
Facade integrated:	As above plus additional	5,00 Cent/kWh
Other systems:		37,96 Cent/kWh
* For systems larger than 30/100 kW reduced values refer to the system fraction beyond the threshold. For systems installed in 2008 and later feed-in tariffs are reduced by 5 % for building mounted systems and by 6,5 % for other systems.		

A detailed discussion of the provisions of EEG is found in /EEG 2004/ also included as Annex D4_2_DE_A1_eeg_main_features_en. The text of the act translated into English language is reproduced as annex D4_2_DE_A4_eeg_act_text_en.

4.1.4 Technical rules and standards

Specifically for the construction of small, dispersed, grid-connected PV-systems a special section to the basic electric safety code, the VDE 0100, has been written, the "VDE 0100 Teil 712, Photovoltaikanlagen". This code section applies to the erection of PV systems and deals with protection measures, wiring, short circuit protection, grounding, overvoltage protection and selection of components for these systems.

This code has also been included as part 712 into the IEC 60364 series of standards.

A second set of PV specific rules has been fixed in the specifically German standard DIN VDE 0126-1-1. These concern mainly a safety interface for islanding prevention. Technical specifications and test requirements for inverters, respectively separate interface units, are given. The standard includes specific requirements for transformerless inverters. For systems below 30 kVA generator it allows under certain conditions to replace an external isolation switch. Important requirements for the hardware are “single-fault-security” and “fail-safe” construction /VDE 2007/.

This standard had been revised in 2006 and now includes impedance measurement, as well as other islanding detection methods than. Furthermore, it now uses the same cut-out criteria for inverters as for large power plants connected to the high voltage network. These criteria are listed in /EON 2006/ (see also Annex D4_2_DE_A3_EON_HV_grid _connection_requirements_-ENENARHS2006de).

A third collection of rules is issued as a general guideline by the VdEW, the Association of Electric Power Companies. This guideline, "Guidelines for the operation of private production systems parallel to the low voltage public grid", last updated 2005, does specifically address PV-systems /VdEW 2001/.

Extensive information on structure and content of German standardisation has been collected in the DISPOWER project. The related report can be found in /Viotto 2005/, also annexed as D4_2_DE_A2_Standards_guidelines_DE_tech_2005_0058.

4.2 UTILITIES EXPERIENCE AND PERCEPTION OF DISTRIBUTED PV

This section of the report draws on different sources.

- Interviews with utility personal
- informal discussions with utility personal
- governmental evaluation of effects of the German EEG

4.2.1 Interviews with utilities

4.2.1.1 Approach

As shown in fig. 2 the majority of PV systems is erected in southern Germany. Therefore, utilities from southern Germany had been interviewed with regard to their experiences with PV and other distributed generation. Selected utilities cover a broad range of sizes from serving a village with 500 inhabitants to a city of 300 000 inhabitants. Utility sizes are grouped in size classes according to a VdEW classification as given in annex 1 of this section. A list of the interviewed utilities is found in annex 2.

The interviews were conducted openly taking the questionnaire as a guide.

4.2.1.2 Results

All utilities have experiences with PV or other distributed generation systems.
Other distributed generation includes manly small hydro and cogeneration.

The result of the interviews is summarized in table 2.

Table 2: Summary of results of utility interviews in DE. Effects and problems from distributed generation; responses are grouped according to utility size.
The GK parameter indicates the size of a company. The meaning of it is listed in Annex 1.

size of utility	medium GK 8-12		small GK 4-7		total	
statements	hits	relative hits [%]	hits	relative hits [%]	hits	relative hits [%]
no effect noticed	2	17	8	67	10	42
no problem in urban networks	2	17	-	-	2	8
voltage rise effect	10	83	3	25	13	54
only voltage rise effect, no other effect	6	50	3	25	9	38
problems due to voltage rise	-	-	1	8	1	4
effects due to phase imbalance	3	25	-	-	3	13
effects due to flicker	1	8	-	-	1	4
effects due to harmonics	1	8	1	8	2	8
solution: change transformer tap position	9	75	1	8	10	42
solution: network strengthening/extension	9	75	7	58	16	67
future problems expected	6	50	8	67	14	58
rules should be changed	1	8	-	-	1	4

Main findings are:

Actual problems from decentral generation (DG) were hardly noticed. Urban networks were two times (8%) explicitly called immune to voltage quality problems from DG due to their low impedance. One out of 24 utilities had to do severe grid strengthening. Several utilities (13 %) noticed phase imbalance from single phase PV systems as undesirable effect, one utility even suggested to change the guidelines and require 3-phase generation only.

Generally, voltage rise from decentral generation is seen as the only effect which may cause trouble. Other effects, flicker, harmonics were noticed in one case (4%) only.

Guidelines and standards were perceived to be appropriate.

Interestingly, several utilities reported voltage rise effects, but did not regard this as a “problem”.

Apparently, in most cases voltage rise is moderate. Furthermore, it was quite clear that they could change the transformer tapping to reduce the output voltage and, if this would not solve the problem, would strengthen the network. This may be due to the effect that the relevant act firmly requires the DNO to strengthen the network, when necessary, to put up a new RE DG system.

Nearly 60 % of people expect problems for the future, when the growth of DG continues. Weaker grid segments, i.e. city outskirts and rural areas are more likely to develop problems, especially, because many farmers build large PV systems.

“Elektrizitätswerk Ley” (EWL) at Wolpertshausen is an example, how a decentral electrical network with high DG penetration can look like. In its grid one biogas system, 80 PV systems, three hydropower systems and two wind turbines are connected. A total of 1200 customers is served. EWL encountered severe problems with voltage rise and had to strengthen the grid structure.

Interestingly, smaller utilities reported significantly fewer effects from DG. We assume that this can be simply attributed to fewer systems in smaller grid sections.

It appears that often little knowledge of LV grid is available. If no customer complaints, the system is thought to work fine.

In earlier years larger utilities experienced many complaints from PV system owners, who blamed the utility for frequent inverter cut-outs. This subject was no issue in the interviews and seems to be solved.
Probably, inverter and ENS interface controls have matured and in combination with broadened cut-off limits nuisance tripping had been markedly reduced.

One utility reported a legal controversy with a PV owner, who had built without prior informing the utility. He now requests an expensive new connection to the grid.

However, main issue for German utilities operating transmission lines is wind power, which has a much higher capacity than PV. Wind power sometimes leads to bottlenecks in the transmission lines from Northern to Southern Germany.

4.2.2 Informal communications

In personal communication it was mentioned that the EEG causes a significant effort in manpower. The technical and administrative effort to deal with some 25 MWp installed PV operated by some thousand producers needs two people working full time.

Currently re-organisation for unbundling and new regulation from FNA absorb quite a lot of labour and lead to reduction of technical personal. This leaves little room for adopting new generation technologies.

Some utilities with a significant PV capacity in their network area have included PV into their load prediction tools.

4.2.3 Evaluation of EEG

Due to the fast growing wind energy capacity in northern Germany some transmission network operators face occasional near-overload situations for their network components. This affects especially transmission lines from northern to southern Germany during strong wind regime. On the long run the lines concerned need to be strengthend.

To avoid overloading the network and subsequent instability in the mean time power generation has to be controlled. This approach is discussed for general application.

EEG includes the obligation to regularly analyse its effects and discuss improvements. The last evaluation took place in 2006 and a draft report was published in July 2007 /BMU 2007/.

This report gives suggestions for future changes:

"For better integration of renewable Energies, especially from fluctuating sources PV and wind, into the transmission and distribution network the network operator should have the option to temporarily reduce power output from these sources, if grid stability is at risk.

This option affects profitability of the RE system and has therefore be used as limitedly as possible. Furthermore, it should be connected to an obligation to employ all other options of technical network optimization, including strengthening of the network.

Governing aim is to maximize electricity production from Renewable Energy and Cogeneration plants – as long as transmission system stability is insured.

Operators of RE and Cogen systems, however, should be obliged to implement the technical means for remote control of their systems´ output by the responsible network operator.

Operation of the generation management should be transparent and a compensation scheme should be introduced, which compensates for financial losses of RE system operators, which are heavily subjected to generation management.

System below a certain threshold capacity (for example 30 kWp PV) should be excluded from the generation management."

A discussion paper */VDN 2006/* by the Association of Network Operators (VDN) suggests to employ a variable power reduction scheme using several reduction levels: 0 %, 30 %, 60 %, and 100 % with respect to nominal system power:

"The network operator does not directly control the generation system, but sends suitable control signals. Reduction of generation power falls within the responsibility of the generation system owner. Power reduction should affect all systems to the same degree. A relation to the date of commissioning – "last in / first out"- is not intended.

Otherwise the administrative burden for network operators would rise and erection of new systems would be discouraged".

4.3 ANALYSIS OF RESULTS AND CONCLUSIONS

4.3.1 Analysis and Conclusions

In Germany the EEG act determines rights and duties of utilities very well and leaves little room for arguments. Nearly all utilities have some experience with distributed PV systems. In most cases these systems are easily integrated into everyday business.

The effect of voltage rise due to distributed generation is known but hardly ever causes problems. In most cases loads prevail in the distribution network. In densely populated urban areas technical problems to grid operation were virtually excluded. Technical standards are perceived to be sufficient, as minor improvement a rule is suggested to watch phase symmetry with a larger number of small single phase systems.

Unintended islanding is not seen as a problem.

For future, higher penetration ratios of DG there are some concerns about voltage rise which would need costly grid strengthening requested by law. Also, on MV level, protection schemes might eventually need adaption to bidirectional power flow. However, there are little chances to reach the necessary penetration ratio on a broad scale with PV only. Other DG technologies, mainly cogeneration and wind power, are viewed more critical.

Due to high wind power capacities in Northern Germany transmission lines into the South are sometimes heavily loaded. There are concerns that during transmission networks failures this might lead to break down of the electricity supply.
This concern lead to quests for operational control of all larger generation capacity including PV. Therefore, for system larger than e.g. 30 kWp - this figure is somewhat arbitrary - some utilities operating high voltage transmission lines require an option to reduce power output by remote control. This issue, however, results from limited high voltage transmission line capacity, not from PV specific features.

Utilities and standardisation bodies acknowledge the large PV capacity on the grid and changed the thresholds for under/over voltage and –frequency cut-out to the same values as used for central power stations. Now PV systems do stabilise the network in case of major disturbances.

In future, some utilities envision potential benefits from PV systems in terms of active filtering, especially to reduce the 5th harmonic, providing reactive power control including voltage control on overhead lines and improving phase symmetry.

However, these features will require major changes in equipment standards and new tariff models. Currently, PV system owners could not make profit from these services.

4.4 REFERENCES

/BMU 2007/ Erfahrungsbericht 2007 zum Erneuerbaren-Energien-Gesetz (EEG) – BMU Entwurf, Kurzfassung, 5.7.2007; *(report on experiences with the Renewable Energies Act (EEG) – draft of 2007-07-05*), BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), 2007

/BNA 2007/ http://www.bundesnetzagentur.de/

/EEG 2004/ The main features of the Act on granting priority to renewable energy sources, BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), 2004

/EON 2006/ Grid Code for high and extra high voltage, April 2006, EON Netz GmbH,

/VDE 2006/ DIN V VDE V 0126-1-1, Selbsttätige Schaltstelle zwischen einer netzparallelen Eigenerzeugungsanlage und dem öffentlichen Niederspannungsnetz *(Automatic disconnection device between a generator and the public low-voltage grid)*, prestandard, February 2006

/VDEW 2001/ Eigenerzeugungsanlagen am Niederspannungsnetz – Richtlinie für Anschluss und Parallelbetrieb von Eigenerzeugungsanlagen am Niederspannungsnetz *(private electricity generation systems at the low voltage grid – Guideline for connecting and operating of distributed generation systems on the low voltage grid), VDEW; 4. Ausgabe 2001*

/VDEW 2006/ Stellungnahme zur Änderung des Erneuerbare-Energien-Gesetzes aufgrund des „Erzeugungsmanagements" (Comments for the amendment of the *Renewable Energies Act regarding "bottle –neck management"*, VdEW und VDN, Berlin, 31. Oktober 2006

/Viotto 2005/ Present status of DG in Germany: National codes, standards, requirements and rules for grid interconnection and operation, Technical report "tech_2005_0058", DISPOWER project, 2005

4.5 *Annexes*

4.5.1 Definition of size class of utility according to VdEW

size class (GK)	delivered electrical energy per year
1	< 100 MWh
2	100 - 250 MWh
3	250 - 630 MWh
4	630 - 1.600 MWh
5	1.600 - 4.000 MWh
6	4.000 - 10.000 MWh
7	10.000 - 25.000 MWh
8	25.000 - 63.000 MWh
9	63.000 - 160.000 MWh
10	160.000 - 400.000 MWh
11	400.000 - 1.000.000 MWh
12	1.000.000 - 2.500.000 MWh
13	2.500.000 - 6.300.000 MWh
14	6.300.000 - 16.000.000 MWh
15	16.000.000 - 40.000.000 MWh
16	40.000.000 - 100.000.000 MWh
17	> 100.000.000 MWh

source: VDEW Mitgliederverzeichnis, 22. Auflage, Frankfurt 2001 (VdEW membership directory, issue 22, 2001)

4.5.2 List of contacted utilities

size class (GK)	Name
GK 4	Philipp Maier jr. Säge- und Elektrizitätswerk Altensteig
GK 5	Strombezugsgenossenschaft Saig e.V.
	Elektrizitätswerk Karl Stengele Rottenburg
GK 6	Elektrizitätswerk Leitlein Forchtenberg
	Elektrizitätswerk Ley Wolpertshausen
GK 7	Stadtwerke Bad Herrenalb
	Elektrizitätswerk Ziegler Kappelrodeck
	Stadtwerke Elzach
	Elektrizitätswerk Owen
	Gemeindewerke Krauchenwies
	Kraftwerk Köhlgartenwies
	Energie- und Wasserversorgung Kirchzarten
GK 8	Stadtwerke Oberkirch
	Gemeindewerke Schutterwald
	Gemeindewerke Sinzheim
GK 9	Stadtwerke Tuttlingen
	Überlandwerk Schäftersheim, Weikersheim
	Wendelin Maunz GmbH, Ehingen
GK 10	GEWS Contigas Deutsche Energie AG, Singen
	Stadtwerke Villingen-Schwenningen
	Stadtwerke Tübingen
GK 11	Fair Energie Reutlingen
	Stadtwerke Pforzheim
	Albwerk GmbH & Co KG, Geislingen
	Stadtwerke Heidelberg
GK 12	SWU Energie GmbH, Ulm
	Kraftübertragungswerke Rheinfelden
	MVV Energie AG, Mannheim
	Stadtwerke Karlsruhe

4.5.3 List of Abbreviations

Abbreviation	term	meaning
PV	Photovoltaik	Photovoltaics
EEG	Erneuerbare-Energien-Gesetz	Renewable Energy Act
KWK	Kraft-Wärme-Kopplung	Heat /electrical power cogeneration
VDEW	Verband der Elektrizitätswirtschaft	Association of electricity companies
VDN	Verband der Netzbetreiber	Association of electrical network operators
ENS	Einrichtung zur Netzüberwachung mit jeweils zugeordnetem Schaltorgan in Reihe	Safety grid interface (for PV systems)

5 SPAIN

5.1 Iberdrola Distribución Eléctrica

CONTACT PERSON: **JOAQUÍN CABETAS FELIPE (Operación y Planificación de la red – Network Planning and Operation)**

INTERVIEW DONE BY: **UNIVERSIDAD POLITÉCNICA DE MADRID – INSTITUTO DE ENERGÍA SOLAR (Estefanía Caamaño-Martín)**

DATE: **2006.06.30**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by the Distribution company**	
LV: In accordance with CEI EN 50160 (Voltage characteristics of electricity supplied by public distribution networks): THD ≤ 8% (95% of the week, 10 min RMS)	MV: In accordance with CEI EN 50160 (Voltage characteristics of electricity supplied by public distribution networks): THD ≤ 8% (95% of the week, 10 min RMS)
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: No.	MV: Yes (“Solar gardens”[a]). o Recent experience (< 2 years) with a 500 kW PV plant (100 x 5 kW single-phase PV systems) in which almost 80% of electricity meters were burned due to harmonics induced by inverters (see also 1.2).

[a] “Solar garden” is the name used in Spain for centralized PV plants generally installed in rural areas and usually owned by private investors.

▪ **Concern about future problem?**	
LV: No.	MV: Yes. Iberdrola has issued specific interconnection requirements for PV-DG, due to the fact that current Spanish requirements are considered insufficient.
▪ **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**	
LV: Yes, in urban areas where current harmonics are higher.	MV: Yes (same reason as in LV).
1.2 – VOLTAGE REGULATION	
▪ **Perception of current problem?**	
LV: No.	MV: Yes ("Solar gardens") o Recent experience (< 2 years) with a 500 kW PV plant (100 x 5 kW single-phase PV systems). Measurements were performed during 1 week: up to 5-6 important power fluctuations per hour were detected, which were not due to meteorological conditions, but to other unknown reasons.
▪ **Voltage regulation systems used by the Distribution company**	
LV: Manual (fixed) off-load tap changers in MV/LV transformers (no dynamic voltage regulation is performed).	MV: o Automatic tap changers on the secondary side of HV/MV transformers. Output voltage is usually 5% over nominal value (Spanish regulation: variations must be within ± 7%) In rural areas regulation is also performed in intermediate points of the lines, based on measurements of the circulating currents. o In long lines with high voltage drops, regulating transformers are used.
o **Are such systems adequate for bidirectional power flows?**	
LV: Not applicable (no dynamic voltage regulation is performed).	MV: Yes. HV/MV transformers withstand bidirectional flows of active power. In the case of regulating transformers used in long lines with high

	voltage drops, they are designed so that the "source node" maintains the voltage, which is generally not the case in DG technologies.
▪ **Maximum overvoltage allowed to PV-DG : [SPAIN: Maximum overvoltage allowed is 5% of nominal voltage]** **Are national regulations enough?** **Are there any requirements set by the Distribution company?**	
LV: National regulation is considered sufficient.	MV: A stricter limit is considered necessary and applied in Iberdrola distribution networks, with a maximum allowed overvoltage being 3% of nominal voltage level.
▪ **Concern about future problem?**	
LV: Not in urban areas, where the networks are stronger and higher power levels circulate. In rural areas case-by-case analysis is needed.	MV: Yes. More research is needed in case of high penetration levels of PV-DG, due to the tight requirements of voltage changes stated by National standard (within ±7% of nominal voltage).
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: Not with current technology. Voltage variation by PV-DG should be included within the expected voltage regulation ranges of MV/LV transformers	MV: Regulation with telecontrol would be interesting. However, this seems difficult, since PV-DG telecontrol mechanisms should be compatible with those used in the networks (e.g. precision levels of regulating devices). Power Factor regulation would be a more interesting option.
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: No.
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: Yes.	MV: Yes.

1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: No.	MV: No.
▪ **Concern about future problem?**	
LV: No. Currently, discussions are under way regarding the convenience of grounds interconnections in urban areas; PV-DG shall complay with the existing requirements on any case.	MV: Same as in LV.

1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	
LV: Concern exists that inverters may maintain the voltage.	MV: Same as in LV.
▪ **Concern about future problem?**	
LV: Concern exists that, in case of shut-down of a sub-system and high PV-DG penetration, PV generation is not disconnected. It is unknown whether the regulation speed, together with a (PV-DG) generation - load balance could induce an island event within a sub-system.	MV: Concern exists that, in case of shut-down of a sub-system and high PV-DG penetration, PV generation is not disconnected. Moreover, in severe accidents where no island conditions occur (generation different from load) and high PV-DG penetration, the unintended trip of inverters could make the problem worse. It is unknown whether the regulation speed, together with a (PV-DG) generation - load balance could end in an island event within a sub-system.
▪ **Are current technical requirements adequate and sufficient?**	
LV: Yes.	MV: Yes.

▪ **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**	
LV: o Impedance measurement not recommended (complex parameter). o Stability studies have shown that if there is no capability of frequency maintenance, no islanding problems occur.	MV: Same as in LV.
1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ **Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment) ?**	
LV: There is lack of technical knowledge; more research is necessary.	MV: Same as in LV.
▪ **Concern about mutual disturbance of large numbers of inverters?**	
LV: Yes.	MV: Yes.
1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: Difficult implementation; telecontrol in each PV plant would be necessary.	MV: In high power PV plants (MW level), telecontrol is considered convenient.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: Not Applicable.	MV: Up to 3 authomatic reconnections can occur, with delay times between 100 miliseconds and 30 seconds. It is not always applied in urban networks.

1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: Low voltage PV plants must have a galvanic separation between the LV distribution grid and the PV plant by means of an insulation transformer or another appropriate solution.	MV:
▪ **Have tranformerless inverters shown "noticeable" differences from inverters comprising a transformer?**	
LV: N.A.	MV:

1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: As current regulation states: 50% of the transport capacity of the LV line / transformer capacity.	MV: Current regulation (50% of the transformer capacity) is insufficient. The 50% limit should be smaller, and adapted to the specific network characteristics.
▪ **Are/should penetration limits be different in urban and rural grids?**	
Yes. In urban areas, networks are rather strong and loads are predominant: higher penetration limits would be achievable. In rural areas, networks are weaker and penetration limit smaller. In MV networks, as the distance to the substation transformer increases, DG capacity decreases.	

1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: PV plants ≤ 100 kW (inverter's nominal power) Connection requests follow a quick procedure. In urban areas technical connection issues are easy. In the commissioning phase, tests are done to ensure that voltage increases is within the limit (≤5%).	MV: PV plants > 100 kW o Connection requests are dealed with in Planning departments. Simulations are carried out to ensure compliance with voltage increase due to PV-DG connection. o Iberdrola (as well as other distribution companies) have worked out a standard procedure (in collaboration with the Regional Governments), in which further requirements are set

	for PV plants. For example, a deposit of 1 €/kW is asked (payment in advance for later connection works), so that "mature" projects can be differentiated from "speculative" ones. Priority in access to the network is defined by the Regional Governments. o At present, in many Spanish regions connection requests of "solar gardens" already exceed the networks capacity. The initial (provisional) assignment of a connection point does not imply that the point is available when the PV plant is finished. Distribution companies cannot reserve power by law. o An alternative solution for situations of high demand of connection points can be to build specific reception networks for PV systems (i.e. PV networks separated from the consumer networks). Associated costs would be shared between the PV investors and the Regional Governments. o Operation departments do not count on PV-DG due to its non-controllable characteristics (not predictable). Therefore, the Planning departments design the networks so that the expected network voltage variations due to Distributed Generators stay within the operation limits, in all foreseeable generation and load conditions.
▪ **Are new tools needed?**	
LV: --- *[The interview with Iberdrola was done before this version of the questionnaire was produced (2007-3-20)]*	MV:
▪ **Potential interest for incluing PV-DG into load dispatching?** **Are new tools needed?**	
LV: *[Same as above)]*	MV:

▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: No.
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: *[Same as above)]*	MV:
2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
Concern about the current "boom" of PV-DG in MV grids ("Solar gardens") and the lack of proper regulations. Should all the connection requirements received be awarded, many rural distribution networks would turn into "exporting" ones. Concern also about too permisive conditions, due to the fact that the distribution systems has no tools for generation dispatching. Problems with PV-DG may result in damages for customers or expensive solutions to avoid them (costs for PV-DG owners and utilities).	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: *[The interview with Iberdrola was done before this version of the questionnaire was produced (2007-3-20)]*	MV:
▪ **Are the PV plants where regular measurements are done?**	
LV: No.	MV: No comprehensive measurements. Just some measurements performed on specific PV plants where operation problems have occurred ("Solar gardens" type).
▪ **Incidents with PV-DG over the last 10 years**	
LV: No evidences.	MV: Just a few evidences, for the time being.

2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: Royal Decree 1663/2000, on the interconnection of PV systems to Low Voltage electricity networks (maximum inverter(s) size: 100 kW). Also, Iberdrola own technical guidelines: o "Normas técnicas de Iberdrola. Anexo A: Información sobre la conexión de instalaciones fotovoltaicas a la red de distribución" (Ediciones 2006 y 2007). o "Normas técnicas de Iberdrola. Anexo B: Formulario de solicitud de punto de conexión". o "Normas técnicas de Iberdrola. Anexo C: Cálculo de la variación de la tensión".	MV: Order 5/1985, on the interconnection of PV systems to Medium and High electricity networks. Also, Iberdrola own technical guidelines: o "Normas técnicas de Iberdrola. Anexo A: Información sobre la conexión de instalaciones fotovoltaicas a la red de distribución" (Ediciones 2006 y 2007). o "Normas técnicas de Iberdrola. Anexo B: Formulario de solicitud de punto de conexión". o "Normas técnicas de Iberdrola. Anexo C: Cálculo de la variación de la tensión".
▪ **Are current standards for PV-DG sufficient?**	
LV: No.	MV: No.
▪ **Issues at present not covered by standard, which should be included**	
LV: Harmonics, flicker, islanding.	MV: Connection procedures, network limitations, harmonics, flicker, islanding.

2.3 – OTHER ISSUES
▪ **Any research/development need identified?**
o Islanding (possibility that PV plants may maintain the voltage) o Harmonics o Flicker o Power factor regulation according to the voltage

5.2 Unión Fenosa Distribución

CONTACT PERSONS: **RUFINO VIGIL (Responsable de Compras de Energía del Régimen Especial – Responsible of electricity purchases of the Special Regime), JAVIER SACRISTÁN (Estudios DYC Madrid – Studios Madrid), JULIO MATEO (Estudios Castilla – Studios Castilla)**

INTERVIEW DONE BY: **UNIVERSIDAD POLITÉCNICA DE MADRID – INSTITUTO DE ENERGÍA SOLAR (Estefanía Caamaño-Martín)**

DATE: **2007.03.27**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by the Distribution company**	
LV: In accordance with CEI EN 50160 (Voltage characteristics of electricity supplied by public distribution networks): THD ≤ 8% (95% of the week, 10 min RMS)	MV: In accordance with CEI EN 50160 (Voltage characteristics of electricity supplied by public distribution networks): THD ≤ 8% (95% of the week, 10 min RMS)
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: No, giving the existence of certificates by the inverters manufacturers.	MV: Same as in LV.
▪ **Concern about future problem?**	
LV: No. Harmonic emmissions could condition the maximum PV power to be installed; current PV penetration in the networks is however very far from that situation.	MV: Same as in LV. It is worth mentioning that harmonics related problems would appear first in rural networks.

- **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**

LV: PV-DG is not controllable (it cannot be managed), which means that it is not reliable enough to perform active filtering.	MV: Same as in LV.

1.2 – VOLTAGE REGULATION

- **Perception of current problem?**

LV: Yes, but not because of Distributed Generation (Special Regime). Voltage regulation of the networks done in Spain responds to economic reasons —not technical ones—, which has a negative impact on their optimization.	MV: Same as in LV.

- **Voltage regulation systems used by the Distribution company**

LV: Manual (fixed) off-load tap changers in MV/LV transformers (no dynamic voltage regulation is performed).	MV: o Automatic tap changers on the secondary side of HV/MV transformers. o Capacitor banks. o Further regulation in some lines.

  - **Are such systems adequate for bidirectional power flows?**

LV: Not applicable (no dynamic voltage regulation is performed).	MV: Yes.

- **Maximum overvoltage allowed to PV-DG : [SPAIN: Maximum overvoltage allowed is 5% of nominal voltage]**

  Are national regulations enough?

  Are there any requirements set by the Distribution company?

LV: National regulation is considered sufficient, for the time being. More strict limits could be detrimental for PV-DG; less strict ones could be so for stability of supply.	MV: Same as in LV.

▪ **Concern about future problem?**	
LV: No.	MV: Yes, in PV plants of a certain size (> 2MW). However, if calculations for the connection and reception are correctly done, no problems should occur.
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: Yes; nevertheless, it is not considered necessary at this moment.	MV: Same as in LV.
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No different requirement form other Special Regime Technologies (Renewables and Cogeneration).	MV: Same as in LV.
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: No.	MV: No.
1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: No.	MV: No.
▪ **Concern about future problem?**	
LV: No.	MV: Same as in LV.

1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	
LV: No, because it is not allowed. Inverters are required to monitor basic grid parameters (voltage and frequency); also, for PV grid connected systems approval, a certificate issued by the inverter manufacturer on islanding issues must be provided.	MV: Same as in LV. Also, for big PV plants such as "Solar gardens", the grid interconnection must be telecontrolled.
▪ **Concern about future problem?**	
LV: No.	MV: No.
▪ **Are current technical requirements adequate and sufficient?**	
LV: Yes.	MV: Yes, together with the telecontrol requirement issued by Unión Fenosa for PV plants connected to MV networks.
▪ **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**	
LV: ---	MV: ---

1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ **Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment) ?**	
LV: Yes, for the time being. In case of a higher penetration of PV plants, specific standards for inverters may be necessary. Also for inverters that perform complementary functions (e.g. voltage regulators).	MV: Same as in LV.

▪ **Concern about mutual disturbance of large numbers of inverters?**	
LV: ---	MV: ---
1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: It is not considered necessary. What is very important is to haver properly identified the connections of the PV plants in the distribution networks.	MV: It is not considered necessary, given the existence of telecontrolled interconnection switches.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: Not Applicable	MV: Up to 3 authomatic reconnections can occur, with typical performance times of 1 second, 15 seconds and 1 minute.
1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: Low voltage PV plants in Spain must have a galvanic separation between the LV distribution grid and the PV plant by means of an insulation transformer or another appropriate solution.	MV: Insulation transformers are normally required. However, in case a Transformation Center exists (with galvanic insulation), inverters without galvanic insulation can be also accepted.
▪ **Have tranformerless inverters shown “noticeable” differences from inverters comprising a transformer?**	
LV: N.A.	MV:

1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: As current regulation states: 50% of the transport capacity of the LV line / transformer capacity. However, interpretation of this regulation should be clarified, since at present it can be confusing.	MV: Same as in LV.
▪ **Are/should penetration limits be different in urban and rural grids?**	
Absolute penetration limits should be the same. There should be differences between the requirements for voltage stability, which should be more restricted in rural areas.	

1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: PV plants ≤ 100 kW (inverter's nominal power) Analyses are performed to verify that the voltage increase due to the PV plant grid connection complies with acceptable limits (≤5%).	MV: PV plants > 100 kW Analyses are performed to verify that the voltage increase due to the PV plant grid connection complies with acceptable limits (≤5%). Simulations of load flows are also performed.
▪ **Are new tools needed?**	
LV: No.	MV: No.
▪ **Potential interest for incluing PV-DG into load dispatching?** **Are new tools needed?**	
LV: No, given the present separation of generation, distribution and commercialisation businesses.	MV: Same as in LV.
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: No.

▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: PV plants must disconnect when they detect absence of the grid; no special protocol for disabling is carried out.	MV: PV plants must include telecontrolled interconnection switches: the disconnection order is therefore sent to these plants.
2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
No technical problems have been experienced up to now. However, it is considered that severe administrative problems exist associated to the implementation and commissioning of big PV plants, the burden of which fall on promoters, distribution companies and the Regional Governments.	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: No.
▪ **Are the PV plants where regular measurements are done?**	
LV: No measurements are performed regularly, just if technical problems occur, which has not been the case up to date.	MV: Same as in LV.
▪ **Incidents with PV-DG over the last 10 years**	
LV: No evidences, for the time being.	MV: No evidences, for the time being..
2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: Royal Decree 1663/2000, on the interconnection of PV systems to Low Voltage electricity networks (maximum inverter(s) size: 100 kW). Also, Unión Fenosa own technical guidelines: “Norma de Instalaciones fotovoltaicas conectadas	MV: Order 5/1985, on the interconnection of PV systems to Medium and High electricity networks. o Also, Unión Fenosa own technical guidelines: “Condiciones técnicas para la conexión a la red de Media tensión de instalaciones o agrupaciones fotovoltaicas fotovoltaicas

a la red de Baja tensión (2004)".	conectadas a la red de Baja tensión. Documento AG8".
▪ **Are current standards for PV-DG sufficient?**	
LV: Should the penetration level of PV plants in the networks increase, specific standards for inverters should be developed.	MV: Same as in LV.
▪ **Issues at present not covered by standard, which should be included**	
LV: Maximum PV penetration limits should be clarified (see reply to question 1.10).	MV: Same as in LV.

2.3 – OTHER ISSUES
Distributed PV generation is rather far from other renewable electricity technologies, such as wind technology. Given the stated objectives of the Spanish Promotion plan for Renewable Energies (371 MW grid connected by 2010), no significant concern exists on technical problems that may arise from PV technology. Concern exists, however, on the administrative complexity falling nowadays on electricity distribution companies, as well as on the burden that may fall in the future. Not withstanding the previous comments, the majority of the big PV plants ("Solar garden" type) connected to Unión Fenosa Distribución networks will begin operation during 2007, so that further learning from PV technology is expected in the coming months.
▪ **Any research/development need identified?**

5.3 *Endesa Distribución Eléctrica*

CONTACT PERSONS: **ALFONSO SALVADOR ANDRÉS (Subdirector de Nuevos Suministros), JULIO GARCÍA CAVETE (Dirección Planificación y Calidad de la red)**

INTERVIEW DONE BY: **UNIVERSIDAD POLITÉCNICA DE MADRID – INSTITUTO DE ENERGÍA SOLAR (Estefanía Caamaño-Martín)**

DATE: **2007.04.10**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by them**	
LV: Less than 3%.	MV: Same as in LV.
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: No.	MV: Same as in LV.
▪ **Concern about future problem?**	
LV: Yes, in case of high PV penetration, given the absence of specific regulations about harmonics emmissions by means of inverters. Specially to be mentioned are small single-phase PV plants (< 5 kW), which have higher posibilities to create unbalances in the networks.	MV: MV networks are less sensible to Harmonic Distortion, mainly due to the fact that energy supplies come from 3-phase systems, so that currents in the neutral wire are by definition minimised.
▪ **Potential interest of PV plants operating as “active filters”? (harmonics generation in order to reduce/suppress existing network harmonics)**	
LV: Yes. Such functionality should be dynamic, especially in 3-phase PV plants.	MV: Same as in LV.

1.2 – VOLTAGE REGULATION	
▪ **Perception of current problem?**	
LV: No.	MV: Same as in LV.
▪ **Voltage regulation systems used by the Distribution company**	
LV: Manual (fixed) off-load tap changers in MV/LV transformers (no dynamic voltage regulation is performed).	MV: o Automatic tap changers on the secondary side of HV/MV transformers.
o **Are such systems adequate for bidirectional power flows?**	
LV: The main problem arises from the fact that the networks have been designed to export energy, so the answer depends on each specific case. Adaptation of the networks is therefore possible, but the solution is case-specific. For the design of new networks, or for extensions of existing networks, the capacity to include DG will have to be considered.	MV: Same as in LV.
▪ **Maximum overvoltage allowed to PV-DG : [SPAIN: Maximum overvoltage allowed is 5% of nominal voltage]** **Are national regulations enough?** **Are there any requirements set by the Distribution company?**	
LV: National regulation is considered sufficient, given the Spanish regulation for voltage variation in distribution networks (±7%). However, voltage variation problems are more important in rural areas, where the contracted powers are generally smaller and transformers supply many lines of considerable length and relatively small sections. This means that for the same power variation level, voltage variations are	MV: MV lines are much stronger than LV lines, irrespective of the environment (rural or urban), so that for the power sizes used in PV-DG, overvoltage problems do not generally occur. Nevertheless, in specific cases such as the "Solar Gardens" (centralised PV plants owned by several investors that are installed in rural areas), if potential problems are detected in the previous study phase (to be done by Endesa Distribution before a connection point is proposed to the PV plant promoters), it may determine the connection point of the PV plant to the distribution network or the characteristics of the specific dedicated line to

more important in rural areas compared to urban ones.	connect the PV plant to the Transformer Substation.
▪ **Concern about future problem?**	
LV: Yes, in case of high penetration of PV plants in the networks, if all plants connect quasi-simultaneously. If the interconnection is done gradually, no problems should occur.	MV: Yes, in PV plants of a certain size (MW levels).
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: Yes. However, such plants could create undesired islanding situations, which should be excluded by means of the corresponding control mechanisms.	MV: Same as in LV.
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No (PV-DG strengthens the networks)	MV: Same as in LV.
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: Concern exists of a large number of PV plants dispersed and connected to the networks, and the lack of control over these plants by means of the distribution companies. As a general principle, the lesser control, the higher potential problems can occur.	MV: Same as in LV.
1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: ---	MV: ---

▪ Concern about future problem?	
LV: ---	MV: ---
1.5 – ISLANDING OPERATION	
▪ Perception of current problem?	
LV: No.	MV: Same as in LV.
▪ Concern about future problem?	
LV: Yes.	MV: Yes.
▪ Are current technical requirements adequate and sufficient?	
LV: Yes, in principle. However, research is being done on islanding related risk analysis.	MV: Same as in LV.
▪ Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)	
LV: ---	MV: ---
1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment) ?	
LV: Yes, for the time being. It is worth mentioning the high emmission levels of harmonics in periods of low solar radiation (typically at the beginning and end of the day), by means of certain inverters. This aspect should be regulated in a specific standard. On another hand, concern exists about multiple operation of inverters connected to different phases, in which the energy feeding in one of the	MV: Same as in LV.

phases may be affected (highly reduced or eliminated), so that an unbalance situation occurs in the neutral wire, with the corresponding harmonics-related problems.	
▪ **Concern about mutual disturbance of large numbers of inverters?**	
LV: Yes.	MV: Yes.
1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: Yes. However, control conditions should be established, so that the distribution companies can operate on the switches based on technical reasons. The economical benefits perceived nowadays by PV plants investors makes this aspect (remote disconnection) a difficult issue to manage.	MV: Same as in LV.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: Not Applicable	MV: Up to 3 authomatic reconnections can occur, with typical performance times of 1 second, 15 seconds and several minutes. It is worthwhile mentioning the fact that some inverters do not comply with the (Spanish) requirement that reconnection after loss of the grid supply must be performed 3 minutes after the grid supply returns. Because of that, Endesa Distribución is going to demand specifically such requirement in the future.

1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: Low voltage PV plants in Spain must have a galvanic separation between the LV distribution grid and the PV plant by means of an insulation transformer or another appropriate solution. Inverters with high frequency insulation transformers are however accepted.	MV: In all cases, a coupling LV/MV transformer must exist.
▪ **Have tranformerless inverters shown "noticeable" differences from inverters comprising a transformer?**	
LV: N.A.	MV:

1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: Current regulation (50% of the transport capacity of the LV line / transformer capacity) is considered inappropriate, due to the fact that in certain circumstances (for example, locations with a much smaller load than local generation), the existing requirement may be excessive. The penetration limit should take into account the loads in the specific location of the PV plant.	MV: Same as in LV.
▪ **Are/should penetration limits be different in urban and rural grids?**	
Penetration limits should be different. In urban areas the electricity demand is generally higher and the networks are stronger, so that higher penetration should be allowed compared to rural areas. Unfortunately, in urban areas available surfaces for PV generators are generally limited, which therefore limit the opportunities of PV-DG. For the surfaces available, related PV-DG powers do not affect at present negatively the networks.	

1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: PV plants ≤ 100 kW (inverter's nominal power) For 3-phase PV plants of a certain size, simulations of the network are performed with and without PV injection.	MV: PV plants > 100 kW Simulations of the network are performed with and without PV injection.
▪ **Are new tools needed?**	
LV: Yes.	MV: Yes.
▪ **Potential interest for incluing PV-DG into load dispatching?** **Are new tools needed?**	
LV: Yes, but associated to a continued support to Demand Side Management mechanisms (not as it has been the case in Spain, where DSM programmes have been discontinuous over time). However, present Spanish legislation does not facilitate the implementation of such mechanisms, due to the fact that hourly discrimination of electricity prices is not considered (even period-discrimination has been recently reduced, from the previous 3 levels peak-flat-valley, to 2 levels peak-flat).	MV: Same as in LV.
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: Same as in LV.
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: PV plants must disconnect when they detect absence of the grid voltage; no special protocol for disabling is carried out.	MV: Same as in LV.

2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
No technical problems have been experienced up to now. However, it is considered that severe administrative problems exist associated to the implementation and commissioning of big PV plants ("Solar garden" type): o On the one hand, "filters" should be applied to discriminate the "mature" projects from those immature. o On the other hand, a clear legislation is necessary for PV-DG. Currently it is considered incomplete and fragmented. Besides, it differs in the different Regional Communities (for example, Transformation centers exclusively associated to PV plants feeding into MV networks have to be in some cases mandatory transferred to the distribution companies).	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: No.	MV: No.
▪ **Are the PV plants where regular measurements are done?**	
LV: No measurements are performed regularly, just if technical problems occur, which has occurred very rarely up to date.	MV: Same as in LV.
▪ **Incidents with PV-DG over the last 10 years**	
LV: No evidences, for the time being.	MV: No evidences, for the time being.
2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: Royal Decree 1663/2000, on the interconnection of PV systems to Low Voltage electricity networks (maximum inverter(s) size: 100 kW). Also, Endesa own technical guidelines.	MV: Order 5/1985, on the interconnection of PV systems to Medium and High electricity networks. Also, Endesa own technical guidelines.

▪ **Are current standards for PV-DG sufficient?**	
LV: No.	MV: Same as in LV.
▪ **Issues at present not covered by standard, which should be included**	
LV: Specific standards for inverters should be developed, covering amongst others: o Limits for harmonics emmissions under any circumstance (including low power operation). o Reliable detection of islanding phenomena. Also, maximum allowed voltage umbalances and adequate interconnection topologies for multiple inverters should be specified.	MV: Same as in LV.

2.3 – OTHER ISSUES

Distributed PV generation is rather far from other renewable electricity technologies. Given the stated objectives of the Spanish Promotion plan for Renewable Energies (371 MW grid connected by 2010, which can be fulfilled according to the present market evolution), concern exists about the administrative complexity falling nowadays on electricity distribution companies (also about the one that may fall in the future).

Also, a more clear legislation is necessary for PV-DG.

▪ **Any research/development need identified?**

- o Operation of PV-DG under islanding conditions, at the level of inverters design and interaction of different technologies.

6 THE NETHERLANDS

6.1 Continuon, Essent, Eneco

CONTACT PERSON: **SJEF COBBEN (Continuon)**

DATE: **2007.04.12**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by them**	
LV: 3.5%	MV: 2.5%
▪ **Perception of current problem? (very small/small penetration of PV-DG)**	
LV: In some special cases (resonance). Due to the capacitors of the inverters in combination with background harmonic voltages there were resonance problems at a few sites with PV-systems.	MV: No.
▪ **Concern about future problem?**	
LV: Yes, there has to be found a limit to the capacitor for PV-inverters and in general for low voltage devices.	MV: No.

▪ **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**	
LV: No, in principle the current should be limited at the source so filtering should not be needed. Perhaps in special cases it could be advisable (high power inveters).	MV: On MV it could be interesting because the power of the invererters shall be higher and a more concentrated approach is possible.
1.2 – VOLTAGE REGULATION	
▪ **Perception of current problem?**	
LV: No, in some cases the upper limit in the voltage was reached but by changing the setpoint of the tap changer of the MV/LV transformer the voltage level could be improved.	MV: No.
▪ **Voltage regulation systems used by the Distribution company**	
LV: None (only manual changing the tap changer of ther MV/LV transformer).	MV: Regulator on HV/MV transformer.
o **Are such systems adequate for bidirectional power flows?**	
LV: Yes.	MV: To some extent. For implementation of a lot of dispersed generators additional regulation principles will be needed.
▪ **Maximum overvoltage allowed to PV-DG : [THE NETHERLANDS: Maximum overvoltage allowed is 6% of nominal voltage]** **Are national regulations enough?** **Are there any requirements set by the Distribution company?**	
LV: Not the good values in national grid code No additional requirements are needed. EN 50160 could be used.	MV: - No additional requirements are needed.

▪ **Concern about future problem?**	
LV: No, Voltage level can be easily controlled and calculation of this power quality phenomenom can be done easily.	MV: No, Voltage level can be easily controlled and calculation of this power quality phenomenom can be done easily.
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: No.	MV: No.
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: For operation no new requirements are necessary.	MV: Only with very high amount of PV.
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: No.	MV: Only with very high amount of PV.
1.4 – PV SYSTEMS GROUNDING	
▪ **Perception of current problem?**	
LV: No.	MV: No.
▪ **Concern about future problem?**	
LV: No.	MV: No.
1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	
LV: No.	MV: No.
▪ **Concern about future problem?**	
LV: No.	MV: No.
▪ **Are current technical requirements adequate and sufficient?**	

LV: Yes, only a voltage and frequency window is required and is proven to be sufficient.	MV: Yes, only a voltage and frequency window is required and is proven to be sufficient.
▪ **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**	
LV: Not necessary.	MV: Not necessary.
1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS	
▪ **Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment) ?**	
LV: No, there are no harmonic emission limits in combination with harmonic distortion, and no limiting of capacitance.	MV:
▪ **Concern about mutual disturbance of large numbers of inverters?**	
LV: Concern about harmonic distortion and due to capacitance low resonance frequencies.	MV: Same as in LV.
1.7 – EXTERNAL DISCONNECT	
▪ **Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels**	
LV: No, in principle not. With the implementation of the "smart meter" this can be done with this meter.	MV: No.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: In Dutch grid code are requirements implemented about disconnection. In the final draft prEN50438 requirements for the connection of micro generators times for reclosing are given.	MV: In Dutch grid code are requirements implemented about disconnection.

1.9 – DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: No.	MV: No.
▪ **Have tranformerless inverters shown “noticeable” differences from inverters comprising a transformer?**	
LV: Inrush currents noticed from inverters with transformer leading to disconnection of B-type circuit breaker.	MV: No.
1.10 – PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: 75%.	MV: 50%.
▪ **Are/should penetration limits be different in urban and rural grids?**	
In rural grids limits could be a little bit lower.	
1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: Yes, in low voltage grid the design is made with 500 W dispersed generation for each connection point (not for all grid operators).	MV: No.
▪ **Are new tools needed?**	
LV: No, there are several software packages for grid calculation where dispersed generation can be implemeted in the grid and the grid calculations.	MV: No, there are several software packages for grid calculation where dispersed generation can be implemeted in the grid and the grid calculations.

▪ **Potential interest for incluing PV-DG into load dispatching?** **Are new tools needed?**	
LV: No, there are several software packages for grid calculation where dispersed generation can be implemeted in the grid and the grid calculation.	MV: No, there are several software packages for grid calculation where dispersed generation can be implemeted in the grid and the grid calculation
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: Yes, but only when high amount of PV systems are considered.	MV: Yes, but only when high amount of PV systems are considered.
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: Standard safety procedures.	MV: Standard safety procedures.
2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
Positive, only harmonic problems in special cases. Also a problem with connection of a external generator to the system in the case of a outage of the normal supply. The generator disconnected from the grid (perhaps due to inverse current).	
▪ **Are the PV plants where regular measurements are done?**	
LV: Yes. In several cases measurements have been made. A national PQ program is done where PV-sites are compared with the average PQ-levels.	MV: No.
▪ **Incidents with PV-DG over the last 10 years**	
LV: Only harmonic problems.	MV: None.

2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: National grid code, NTA (Dutch standard) about inspection of PV-systems, NEN 1010 installation requirements based on European normalisation.	MV: ---
▪ **Are current standards for PV-DG sufficient?**	
LV: Values in Dutch grid codes have to be changed. Changes in IEC 61000-3-2 (Limits for harmonic current emissions, equipment input current <= 16 A per phase) are advisable.	MV: ---
▪ **Issues at present not covered by standards, which should be included**	
LV: o Maximum value of capacitance in inverters. o IEC standards about limits for harmonic currents. o Maximum harmonic current limits in environments with harmonic voltage distortion. o Also, coordination of standards concerning safety in low voltage, connection of micro-generators	MV:

2.3 – OTHER ISSUES
▪ **Any research/development need identified?**
o Application of PV-systems in combination with generators used to deliver electrical energy in emergency cases. o Development of inverters with low harmonic currents and limited capacity. o Coordination of standards concerning safety in low voltage, connection of micro-generators.

7 UNITED KINGDOM

7.1 Central Networks

CONTACT PERSON: **DAVID HARRISON (Network Design Team, Network Strategy & Regulation)**

DATE: **June 2007**

NOTES:

- **THREE SOURCES OF INFORMATION HAVE BEEN INCLUDED TO ILLUSTRATE THE SITUATION IN THE UK AS COLOUR & FONT CODED ON THE KEY BELOW:**

Key	**DNO Opinion**	***Standard/Engineering Recommendation***	**Previous Survey reports**

- **REFERENCES TO RELEVANT DOCUMENTS ARE NUMBERED WITHIN BRACKETS, WITH COMPLETE REFERENCES AT THE END OF THE INTERVIEW.**

1 – TECHNICAL ASSESSMENT OF PV DISTRIBUTED GENERATION (PV-DG)	
1.1 – HARMONICS	
▪ **Typical THD_V values in the networks operated by them**	
LV: ***[1] ER G83/1, 5.4 Quality of Supply*** *The connection of the SSEG in parallel with a DNO's Network must not impair the quality of supply provided by the DNO to the User or any other Customer. In this respect the SSEG shall comply with the requirements of the EMC Directive and in particular the product family emission standards listed in Table 2.*	MV: ***[2] ER G59/1, 6.2.3 Distortion & Interference*** *Harmonic Voltages and currents produced within the Embedded Generator's system may cause excessive harmonic distortion of the REC's system. The Embedded Generator's installation must be designed and operated to comply with the criteria specified in Engineering Recommendation G 5/3*

Table 2. Basic Emission Standards

Parameter	***SSEG rating***	***Standard***	***Class***
Harmonics	*≤ 16 A*	*EN 61000-3-2*	*Class A*
Voltage fluctuations and Flicker	*≤ 16 A*	*EN 61000-3-3*	*dc = 4% max*

Note 1: Compliance with EN 61000-3-2 will ensure compliance with Engineering Recommendation G5/4.

Note 2: Compliance with EN 61000-3-3 will ensure that the voltage changes caused during starting and stopping of the SSEG are within acceptable limits.

{NOTE now superseded by ER G5/4}

- **Perception of current problem? (very small/small penetration of PV-DG)**

LV: The Utility perception was that for the relatively low installation rate of 2-3 installations per week under G83/1 this was OK. The type testing of inverters ensured that the additional harmonics were limited to EN limits as above.

MV: There was an instance of a 100kW biomass plant with inverters supplied as part of the kit which only just met G5/4 limits. As harmonic levels are cumulative on the network, this although acceptable as an 'isolated' installation, could create problems if installed at higher densities in future.

- **Concern about future problem?**

LV: Not at present based on current growth rates.

MV: See above

- **Potential interest of PV plants operating as "active filters"? (harmonics generation in order to reduce/suppress existing network harmonics)**

LV: This was seen as a very involved concept to introduce on the network as operated at present, but could produce some potential benefits. It would need demonstrating, and sophisticated inverters to track the background levels of harmonics in order to help cancel them

MV: Thought to be more likely to be piloted at higher voltages where the inverters could absorb the extra cost more easily.

The 3^{rd} & 5^{th} harmonics are currently high due to TV

	equipment etc.

1.2 – VOLTAGE REGULATION

- **Perception of current problem?**

LV: **[4] 2.1.9.8 Power Quality & Voltage Levels** Six respondents *{generators}* recorded issues here, although most reported that these were resolved by negotiation or through incurring added expense. One respondent raised the possibility of the recommendations allowing for transient excursions outside the permitted ranges. The Utility view was that this was the major current problem introducing small generators onto the system, as networks tend to be run at the higher end of the voltage setting anyway to reduce losses (and because the previous statutory level was 240V). This leaves little headroom for local generation. The system at LV has only manual taps on the transformers which can only be changed when the system is off, so would require a major programme, to realign the network.	MV: The Utility view was that this would need a 'radical rethink' to restructure the network for very high densities. It is a current problem particularly on rural networks at 11kV and to some extent at LV, where the source voltage has to be set high to cater for high loads at the far end in winter. However, in summer when the load is lighter, coupled to generation at the far end can push the voltage at the source end out of limits.

- **Voltage regulation systems used by the Distribution company**

LV: Manual tap change on transformers. Can be operated only when system is off – as above.	MV: Voltage regulators are fitted to some rural networks to counter the problems as described above.

- **Are such systems adequate for bidirectional power flows?**

LV: Yes	MV: No. The older ones can only be used in one direction, although the ones currently being installed can cater for flow in both directions.

- **Maximum overvoltage allowed to PV-DG :**

LV: **Are national regulations enough?** At present yes.	MV: As left

Is there any requirements set by the Distribution company? The G83/1 settings are set outside of the statutory limits to limit nuisance tripping, and help sustain the network. However, at least one DNO would prefer them to be brought back to the statutory limits as it could be seen to be encouraging out of statutory operation, made worse by the local generation.	
▪ **Concern about future problem?**	
LV: Yes – seen as the major problem for allowing more Distributed Generation. See comments under Current Situation above. However, densities for PV are still relatively very small.	MV: Yes – seen as the major problem for allowing Distributed Generation. See comments under Current Situation above.
▪ **Potential interest of PV plants operating as "voltage regulators"? (compensation of voltage drops under high loads conditions)**	
LV: Potentially yes, but not the in foreseeable future for PV – the density is too small to have much effect.	MV: Yes – however, one system that was set to a leading pf to help the situation, became reset to unity pf by mistake during maintenance and this caused the voltage level to be pushed the wrong way!
1.3 – ANOMALOUS SITUATIONS IN DISTRIBUTION NETWORKS	
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: Not so far specifically for PV: • Main problem is where network trips on overvoltage – potential problem for future in reconfiguring tap settings for higher densities • Not many problems on equipment ratings • Network is assumed to be live for maintenance anyway	MV: Yes – there will be a need for 'Active' Networks, not just for PV, but PV will contribute to the need.
▪ **Concern on malfunction of networks protections due to PV-DG?**	
LV: None recorded so far for PV	MV: Yes – a concern is that the network will be designed by the DNOs using the best available info on generators, but this may change as the generators are not within the direct control of the DNOs and so means that the design

	assumptions could be invalid. It will need constant updating, especially for G83/1 where prior notification is currently not required.

1.4 – PV SYSTEMS GROUNDING

- **Perception of current problem?**

LV: Seen as OK at present as most systems have PV inverters with galvanic isolation & a fully Class 2 floating DC installation which is not required to be earthed. On some networks there is a mix of PME and older non PME systems, which if grounding is required requires different earthing details. Also, an amendment is under consideration to allow earthing of one pole of the DC system, but this is mainly for Fuel Cells: *Amendment 2 to G83/1 {under consultation}* *6.4 Earthing. Replace the existing wording under 6.4 with the following:* *6.4 Earthing* *When a SSEG is operating in parallel with a DNO's Network there shall be no direct connection between the generator winding and the DNO's earth terminal. For installations where the customer provides his own earth terminal, e.g. when connected to a TT system, it is also advisable to avoid connecting the generator winding to this earth terminal. The reason for this precaution is to avoid damage to the generator during faults on the distribution network and to ensure correct operation of protective devices. For a SSEG which is designed to operate in parallel with a DNO's Network but which is connected via an inverter (eg a PV array or fuel cell) it is permissible to connect one pole of the DC side of the inverter to the DNOs Network if the insulation between the AC and the DC sides of the inverter meets the requirements of overvoltage category IV as specified in IEC 60664-1. In such cases the Installer / Manufacturer shall take all reasonable precautions to*	MV: There is currently a debate on the need for NVD (Neutral Voltage Displacement) protection. Whilst it is fitted for overhead lines, it is not always required by DNOs for underground systems. The next version of G59/1 (G59/2) probably will require it. If fitted to a new system, the cost is usually marginal (VTs can be supplied on the new switchgear), but if a retrofit, often generators are allowed to fit as part of the generator switchgear. **[4] 2.1.9.6 Earthing & Neutral Voltage Displacement (NVD)** Six respondents reported issues with earthing & NVD. From the DNO side it was felt that the requirements for earthing and NVD identified in G59 and ETR113 are often overlooked by installers. Another respondent felt that the requirement for NVD protection was not consistent amongst DNOs, while one of the equipment manufacturers felt that the specification of NVD protection was excessive and could make their generation technology commercially non-viable.

ensure that the SSEG unit will not impair the integrity of the DNO's Network and will not suffer unacceptable damage for all credible operating conditions, including faults on the DNO's Network. In all cases the level of DC injection should not exceed that detailed under clause 5.5.	
▪ **Concern about future problem?**	
LV: Adequately covered	MV: Some - Aware of issue, and being addressed under draft G59/2
1.5 – ISLANDING OPERATION	
▪ **Perception of current problem?**	

LV: **[1] ER G83/1**

No current problem seen for G83/1 type tested inverters for 'single installations':

Table 1. Protection Settings

Parameter	Trip setting (maximum range)	Trip time (maximum value) *
Over Voltage	264 volts (230 +14.7%)	1.5 seconds
Under Voltage	207 volts (230 –10%)	1.5 seconds
Over Frequency	50.5 Hz (50 Hz +1%)	0.5 seconds
Under Frequency	47 Hz (50 Hz –6%)	0.5 seconds
Loss of Mains	See 5.3.2	0.5 seconds

** For each protection function listed in Table 1 it is permissible to extend the relay operating time to 5.0 seconds for those SSEG units that can withstand being re-energised from a source that is 180 degrees out of phase with the SSEG output. Typically this will only be applicable to SSEG units connected via an inverter e.g. a PV array.*

…….Active methods which use impedance measuring techniques by drawing current pulses from, or injecting ac currents into, the DNO's system are not considered to be suitable.

Appendix 1

Single SSEG within a single customers installation:

- *SSEG installed in accordance with ER G83/1,*
- *DNO notified as required under ESQCR*
- *Installer submits Commissioning pro-forma (Appendix 3) to local DNO within 30 days of commissioning.*

MV: **[2] ER G59/1, 6.4.3**

Some nuisance tripping found with undervolts caused by faults on adjacent feeders. Sometimes reported as problems with ROCOF settings. Usually overcome be negotiating special settings to meet individual situation, or a two stage undervolts where only a bigger dip takes the generator off.

TABLE 1 - Protective Equipment and Settings for LV Supply Arrangements

Protection	Phases	Trip Setting	Total* Tripping Time
Under Voltage	All	- 10% (phase-neutral)	0.5s
Over Voltage	All	+ 10% (phase-neutral)	0.5s
Under Frequency	One	- 6%	0.5s
Over Frequency	One	+ 1%	0.5s

* The total tripping time includes any integration or timing period of the protection relay as well as relay and circuit-breaker operating time.

- **Concern about future problem?**

LV: ***[1] ER G83/1, Appendix 1***

No – multiple installations are assessed by a pre-notification process under G83/1 as below, allowing the DNO to assess and control the effect on the network in advance.

MV: **[4] 2.3.2 Is there a future need for both fault ride through of aggregated DG and the intent of G59 to prevent unplanned islanding?**

The majority of respondents agreed that there would be a need for both fault ride

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Planned installation of multiple SSEGs in the same geographical area:

- *Installer submits Application pro-forma to local DNO (Appendix 2).*
- *DNO assesses impact of connection, and where necessary carries out network design.*
- *DNO confirms connection requirements with the Installer.*
- *Installer submits Application pro-forma to local DNO (Appendix 2).*
- *SSEG Installed and Commissioned in accordance with ER G83/1, DNO notified*
- *as required under ESQCR.*
- *Installer submits Commissioning pro-forma for each SSEG (Appendix 3) to the local DNO within 30 days of commissioning.*

</td><td colspan="2">

through capability and protection against unplanned islanding.

[4] DNOs
One respondent who agreed mentioned that while G59 allows for flexibility in the settings for protection that would facilitate fault ride through, it is often difficult to predict how local networks will behave under fault conditions due to the limitations of dynamic modelling capabilities Another acknowledged that FRT was becoming increasingly important to prevent system instability, while a third thought that more explicit beneficial guidance could be developed as experience is built up.

One DNO respondent who disagreed thought that FRT for generators under 50MW was impractical, and that G59 under voltage protection was essential to prevent some DG going unstable.

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<tr><td colspan="4">

- **Are current technical requirements adequate and sufficient?**

</td></tr>
<tr><td>LV:</td><td>Yes, G83/1 believed to be sufficient.</td><td>MV:</td><td>G59/1 is being updated to G59/2 to address some possible improvements to meet the current situation, including the consideration of 2 stage protection.</td></tr>
<tr><td colspan="4">

- **Opinion on active methods for islanding detection (network impedance measurement, frequency deviation, active/reactive power deviations,…)**

</td></tr>
<tr><td>LV:</td><td>

The test under G83/1 is a functional test which is non technology specific, so any method or combination of methods may be used as long as they do not disrupt the network as follows:

'…….Active methods which use impedance measuring techniques by drawing current pulses from, or injecting ac currents into, the DNO's system are not considered to be suitable.'

</td><td>MV:</td><td>Current methods seem adequate although 'centralised methods' have been considered under the Electricity Networks Strategy Group (ENSG) Distribution Working Group www.ensg.gov.uk as below.</td></tr>
</table>

<table>
<tr><th colspan="2">1.6 – ELECTROMAGNETIC COMPATIBILITY OF INVERTERS</th></tr>
<tr><td colspan="2">▪ Are current standards sufficient (↔ emmission limits and susceptibility for electrical equipment) ?</td></tr>
<tr><td>LV: Yes, no problems with current G83/1 inverters.
[1] ER G83/1, C4.8 Electromagnetic Compatibility (EMC)
All equipment shall comply with the generic EMC standards:
BS EN61000-6-3: 2001 Electromagnetic Compatibility, Generic Emission Standard
BS EN61000-6-1: 2001 Electromagnetic Compatibility, Generic Immunity Standard</td><td>MV:</td></tr>
<tr><td colspan="2">▪ Concern about mutual disturbance of large numbers of inverters (nuisance tripping, low voltage quality) ?</td></tr>
<tr><td>LV: No, not enough systems to be a concern at present
[4] 2.2.1 What are the key interaction issues when connecting multiple DG to a network?
DNOs
• Network Stability
• Managing Voltage Levels in real time
• Assessment of grouped output! management of power flows /constraints
• Voltage regulation and power flows in rural networks
• Fault levels in urban networks
• Appraisal of additional protection that may need to be considered to offset increased risk of islanding</td><td>MV: [4] 2.2.2 Should G59/75/83 be amended to allow for interaction of multiple DG?
DNOs
One respondent highlighted that G59 presumes no active network management and that the recommended methods for compliance could be modified for installations that were connecting to such networks. Another DNO respondent requested that additional guidance be provided within G59 on the protection requirements for multiple DG installations and particularly on the provision of retrospective additional protection requirements. Other DNO respondents thought that the current recommendations were sufficient to cover multiple DG installations.</td></tr>
<tr><th colspan="2">1.7 – EXTERNAL DISCONNECT</th></tr>
<tr><td colspan="2">▪ Opinion / interest on automatic switches enabling remote disconnect of PV-DG at high penetration levels</td></tr>
<tr><td>LV: Some, but quite far in the future – Control signal switching could be part of Active system. Current requirement is for switch inside</td><td>MV: Some DNOs currently specify ‘intertripping’. Current</td></tr>
</table>

building: *[1] G83 5.2* *….The SSEG shall be connected directly to an isolation switch where for single-phase machines the phase and neutral are isolated and for multi-phase machines all phases and neutral are isolated. In each instance the manual isolation switch shall be capable of being secured in the 'off' (isolated) position; this switch is to be located in an accesible position within the Customer's installation.*	requirement under G59/1 is: ***[2] G59/1, 6.2.5** Points of Interconnection and Means of Isolation* *Every installation or network which includes an embedded generating plant operating in parallel with the REC's supply, must include a means of isolation (suitably labelled) capable of disconnecting the whole of the embedded generating plant infeed from the REC's network.* *This means of isolation must be lockable, in the open position only, by a separate padlock. Access to the points of isolation should be kept clear and unobstructed.* **[4] 2.1.9.4 Points of Isolation** Four respondents reported difficulties with one reporting that it had not been possible to agree on a suitable point of isolation prior to or during the G59 witness test. Another respondent called for a standardized approach to agreeing suitable point(s) of isolation.
1.8 –RECLOSING	
▪ **Description of protocols used by the Distribution company**	
LV: Inverters must not be damaged by reclosing: *5.3.3 Automatic Reconnection* *Some distribution Networks employ automatic circuit breakers that trip and re-close when a fault is detected. In order to prevent a SSEG being damaged by a DNO circuit breaker automatically closing onto the SSEG when it is out of synchronism with the rest of the Network, the protection system shall ensure that the SSEG remains disconnected from the DNO's distribution Network until the voltage and frequency on the DNO's Network have remained*	MV: Synchronous generators adequately covered as well.

within the limits of Table 1 for a minimum of 3 minutes.	
1.9– DC-CURRENT & TRANSFORMERLESS INVERTERS	
▪ **Have (adverse) effects of DC-current injection been observed?**	
LV: Historically there has been evidence of long term degradation in cables caused by DC, but it is unusual for detailed measurements of this to be taken on a network. Also it is very difficult to isolate any possible effects of DC from PV from other sources. There is also the issue of what constitutes DC - slowly oscillating AC, and if so how low a frequency does it have to be?. Also if there can be a cancelling effect from multiple inverters. A report was produced to assess the 20mA limit in G83/1 and it was found to be adequate. However this is being reviewed in the 'EN' Technical committee at present which is considering an equivalent European version of G83/1. **[1] G83/1, C4.4** DC Injection The level of dc injection from the inverter-connected PV generator in to the DNO network shall not exceed 20mA when measured during tests C3.2, C3.3, C3.4 and C4.2. This condition is satisfied by installation of a transformer on the ac side of the inverter-connected PV generator.	MV: Ditto
▪ **Have tranformerless inverters shown "noticeable" differences from inverters comprising a transformer?**	
LV: There are no transformerless inverters which have G83/1 approval at present, so no data available.	MV: Ditto
1.10 - PENETRATION LIMITS FOR PV-DG	
▪ **Define limits in relation to the network / transformer capacity**	
LV: No limits as such are stated. However, for 'multiple systems' the DNO can perform network studies on a case-by-case basis.	MV:

One report estimated up to 30% of houses for a 1kWp system size.	
▪ **Are/should penetration limits be different in urban and rural grids?**	
Experience has been that up to 6kWp is generally OK on a rural network, but that if increased to 10kWp voltage rise problems can occur.	
1.11 – PLANNING, OPERATION AND MAINTENANCE OF DISTRIBUTION GRIDS IN RELATION TO PV-DG	
▪ **Is PV-DG currently considered in planning?**	
LV: No. Too small a number to be significant at present.	MV: Ditto
▪ **Are new tools needed?**	
LV: Yes. The existing LV programmes are now being modified to include for generation.	MV: No – already include for generation.
▪ **Potential interest for including PV-DG into load dispatching?** **Are new tools needed?**	
LV: No, not enough at present to consider.	MV: Ditto
▪ **Does PV-DG imply different/new requirements for network operation?**	
LV: Not at moment – but theoretically could lead to 'active networks'	MV: Ditto
▪ **Procedure used for disabling PV-DG for network maintenance work**	
LV: Relies on inverter protection & assuming 'live working'	MV: **[4] 2.1.9.5 Operational & Safety Aspects** Only three respondents reported difficulties here, with one highlighting that the European HV safety procedures were not as stringent as those in the UK. Another outlined an operational difficulty where a generator is embedded within a clients site with some DNOs insisting on disconnection of the entire site when power is exported from that site onto the network, rather than just

	to disconnect the embedded generator thus leaving the on-site demand energised. It is known that in similar instances, the disconnection of the site is only initiated if the DG zone continues to export.

2 – GENERAL ASSESSMENT OF PHOTOVOLTAIC DISTRIBUTED GENERATION	
2.1 – EXPERIENCE WITH PV-DG	
▪ **General experience**	
LV: 2-3 systems added per week. Procedures seem adequate for this level.	MV:
▪ **Are the PV plants where regular measurements are done?**	
LV: No not in this DNO area.	MV:
▪ **Incidents with PV-DG over the last 10 years**	
LV: None. A few inverter trips were caused in the past by high ambient levels of voltage on the network tripping the inverter on the old overvolts setting which was lower than currently used in G83/1.	MV:
2.2 – APPLICABLE STANDARDS / NEW REGULATION REQUIREMENTS	
▪ **Standards and guidelines used for admission of PV-DG**	
LV: **[1] Engineering Recommendation G83/1**, 'Recommendations for the connection of Small-scale Embedded Generators (up to 16A per phase) in parallel with Public Low-voltage distribution networks', Sept 2003	MV: **[2] Engineering Recommendation G59/1**, 'Recommendations for the connection of Embedded Generation Plant to the Regional Electricity Companies' Distribution Systems'

▪ **Are current standards for PV-DG sufficient?**	
LV: **[4]** 3.2 G83 specific conclusions Generally it was felt that the application of G83 was about right and that the 16A / phase level was adequate as long as the current flexibility remained to apply G83 requirements beyond this level where the DNO deemed it appropriate. **[3]** There is a broad consensus that the procedures in Engineering Recommendations G59 and G83 are functional and do not need significant revision.	MV: **[3]** There is a broad consensus that the procedures in Engineering Recommendations G59 and G83 are functional and do not need significant revision.
▪ **Issues at present not covered by standard, which should be included**	
LV: **[4] 3.2 G83 specific conclusions (cont)** • A further example of flexibility would be the type approval of interface equipment to G83 requirements beyond the current 16A/ phase levels where appropriate, to simplify the commissioning tests (and avoid the hire of expensive specialist test equipment). • It was recognised that the DNO's need to be notified about the connection and disconnection of SSEG on their networks for reasons of managing network safety and planning. The following issues about the DNO notification process were identified: o That it was generally considered that the notification details format incorporated in G83 was adequate o That there were suspicions that a number of SSEG systems were connected to UK DNO networks without notification o That the notification requirement of 30 days subsequent to commissioning the SSEG, identified in G83, was considered to be	MV: **[4] 4.3 G59 specific recommendations** • An alternative approach to specifying approved test equipment could be for the use of type-approved protective devices that are pre-tested and certified before being shipped by the manufacturer and incorporate a self-test capability for confirmation of integrity on installation. • Any review of G59 should consider the most cost-effective and practical means of providing protection against unintentional islanding It will be appropriate for this review to consider the likely impacts of active network management, particularly with regard to enhanced communication systems likely to be in place between the DG facility and the network source substation • The development of an effective LoM protective device be promoted to improve the non-spurious detection of true LoM events and trip the generation only in

preferable to the requirements stated in ESQCR of "... before, or at the time of, commissioning the source." **[3]** Some developers – particularly those whose product falls outside the G83 parameters – would like to see the 16A level raised to make connection easier for them to manage; DNOs are generally not keen to accept this change.	the event of islanded operation whilst also meeting Grid Code resilience requirements for FRT. • The exclusion of generation rated <150kVA from requiring LoM protection should be withdrawn. (This will remove the anomaly/ conflict with G83). • However, LoM protection may be omitted where local network topology means that voltage/frequency protection trip settings would be sufficient to disconnect the generator in the event of a loss of mains type fault, for example where minimum local load significantly exceeds local generation.

2.3 – OTHER ISSUES

- **Any research/development needs identified?**

The DWG has identified the following in its work programme. Not all are specifically in response to PV DG, but more normally from all technologies:

Electricity Networks Strategy Group (ENSG) - Distribution Working Group (www.ensg.gov.uk)

The Distributed Working Group (DWG) continues the work of the earlier Distributed Generation Coordinating Group's (DGCG) Technical Steering Group (TSG), examining the issues to enable the integration of generation onto the distribution network. The DWG manages four Work Programme areas given below:

Work Programme 01: Horizon Scanning

To assess the current state of technology, likely developments, R&D progress, actual and forecast trends in penetration levels and future scenarios, regulatory and political policy to guide and formulate the programmes of work:

Project One: Long Range Scenarios for UK Power Systems
Project Two: Network Architectures to progress towards possible Scenarios for UK Power Systems
Project Three: Network Architectures – definition of future projects for WPs 02/03/04

Project Four: Existing and New Technologies and Infrastructures for the Future Networks Monitoring, Protection and Control (Sensing, Intelligence and
Project Five: Impact of Standards and Migration Planning
Project Six: International Activities on Future Electricity Networks
Project Seven: Stakeholder Liaison

Work Programme 02: Network Design for a Low-Carbon Economy
To evaluate the technology, tools, techniques, processes and standards that would be required to construct power systems, compatible with the developing trends in low-carbon energy technology:

Project One: Review of International / European Network Design Standards, Practices and Plant & Equipment Specifications
Project Two: Identification of current and pending European / UK legislation as a factor in Network Design
Project Three: Corporate & Social Responsibility – Identification of Value Toolkit
Project Four: Network Renewal Synergies
Project Five: Network Security Standards
Project Six: Automation to optimise network configuration in real time – to optimise DG contribution and reduce losses
Project Seven: Sensitivity of DNO HV Networks to Harmonic Capacity Reduction associated with Significant Underground Cable Extensions and Power Factor
Project Eight: Development and Application of Dynamic Equipment Ratings
Project Nine: Application of Fault Current Limiters

Work Programme 03: Enabling Active Network Management
Developing the technologies, protocols, tools, processes, techniques and standards that would be needed to ensure that low-carbon compliant power systems could be operated on an active basis to ensure efficient use of investment and an effective contribution from potential market participants.:

Project One: Programme Outline & Definitions
Project Two: Active Network Management Case Studies
Project Three: Review and Assessment of ANM infrastructures and practices
Project Four: Active Management Pilots, Trials, Research, Development and Demonstration Monitoring
Project Five: Active Network Management – Addressing current and emerging commercial, legislative and regulatory barriers
Project Six: Current Technology Issues & Identification of Technical Opportunities for Active Network Management (ANM)
Project Seven: Functional & Data Requirements
Project Eight: Good Practice Guide

Work Programme 04: Facilitating Small-Scale Generation
Continuing the focus on developing those solutions which would be needed to enable 'non-expert' users (such as home-owners) to take

maximum advantage of emerging small-scale generation technology, so bringing maximum contribution from this part of the sector to the government's low carbon targets.

Project One: Connection Terms
Project Two: Scheme to reward microgenerators exporting excess electricity
Project Four: Accrual of ROCs, LECs & REGOs Phase 3 a – model for annual averages
Project Six: Develop Cenelec standard prEN50438: Requirements for the connection of micro-generators in parallel with public low-voltage distribution
Project Seven: Wiring Regulations
Project Nine: Accreditation of Micro-cogeneration

REFERENCES

[1] **Engineering Recommendation G83/1,** 'Recommendations for the connection of Small-scale Embedded Generators (up to 16A per phase) in parallel with Public Low-voltage distribution networks', Sept 2003

[2] **Engineering Recommendation G59/1,** 'Recommendations for the connection of Embedded Generation Plant to the Regional Electricity Companies' Distribution Systems'

[3] **Small Generator Connection Survey:** DTI Report DG/DTI/00064/00/00, URN 06/879, 2006

[4] **Banding of Connection Standards for Distributed Generation:** DTI Report DG/DTI/00061/00/00, URN 06/647