IEA INTERNATIONAL ENERGY AGENCY

PV system installation and grid-interconnection guideline in selected IEA countries

Task V
Report IEA-PVPS T5-04: 2001
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PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA PVPS

International Energy Agency
Implementing Agreement on Photovoltaic Power Systems

Task V

Grid Interconnection of Building Integrated
and Other Dispersed Photovoltaic Power Systems

Report IEA PVPS T5-04:2001

PV System Installation and Grid-Interconnection Guidelines in Selected IEA countries

November 2001

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R&D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents.
Currently activities are underway in seven Tasks.

The 21 members are: Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR), and The United States (USA).

Task V of the PVPS programme, active since 1993, focuses on the technical aspects of grid interconnection of building integrated and other dispersed photovoltaic power systems. Experts from twelve participating countries are sharing their experiences in this area. Task V participating countries are: Australia, Austria, Denmark, Germany, Italy, Japan, Mexico, the Netherlands, Portugal, Switzerland, the United Kingdom and the United States.

This report is intended for a wide use for utilities, manufactures, PV installers and standard making bodies to increase the knowledge of international trends of PV system installation and grid interconnection guidelines and standards. It has been prepared under the supervision of PVPS Task V by:

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Abstract

This report is the second of its kind issued by Task V of the IEA Implementing Agreement on Photovoltaic Power Systems. (The first report, entiteled: GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEMS : STATUS OF EXISTING GUIDELINES AND REGULATIONS IN SELECTED IEA MEMBER COUNTRIES, appeared as Task V Internal Report IEA-PVPS V-1-03 in March 1998).

Its purpose is to give an overview of the national standards and guidelines governing the erection, installation and operation of small grid-connected PV systems in various IEA member countries. Detailed information is given about the situation in Australia, Austria, Denmark, Germany, Italy, Japan, Mexico, The Netherlands, Portugal, Switzerland, United Kingdom and the USA.

At the time of the first Report (March 1998) only very few countries had PV-specific standards. Fortunately, this situation has changed considerably. For almost all countries a special standard for small grid-connected PV systems is quoted in this Report, together with the information where this standard can be obtained.

On the technical side the following aspects have been investigated:

Regulations on the DC side:

- Modules
- Quality of cabling
- String diodes, string fuses, DC junction box
- DC disconnecting switch

Regulations for Inverter

- Power quality (current harmonics, DC current injection, power factor)
- EMC requirements (Emission and Immunity)
- Required waiting times for connection to the grid
- Operating windows for voltage and frequency
- Required anti-islanding measures or tests

Regulations for the AC Installation

- Necessity of an externally accessible disconnect switch
- Connection point to the public AC grid

System design regulations

- Maximum allowable DC voltage
- Requirements concerning earthing, earth fault protection
- Protection against electric shock
- Necessity of warning signs

Due to the technical progress special chapters have been added dealing with transformerless inverters and AC modules. Final chapters about the general authorisation process and the legal situation of PV systems conclude the Report.

Keywords

Grid-connected PV system; Standard; Guideline; Inverter; DC injection; Power Factor; EMC; Islanding; Islanding protection; Grounding; Ground fault; AC Module

Introduction

The world production of photovoltaic modules has reached more than 200 MWp in 2000, reflecting an annual growth rate of more than 20% for the past few years. The distribution of systems into which these modules were incorporated has changed considerably: while a few years ago most of them were installed in rather small stand-alone systems, the majority of today´s modules is used in grid-connected systems. This growth is mostly due to ambitious subsidy programs in two countries: Japan and Germany, where more than 100 MW were installed in 2000. Several other countries are implementing or close to implementing similar programs to promote grid-connected systems. Among them are Australia, Italy, Spain, The Netherlands and the UK.

A necessary requirement for such national programs is a well-defined and accepted technical standard. Fortunately, a great deal of progress has been achieved since the publication of the first guidelines survey by Task V of the IEA Implementing Agreement on PV Power Systems (March 1998). A few years ago only a minority of countries had PV-specific standards, but today most countries that are looking to implement PV systems have now developed guidelines for the grid inter-connection of PV inverter systems. PV systems using static inverters are technically different from rotating generators and this fact has been generally recognised in these new guidelines. Consequently, the requirements for the grid interface of such systems have been specified in such a way to provide a safe and electrically reliable connection to the public grid whilst mostly avoiding costly and unsuitable technical regulations previously developed for systems with large rotating generators.

This Report presents the current standards and guidelines for system installation and grid-interconnection of PV systems in the following IEA countries: Australia, Austria, Denmark, Germany, Italy, Japan, Mexico, The Netherlands, Portugal, Switzerland, United Kingdom and the USA. It covers electrical requirements on the DC side of the installation (modules, wiring, DC junction boxes, earthing and earth fault protection, DC disconnect switch) as well as requirements for the inverter (EMC, harmonics,

power quality) up to the interface to the public grid (external disconnect switch, overcurrent protection, islanding prevention).
Whilst it is evident that most countries now have specific PV standards, it can be seen that these standards still differ from country to country. Therefore, the next step is to harmonise the national standards as far as possible. Activities at the IEC level have been started to work in this direction. The main focal point is IEC TC 82, Working Groups WG 3 and WG 6. The output of the work from Task V to IEC TC 82 has been essential for some of the present activities in these groups, and several members of Task V are also working as IEC experts. At the same time it is clear that due to differing technical boundary conditions in different countries (earthing philosophy, layout of the grid, etc.) it will be very difficult to achieve total harmonisation.

Nevertheless, it seems possible to reach a consensus in at least 90% of all topics, therefore paving the way for easier progress of grid-connected PV worldwide. As the non-technical barriers to PV are often hidden behind technical arguments, a clear, safe and accepted technical basis is of utmost importance for the future success of photovoltaics. International co-operation, such as that exemplified by the Task V working group, can greatly accelerate the convergence of standards; one lesson learnt from this work is therefore that information exchange between different countries should be encouraged at every possible level.

Australia

COUNTRY	Australia
Person filling in this questionnaire	Phil Gates

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	Australian Guidelines for grid connection of energy systems via inverters Discussion papers for PV DC issues.
Adress where copies of the standard can be obtained	Available at the following website: http://ee.unsw.edu.au/~std_mon/html_pages/inverter_passed.html
Date of last change	June 1999
Topics covered by guideline/standard	Inverter systems requirements, grid connection requirements
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	AS 2915 – 1987 Solar Photovoltaic modules performance requirements
Energy sources covered by this standard	All energy sources that are connected to the electricity system via inverters
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	Yes The guidelines are in the process of becoming a standard. An expected date is by the end of 2000 PV DC issues to become a standard.
FRAMEWORK OF STANDARD	Same framework as guidelines
Power range of individual systems covered by standard	0-10kVA phase to neutral 0-30kVA 3 phase larger systems can be connected and the same general principles of the guidelines will apply. The size of the system may be constrained depending on the capability of the electricity supply network at the point of connection.
Interconnection voltage mentioned in standard	Low voltage grid nominally 240 volts phasse to neutral and 415 volts phase to phase
Limitation of max. PV generator power according to standard	Without specific approval the maximum power is limited to the power ranges above. If grid conditions permit, larger systems may be connected to the low voltage grid with the approval of the local utility.
Procedure for connection of larger PV systems to the grid	Request at local utility, which then determines if grid is suitable for suggested power. Utility may require special protection equipment

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	Not specified
cables (one cable with two conductors / two independent cables, quality insulation strength	The cables and wiring must comply with all appropriate local and Australian standards including but not limited to A3000 for all wiring and AS 3100 for equipment. DC cabling specifications not mandated but generally use the above standards
String diodes (necessity, location, current rating,	Not specified in current guidelines but included in draft „PV DC side System Issues“ documentation where voltage and current ratings, features, placement and failure rates may be specified.
DC fuses (necessity, location	DC side protection is under discussion
Junction box	Not specified, under discussion
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Not specified, under discussion Normal practice has been to include a suitably rated DC isolation device unless using string or module inverters.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Not specified, under discussion Normally overvoltage protection devices have to be installed directly at inverter terminals if required by the inverter manufacturer.

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	Australian grid connect guidelines as extracted form IEEE Draft P929 No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	High Frequency noise: equipment must conform to Australian Communications Authority „Electromagnetic Compatibility framework“
EMC: limits regarding radiated emissions	High Frequency noise: equipment must conform to Australian Communications Authority „Electromagnetic Compatibility framework“
EMC: limits regarding immunity	High Frequency noise: equipment must conform to Australian Communications Authority „Electromagnetic Compatibility framework“
Requirements regarding power factor	0.8 leading to 0.95 lagging
Limits for DC injection into AC grid	DC current not to exceed 5mA. Guidance form AS3300 50 Hz transformer interface between DC and AC preferred transformerless inverters must have DC injection detection device
Requirements regarding flicker	Must conform to AS 2279 part 4 section 6
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	Inverter energy systems must be connected to a dedicated circuit eminating from a switchboard. Lockable switches are to be located on the switchboard.

Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Disconnect from grid and remain isolated for a period of 1 minute after the grid is within voltage and frequency limits.
Behaviour at startup or at restart after automatic disconnection	Inverter must check grid voltage and frequency for allowable values. Only after all parameters are within the limits re-connection to the grid may occur. 1 minute waiting time is specified in the guidelines
TRANSFORMERLESS INVERTERS	Allowable
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the standard
Limits regarding high-frequency capacitive leakage currents	High Frequency noise: equipment must conform to Australian Communications Authority „Electromagnetic Compatibility framework“
Other safety requirements (yes /no; if yes, specify	AS 3100 „approval and test specification – General requirements for household and similar electrical appliances“

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Protection may be either internal to the inverter (preferred) or an independent device installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	Over Voltage Under Voltage Over frequency Under Fequency At least one active methods of detecting AC disruptions
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Australian Guidelines for grid connection of energy systems via inverters Section 4.7 Maximum operating time: 2 seconds
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Australian Guidelines for grid connection of energy systems via inverters. Section 4.7 Maximum operating time: 2 seconds
External accessible disconnecting switch for utility (mandatory / not necessary)	Not necessary
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Australian Guidelines for grid connection of energy systems via inverters Section 4.9. 1 minute after grid within tollerances
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Australian Guidelines for grid connection of energy systems via inverters. Appendix B
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	Not specified.

SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	No explicit limit
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Not specified, under discussion
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Not specified, under discussion
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not specified, under discussion
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	Not specified, under discussion
Protection against electric shock on AC side	AS 3100 „approval and test specification – General requirements for household and similar electrical appliances“
Cabling layout (Cabling layout design rules e.g. for lightning protection)	No
Special requirements concerning mechanical fixing / mechanical protection of cables	No
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	Australian Guidelines for grid connection of energy systems via inverters Section 5.2
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Not specified on AC side. Remains the responsibility of the inverter manufacturer to adequately protect has equipment. DC side under discussion
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Warning labels on AC side as per Australian Guidelines for grid connection of energy systems via inverters Appendix A
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned; in practice several measures on the DC side are not necessary (e.g. disconnecting switch, overvoltage protection on the DC side)

AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Installations are authorised by the local eletricity utility. Usually required: - a copy of inverter conformance certificates - a licenced electrician to connect the PV system to the grid Commissioning tests include visual inspection and tests of the anti-islanding measures
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are not obliged to buy electricity produced by PV systems Tariffs paid for electricity fed into the grid vary with Utility.
FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

Austria

COUNTRY	Austria
Person filling in this questionnaire	Christoph Panhuber

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	ÖVE/Önorm E 2750 "Photovoltaische Energieerzeugungsanlagen – Sicherheitsanforderungen ("Photovoltaic power generating systems – safety requirements")
Adress where copies of the standard can be obtained	
Date of last change	1999-04-01
Topics covered by standard	PV systems – both stand alone and grid connected
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	- - - -
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	No actual limit is specified. The standard only deals with interconnection to the low voltage grid, so that the maximum size of PV systems is limited by local grid capacity.
Interconnection voltage mentioned in standard	Low voltage grid only
Limitation of max. PV generator power according to standard	Without specific approval the maximum power is limited to 5kWp DC (4.6kVA) per phase for small installations. If grid conditions permit, larger systems may be connected to the low voltage grid with the approval of the local utility.
Procedure for connection of larger PV systems to the grid	Request at local utility, which then determines if grid is suitable for suggested power. Utility may require special protection equipment

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required	Some requirements for mechanical stability (ÖVE EN 61215)
cables (one cable with two conductors / two independent cables,	Not explicitly specified. In Austria it is common practice to use two independent DC cables from the PV generator to the inverter. Each cable is in

quality insulation strength	isolation class II (double insulation) Cables have to be selected according to local environmental conditions. Special care has to be taken to use UV resistant cables with high mechanical strength
String diodes (necessity, location, current rating,	String diodes are not necessary for installations with only one string. When more strings are connected in parallel, string diodes may be omitted if - only modules of the same type are used - modules are of protection class II type - manufacturer certifies that modules can withstand 50% of the module short circuit current in the direction opposite to normal current flow
DC fuses (necessity, location	DC fuses are not necessary for installations with only one string. If more strings are connected in parallel then - each string has to be protected by fuses - OR each string must be able to carry the total maximal short circuit of the generator
Junction box	Must be isolation class II
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Mandatory. DC circuit breaker must be capable of being operated under load, i.e. must be able to switch DC short circuit current of PV generator. Exception: not required for AC modules
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Overvoltage protection devices have to be installed directly at inverter terminals if required by the inverter manufacturer. Otherwise not required

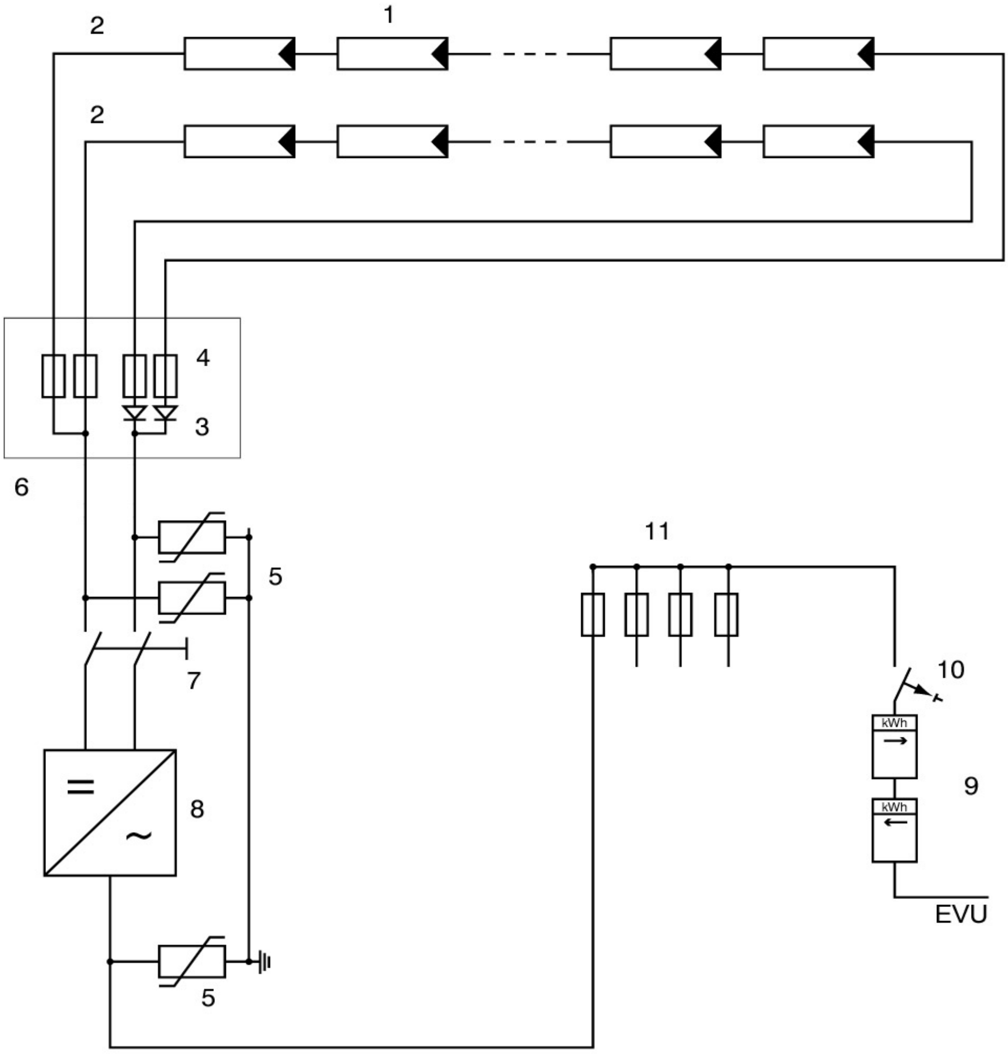
INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter: EN 61000-3-2 No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	EN 50081-1
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	Not mentioned in the standard Usually requirement by local utility that power factor is > 0.9
Limits for DC injection into AC grid	DC injection detection device with inverter disable is required for transformerless inverters. No absolute limit for maximum allowable DC current level is given in the standard
Requirements regarding flicker	Not mentioned in the standard
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	Not required for single phase inverters feeding into a three phase grid
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	not specified in the standard

Behaviour at startup or at restart after automatic disconnection	Inverter must check grid voltage, frequency and impedance for allowable values. Only after all parameters are within the limits re-connection to the grid may occur. No waiting time is specified in the standard; however, all utilities require a waiting period of 10 seconds or more
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the standard
Limits regarding high-frequency capacitive leakage currents	Not mentioned in the standard
Other safety requirements (yes /no; if yes, specify	Only DC injection is adressed, see above

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Protection may be either internal to the inverter or an independent device installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	Two methods are accepted: 1) ENS (impedance measurement method): if grid impedance is > 1,75Ω OR grid impedance jump > 0,5Ω is detected then inverter must disconnect within 5 seconds. Voltage and frequency limits see below. 2) In case of single phase inverter feeding into a three-phase grid: measurement of phase-to-phase voltages (400V) and shutdown in case of undervoltage (any phase-to-phase voltage below 80% of nominal) AND measurement of phase-to-neutral voltage with shutdown in case of overvoltage (> 110% of nominal) Remark: in practice all new PV installations use the ENS; method 2) is only found in older systems
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	according to standard if ENS is used: 230V +10%/-20% Many utilities usually have a narrower allowable voltage range (e.g. a common value is 230V +6%/-15%) Reaction time: 0,2 seconds Some utilities prefer field-adjustable trip points, it is however required that the values cannot be changed by the user
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Not specified if no ENS (impedance measurement system) is used. In combination with an ENS frequency range is 50Hz +/- 0,2Hz Reaction time: 0,2 seconds Frequency limits are not field-adjustable
External accessible disconnecting switch for utility (mandatory / not necessary)	Only mandatory for three-phase inverters feeding into the grid. As three-phase inverters are hardly uses this is not of great importance
Minimum startup time after disconnection from the grid (waiting time after normal grid	Not specified in the standard. Utilities usually require 10-20 seconds.

conditions have been restored)	
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	The ENS (impedance measurement) test method is nationally accepted.
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	Berufsgenossenschaft für Feinmechanik und Elektrotechnik, Cologne, Germany Bundesforschungs- und Prüfzentrum Arsenal, Vienna, Austria
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	Not explicitly limited; as the standard refers to ÖVE EN1 this means that in theory 1000V are the upper limit
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	If DC voltage is < 120V (Safety Extra Low Voltage) then grounding on the DC side is forbidden If DC voltage is > 120V it is still recommended to keep DC side ungrounded
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	A ground fault detection device is recommended; otherwise periodic ground fault measurements have to be performed
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not required
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	DC voltage < 120V: no special measures required (grounding on DC side is forbidden!) DC voltage > 120V: - use of solar modules with protection class II and consequent use of class II equipment for the DC side (cables, switches, junction box, etc) - mounting of solar modules in an area inaccessible for an electrotechnical layman; for the rest of the DC side consequent use of class II equipment
Protection against electric shock on AC side	No additional measures on top of the already implemented safety measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	No
Special requirements concerning mechanical fixing / mechanical protection of cables	No
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	May be connected to any existing branch if equipped with ENS (impedance measurement)
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	If the building is equipped with a lightning protection system the mounting structure of the PV generator must be connected to it. Otherwise all exposed dead metal parts of the PV system (mounting structures, frames etc.) have to be connected to the main equipotential conductor On the DC side class C overvoltage protection devices have to be installed between each DC conductor and ground. On the AC side overvoltage protection devices (phase to

	ground) are recommended, but not mandatory. Remark: in practice it turned out that the danger coming from the AC side is much greater.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Fuses and switches on the DC side which must not be removed/operated under load must be marked accordingly
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned; in practice several measures on the DC side are not necessary (e.g. disconnecting switch, overvoltage protection on the DC side)
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Installations are authorised by the local eletric utility. Usually required: - a copy of the declaration of CE conformity of the inverter - a copy of the type-testing of the built-in anti-islanding measure ENS Only a licenced electrician may connect the PV system to the grid Commissioning tests include visual inspection and tests of the anti-islanding measures
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems Tariffs paid for electricity fed into the grid vary locally; a recent change in law has generally raised the rates in most parts of Austria Rates are between 0,04 and 0,55 Euro / kWh.
FURTHER LITERATURE NORMATIVE REFERENCE	Technische Richtlinien für den Parallelbetrieb von Erzeugungsanlagen mit dem Mittel- oder Niederspannungsnetz eines Verteilnetzbetreibers ("Technical Guidelines for the parallel operation of generation systems with the medium or low-voltage grid of an electric distribution utility")
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	See next page



1 PV module
2 Strings
3 String diode (usually not necessary)
4 String fuse (usually not necessary)
5 Overvoltage protectors
6 junction box (not necessary in case of string inverter)
7 DC disconnect switch
8 inverter with integrated anti-islanding measure (e.g. ENS)
9 separate electricity meters for consumption and energy fed into the grid
10 RCD (residual current device) - mandatory in any household
11 individual branches with overcurrent protection

Denmark

COUNTRY	Denmark
Person filling in this questionnaire	Bertel Jensen

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	In this moment we do not have a PV specific standard i Denmark. We are working with it and expect to have one ready in the middle off 2000. The standard will be based on the IEC draft 60364-7-712 and ours experience during the last 5 years off work with PV systems. The following answers are based on how I believe the standard will be.
Adress where copies of the standard can be obtained	
Date of last change	---
Topics covered by standard	PV systems – only grid connected
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	- - - -
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	No actual limit is specified. The standard only deals with interconnection to the low voltage grid, so that the maximum size of PV systems is limited by local grid capacity.
Interconnection voltage mentioned in standard	Low voltage grid only
Limitation of max. PV generator power according to standard	-----
Procedure for connection of larger PV systems to the grid	Request at local utility, which then determines if grid is suitable for suggested power.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required	Some requirements for mechanical stability, according to IEC 1215
cables (one cable with two conductors / two	According to IEC 60364-7-712 In Denmark it is common practice to use reinforced cables

independent cables, quality insulation strength	with two conductors, but wee also use independent cables.
String diodes (necessity, location, current rating,	According to IEC 60364-7-712
DC fuses (necessity, location	According to IEC 60364-7-712
Junction box	According to IEC 60364-7-712
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Mandatory. DC circuit breaker must be capable of being operated under load, i.e. must be able to switch DC short circuit current of PV generator. Exception: not required for AC modules
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Overvoltage protection devices have to be installed directly at inverter terminals if required by the inverter manufacturer. Otherwise not required

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter: EN 61000-3-2 No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	EN 50081-1
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	----
Limits for DC injection into AC grid	---
Requirements regarding flicker	----
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	According to IEC 60364-7-712
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	According to IEC 60364-7-712
Behaviour at startup or at restart after automatic disconnection	Not determined yet.
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not determined yet.
Limits regarding high-frequency capacitive leakage currents	Not determined yet.
Other safety requirements (yes /no; if yes, specify	Not determined yet.

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	UP to now we only have used protection there is internal to the inverter.
Required islanding detection methods (active / passive methods required by standard or electric utilities	Not determined yet. UP to now we have used inverters with detection according to the ENS system, but also inverters there are tested according to the Dutch K150 standard. We feel that the impedance measurement method Are too sensitive and give too many problems according to the desired security.
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Not determined yet, but it will presumably be: 230V +10%/-20% Many utilities usually have a narrower allowable voltage range (e.g. a common value is 230V +6%/-15%) Reaction time: 0,2 seconds Some utilities prefer field-adjustable trip points, it is however required that the values cannot be changed by the user
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Not determined yet, but it will presumably be: 50Hz +/- 0,2Hz Reaction time: 0,2 seconds
External accessible disconnecting switch for utility (mandatory / not necessary)	not necessary
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Not determined yet, but it will presumably be 10-20 seconds.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Not determined yet
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	1000V are the upper limit
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	According to IEC 60364-7-712 but not recommended
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Not determined yet, but it will presumably be in according with the size of the PV-system
automatic PV array disable in case of	Not required

ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	According to IEC 60364-7-712
Protection against electric shock on AC side	No additional measures on top of the already implemented safety measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	No
Special requirements concerning mechanical fixing / mechanical protection of cables	No
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	dedicated branch for PV inverter
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	If the building is equipped with a lightning protection system the mounting structure of the PV generator must be connected to it. Otherwise all exposed dead metal parts of the PV system (mounting structures, frames etc.) have to be connected to the main equipotential conductor On the DC side class C overvoltage protection devices have to be installed between each DC conductor and ground. On the AC side overvoltage protection devices (phase to ground) are recommended, but not mandatory. Remark: in practice it turned out that the danger coming from the AC side is much greater.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Fuses and switches on the DC side which must not be removed/operated under load must be marked accordingly
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned; in practice several measures on the DC side are not necessary (e.g. disconnecting switch, overvoltage protection on the DC side)
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	The installers had to be authorized according to the Danish laws.

LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems Experimentally in a 4-year period, it is decided that normal households may use meters there can run i in booth directions. I means that they buy and sell electricity to the same price. Over one year there may not be a negative consumption. Companies and similar had to use separate meter for energy fed into the grid. (sorry I don't now the price)
FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	Sorry, they are nor ready yet.

Germany

Specifically for small, dispersed, grid-connected PV-systems a new section to the basic electric safety code, the VDE 0100, has been drafted, the "VDE 0100 Teil 712, Photovoltaikanlagen". This new 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.

A second set of PV specific rules has been fixed in the draft standard DIN VDE 0126. This concerns mainly a safety interface for islanding prevention. Technical specifications and test requirements are given. The standard now also includes requirements for transformerless inverters, as well as additional safety requirements. This standard has been temporarily empowered for product acceptance test in 1999.

A third collection of rules is issued as a general guideline by the VdEW, the Association of Electric Power Companies. It does not bear a direct legal binding, however, it is usually included in the contractual agreement between an utility and an independent producer. This guideline, "Guidelines for the operation of private production systems parallel to the low voltage public grid", last updated 2000, does specifically include PV-systems.
It should be noted, however, that there are some 600 grid operators in Germany, which are essentially free to set their own requirements. Thus, local practises may vary significantly.

COUNTRY	Germany
Person filling in this questionnaire	Hermann Laukamp / Thomas Erge

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems	DIN VDE 0100 Teil 712, Photovoltaische Systeme; draft This standard is the German version of the international draft standard IEC 60364 -7- 712 CDV, ELECTRICAL INSTALLATIONS OF BUILDINGS -Part 7 : Requirements for special installations or locations -Section 712 : Photovoltaic power supply systems, Draft 64/WG9/218, IEC TC 64, Geneve, 1999
Date of last change	1998, German version; 2000, IEC version The standard is still under development at IEC TC 64. There will be no more work on the German version.
Topics covered by standard	PV systems –grid connected, erection and requirements for components
Source	Beuth Verlag GmbH D - 10772 Berlin fon: +49 30 26 01 27 59 fax: +49 30 26 01 12 63 E-mail: postmaster@beuth.de
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -

Is any change in the standard forseeable? If yes, please give an approximate date for new standard	The standard is still under development at IEC TC 64. After completion of this work, the German version will be adapted. Date: possibly in 2002.
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	No general limit for power generation capacity; up to 4.6 kVA (inverter) or 5 kWp (PV generator) single phase connection is permitted (VdEW Guideline). Above 5 kWp three-phase connection is requested. All systems need approval by local grid operator [1].
Interconnection voltage mentioned in standard	Guidelines only for low voltage grid –400 V
Limitation of max. PV generator power according to standard	see above
Procedure for connection of larger PV systems to the grid	Request at local grid operator, which then determines, if the local grid is suitable for the suggested nominal power. Grid operator may require special protection equipment

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	PV modules shall comply with the requirements of the relevant equipment standard e.g. IEC 61215 for crystalline PV modules. It is recommended to use preferably PV modules of class II or equivalent insulation. (DIN VDE 0100 Teil 712)
cables (one cable with two conductors / two independent cables, quality insulation strength	not explicitly specified, It is required that the risk of an earth fault or a short-circuit be at a minimum. This may be achieved for example by use of single core sheathed cables. (DIN VDE Teil 712) fire regulations for parts and houses have to be observed (e.g. DIN 4102)
String diodes (necessity, location, current rating,	not required
DC fuses (necessity, location	not required; necessary only, when a prospective fault current exceeds the rated current of the string conductor and modules are not of class II.
Junction box	Not regulated; protection class II recommended
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Mandatory. DC circuit breaker outside of inverter must be capable to break 1.25 * DC short circuit current of PV generator.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	not regulated

[1] The German electricity market has been deregulated in 1999. Now, what used to be called „utility“ is called „grid operator“.

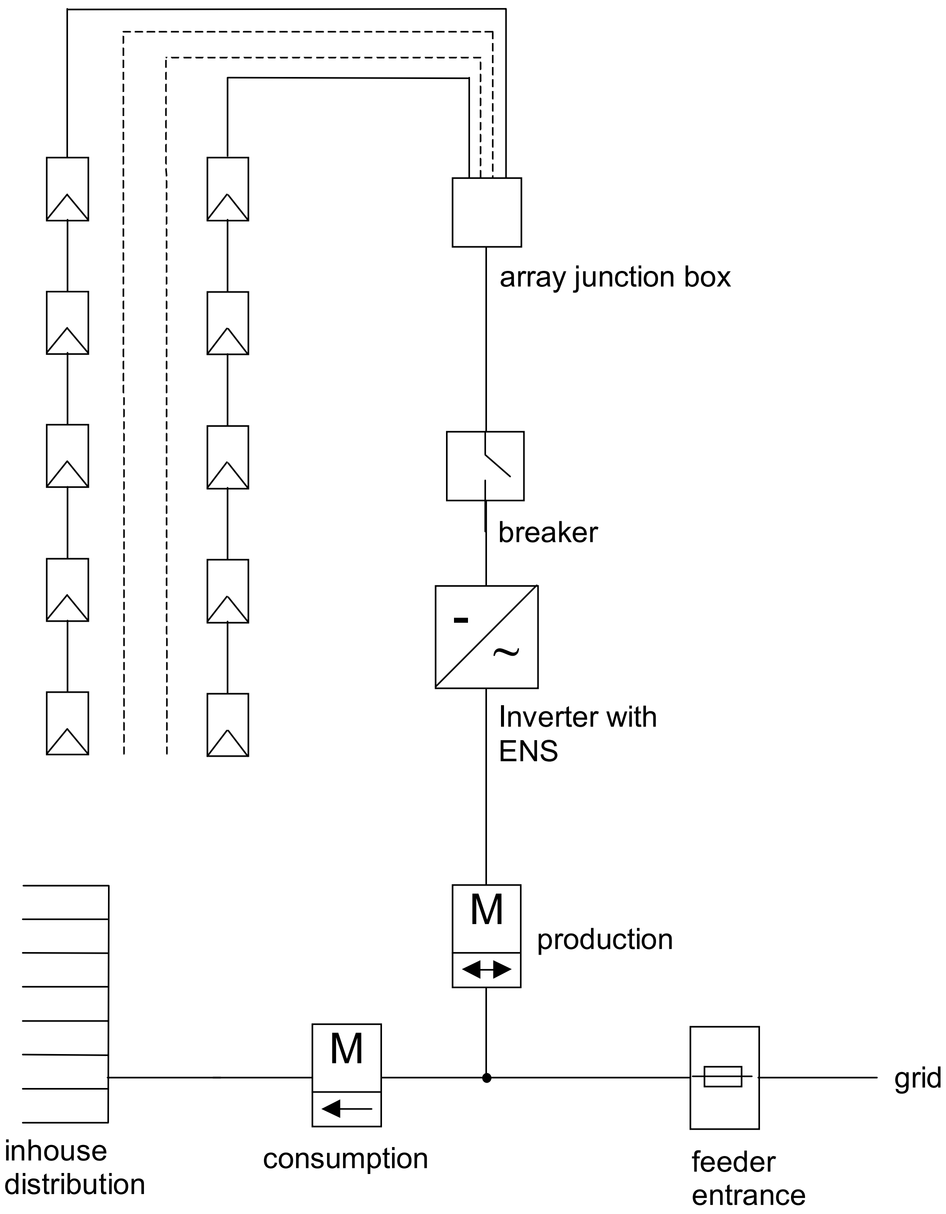
INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	Specific limits for current harmonics set in European standard EN 61000-3-2.
EMC: limits regarding conducted emissions	EN 50081-1, EN 50081-2, no standard for PV systems, inverters are subject to EN 55011 or EN 55014-1
EMC: limits regarding radiated emissions	EN 50081-1, EN 50081-2
EMC: limits regarding immunity	EN 50082-1, EN 50082-2
Requirements regarding power factor	0.8 ind. ≤ Pf ≥ 0.9 cap. recommended; (VdEW)
Limits for DC injection into AC grid	DC injection detection device with inverter disconnection is required for transformerless inverters. Detection threshold is 1 A (DIN VDE 0126:1999-04).
Requirements regarding flicker	Voltage fluctuations ≤ 3 % (EN 61000-3-3)
AC Disconnecting switch for maintenance work (external / internal to the inverter accessibility requirements purpose)	Load breaking switch required for work on PV system. Location : next to inverter. It is often accepted to use plug/receptacle connectors (Multi Contact) at inverter for this purpose. A switch always accessible for grid operator personal is not necessary, if the safety device "ENS" (DIN VDE 0126:1999-04) is used. It is also not necessary if a 1 phase inverter feeds into a 3-phase grid via a 3-phase undervoltage relay.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300 ms or less)	Not regulated.
Behaviour at startup or at restart after automatic disconnection	Check of grid voltage, frequency and impedance (ENS). For transformerless inverters: check of leakage resistance at DC side (DIN VDE 0126:1999-04). Waiting time not specified. After restoration of grid voltage on all phases some minutes delay for reconnection are recommended (VdEW Guidelines).
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	DC sensitive residual current device required. Disconnection required, if a current step of 30 mA or larger within 1 s occurs, or the continuous residual current exceeds 60 mA per kVA of inverter rated power. Disconnection time depends on level of residual current step. Maximum 0.2 s.
Limits regarding high-frequency capacitive leakage currents	not mentioned
Other safety requirements (yes /no; if yes, specify	Yes, two load breaking relays in series in "ENS".

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Islanding protection by: • An external disconnection switch or • 3-phase over- / undervoltage relay or • "ENS" ENS may be either internal to the inverter or an external device installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	Islanding prevention device ENS (also called MSD) has become the de-facto standard for new systems. It monitors grid voltage, grid frequency, grid impedance and ground leakage current and disconnects the inverter, if one parameter is out of bounds. Older requirement for 1-ph inverters (still possible as alternative to ENS): 3-ph undervoltage relay and 1ph overvoltage relay required.
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	According to VDE 0126: $0.8*U_N \leq U \leq 1.15*U_N$; explicitly not field programmable; reaction time: 0,2 s According to VdEW Guidelines: $0.7*U_N \leq U \leq 1.10*U_N$, field adjustable
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	According to VDE 0126: 50 Hz +/- 0,2 Hz; explicitly not field programmable; In VdEW Guidelines: not required; (general: 50 Hz +4% / -6 % according to DIN EN 50160),
External accessible disconnecting switch for utility (mandatory / not necessary)	Not necessary (see above)
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	According to VDE 0126: for ENS 20 s; Otherwise not specified; 1 min is recommended (VdEW Guidelines)
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	The ENS (impedance measurement) test method as defined in VDE 0126 is empowered and nationally accepted.
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	Authorisation is not regulated, theoretically each laboratory could conduct the type approval test. In fact type tests are performed by: Berufsgenossenschaft der Feinmechanik und Elektrotechnik Gustav-Heinemann-Ufer 130 D-50968 Köln fon: + 49 2 21 37 78-0; fax: +49 2 21 34 25 03 E-Mail: hv@bgfe.de And by. TÜV Rheinland Sicherheit und Umweltschutz GmbH Am Grauen Stein D-51105 fon: + 49 2 21 806 –0 fax: +49 2 21 806 -1327 E-Mail: mail@de.tuv.com

SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	1500 V according to DIN VDE 0100. Real system voltage depends on selected protection class according to DIN VDE 0106
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Generally permitted, if there is at least simple separation between the AC and DC sides. Prohibited for SELF, PELF and Class II installations (DIN VDE 0100 Teil 712) It is recommended to keep DC side ungrounded
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Generally not regulated; Required for transformerless inverters; Disconnection from grid
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not required For transformerless inverters disconnection from grid is required;
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	Safety and wiring of DC-side is covered in VDE 0100 Teil 712; SELF, PELV, Class II equipment, locked electrical facility and “placement out of reach” is permitted. Use of Class II is recommended. For SELF and PELV Voc shall not exceed 120 V DC.
Protection against electric shock on AC side	no additional measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	not specified
Special requirements concerning mechanical fixing / mechanical protection of cables	PV string cables, PV array cables and PV DC main cables shall be installed in such a manner as to reduce the risk of an earth fault or a short-circuit to a minimum (DIN VDE 0100 Teil 712).
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	May be connected to any existing branch. However, separate branch is recommended. If a generator feeds into an existing branch, the grid side fuse of this branch has to be reduced by the maximum current delivered by the generator.
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	The line conductors L+ and L- of the PV dc main cable should be protected by use of overvoltage protective devices located near the PV inverter. Where surge arrestors are used, they should be of the metal oxide or comparable type. The inception and inclination voltage shall be at least 1.4 times the value Uoc stc V. Where equipotential bonding conductors are installed they shall be parallel to and in as close contact as possible with DC and AC cables and accessories. Earthing of mounting structure is recommended.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	A warning label at any concerned junction box on the DC side shall state that: - active parts inside the box may be live after isolation from the PV inverter - fuses shall not be removed and isolating devices shall not be switched under load conditions.

	If protection against indirect contact of the PV generator has been omitted, because the PV generator is located within an area accessible only to skilled or instructed persons, easily visible warning signs with the symbol 5036 as shown in IEC 60417 shall be placed in the vicinity of the PV generator.
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Approval by grid operator is required. Installation work may be performed only by authorised, i.e. skilled and concessioned craftsman. The grid operator usually demands – single phase circuit diagram of installation - a copy of the declaration of CE conformity of the inverter - a copy of the type test approval of the anti-islanding ENS - protocol of commissioning by installer Tests are not regulated; Generally simple functional tests of inverter and ENS are conducted. Documentation of commissioning procedure is requested.
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems, “Gesetz für den Vorrang Erneuerbarer Energien - (Erneuerbare-Energien-Gesetz - EEG)“ (Law for Privilege for Renewable Energies). Tariffs are defined in this law. They are fixed for 20 years and depend on the year of installation. Price for systems built in 2001 is 0.99 DM/kWh. Metering is not regulated, it depends on local grid operator. Usually energy fed to the grid is measured using a net metering meter. The meter belongs to the grid operator and is rented for some 20 ... 50 Euro annually to the Independent Power Producer.
FURTHER LITERATURE NORMATIVE REFERENCE	Richtlinien für den Parallelbetrieb von Erzeugungsanlagen mit dem Niederspannungsnetz eines Verteilnetzbetreibers („Guidelines for the operation of private power production systems parallel to the low voltage public grid“), VdEW (Association of electric power companies), 2000 Source: Verband der Elektrizitätswirtschaft VDEW - e. V. Stresemannallee 23 D-60596 Frankfurt am Main Telefon + 49 69 63 04-1 Telefax + 49 69 63 04-289

	DIN VDE 0126:1999-04, Selbsttätige Freischaltstelle für Photovoltaikanlagen einer Nennleistung <= 4,6 kVA und einphasige Paralleleinspeisung über Wechselrichter in das Netz der öffentlichen Versorgung, Entwurf 1999-04; (Automatic safety disconnect for single phase grid connected PV systems up to 4.6.kVA nominal power), draft 1999-04 This standard covers the grid interface, inverter requirements and some erection requirements. It has been „ermächtigt"(empowered), i.e. it may legally be used as a reference for testing products. Source: Beuth Verlag GmbH D - 10772 Berlin fon: +49 30 26 01 27 59 fax: +49 30 26 01 12 63 E-mail: postmaster@beuth.de
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	Blockdiagram of a typical installation in Germany as it is built according to the "EEG" law.


array junction box
breaker
-
~
Inverter with
ENS
M
production
M
grid
inhouse
distribution
consumption
feeder
entrance

Italy

COUNTRY	Italy
Person filling in this questionnaire	Francesco Groppi

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems	
Adress where copies of the standard can be obtained	Comitato Elettrotecnico Italiano CEI Viale Monza, 261 20126 Milano Tel. 02-257731 02-25773222 02-25773210 e-mail: cei@ceiuni.it
Date of last change	
Topics covered by standard	
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators	CEI 11-20 – Impianti di produzione di energia elettrica e gruppi di continuità collegati a reti di I e II categoria (Power production plants and uninterruptable power systems connected to 1st and 2nd grids)
Energy sources covered by this standard	Internal and external combustion engines, turbines, wind generators, hydraulic turbines, electric engines, combustion cells, batteries, photovoltaic systems.
Date of last change	November 1997
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	Yes, it is under study. Probably will be in force before the end of 2000.
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	The standard gives an indication of 50 kVA for LV systems and 8 MVA for MV systems (HV systems are not covered by this standard).
Interconnection voltage mentioned in standard	Low voltage and medium voltage.
Limitation of max. PV generator power according to standard	Not specified.
Procedure for connection of larger PV systems to the grid	Not specified.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	CEI 82-8 (EN 61215) for crystalline modules and CEI 82-12 (EN 61646) for thin-film modules
cables (one cable with two conductors / two independent cables,	According with CEI 64-8

quality insulation strength	
String diodes (necessity, location, current rating,	According with CEI EN 61277
DC fuses (necessity, location	According with CEI EN 61277 Usually, in Italy fuses are not used.
Junction box	According with CEI 64-8
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Not mandatory for SELV circuits but, in practice, always used.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	According with CEI EN 61173 and CEI 81-1

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter: EN 61000-3-2 No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	EN 50081-1
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	Not mentioned in the standard, but required by utilities that power factor is > 0.9
Limits for DC injection into AC grid	Three-phase transformless inverters are, in practice, not allowed because a galvanic insulation between DC and AC section is necessary. Single-Phase transformless inverters (≤5 kVA) must have a protection device against DC injection into the grid.
Requirements regarding flicker	Not mentioned in the standard
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	A switch accessible to the utility must always be present. It can be the same device installed at the delivery point of the energy.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Not specified in the standard
Behaviour at startup or at restart after automatic disconnection	Not specified
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the standard
Limits regarding high-frequency capacitive leakage currents	Not mentioned in the standard
Other safety requirements	Only DC injection is adressed, see above

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Normally, the protection device is external: DV604 for three-phase inverters or DV606 for single-phase inverters. In case of a single-phase connection, the external device may be omitted if the inverter is equipped with an equivalent internal device.
Required islanding detection methods (active / passive methods required by standard or electric utilities	Voltage and frequency window
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	0.8 Vn ÷ 1.2 Vn max delay: 0.1 sec at 1.2 Vn and 0.15 sec at 0.8 Vn
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	49.7 ÷ 50.3 Hz without delay
External accessible disconnecting switch for utility (mandatory / not necessary)	A switch accessible to the utility must always be present. It can be the same device installed at the delivery point of the energy.
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Not specified in the standard.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	None
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	1500 V in order to be considered a LV system (CEI 64-8)
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Forbidden in SELV (Safety Extra Low Voltage) systems, necessary in PELV (Protection Extra Low Voltage) systems, allowed both in FELV (Functional Extra Low Voltage) and LV systems. (CEI 64-8)
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Only if the DC circuit is an IT system (circuit with galvanic insulation and not grounded)
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not required
Protection against electric shock on	Not particularly protections in case of SELV or PELV circuits

DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	unless: - they are built in cattle-houses (in this case the DC voltage must not exceed 60 V); - they are located in the vicinity of swimming pool or equivalent zones (voltage is also lower, 12 or 24 V); - they are in areas with explosion risk (e.g. gas stations). LV protection (i.e. double insulation) in case of LV and FELV systems.
Protection against electric shock on AC side	No additional measures on top of the already implemented safety measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	No
Special requirements concerning mechanical fixing / mechanical protection of cables	No
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	May be connected to any existing branch provided the safety conditions are verified.
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	The „safety“ aganist lightening should be verified by using the standards CEI 81-1 and/or CEI 81-4. If the installation of a new PV plant involves a lightening risk for the building, a suitable LPS must be realised.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Fuses on the DC side, if present, which must not be removed/operated under load must be marked accordingly
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned; in practice several measures on the DC side are not necessary (e.g. disconnecting switch, overvoltage protection on the DC side)
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Installations are authorised by the local eletric utility. Usually required: - a copy of the declaration of CE conformity of the inverter - a copy of the type-testing of the built-in anti-islanding measure ENS Only a licenced electrician may connect the PV system to the grid Commissioning tests include visual inspection and tests of the anti-islanding measures
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy	In preparation

PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	
FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	Please include figure as a separate page, but in any case electronically into this file (no paper copies, please!)

Japan

COUNTRY	Japan
Person filling in this questionnaire	Tadao Ishikawa

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	
Date of last change	
Topics covered by standard	
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	Technical Guideline for the Grid Interconnection of Dispersed Power Generating Systems (only avairable in Japanese)
Adress where copies of the standard can be obtained	For grid-interconnection guideline Commentary for Grid-interconnection guideline '98 (in Japanese): Denryoku Sinpousha 5-13-3 ginza, chuou-ku, Tokyo 104-0061, Japan tel: +81-3-5565-4091 fax: +81-3-3545-5715 e-mail:LED00642@nifty.ne.jp http://www.energy-forum.co.jp/index.htm (only Japanese pages) For photovoltaic generation system standards: JIS (Japan Industry Standard) Japanese Standards Association 4-1-24 Akasaka, Minato-ku, Tokyo 107-8440 tel: +81-3-3583-8002 fax: +81-3-3583-0462 to order from outside Japan, please contact English page of JSA website http://www.jsa.or.jp/eng/index.htm
Energy sources covered by this standard	All generating sources (Different grid-interconnection requirements for utility frequency rotating generators and DC sources utilizing inverter for grid-interconnection.)
Date of last change	1998-03-10
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	Yes (minor change) 2001-03
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	Depends on the utility system grid voltage. Low voltage distribution grid: Up to 50 kW High (Middle) voltage distribution grid: Up to 2000 kW Transmission grid: No limit
Interconnection voltage mentioned in	Low voltage distribution grid: 100 or 200 V

standard	High (Middle) voltage distribution grid: 6600 V Transmission grid: Over 20 kV
Limitation of max. PV generator power according to standard	Low voltage distribution grid: Up to 50 kW High (Middle) voltage distribution grid: Up to 2000 kW Transmission grid: No limit
Procedure for connection of larger PV systems to the grid	Request at local utility. Utility determines the connecting grid and protecting devices according to the guideline.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	Some requirements for enviromental and endurance test (JIS C 8917:1998 which corresponds to IEC 61215 and IEC 61701)
cables (one cable with two conductors / two independent cables, quality insulation strength	600V cable (IV, CT, EV), either two conductors or two independant cables minimum size is 2mm^2 (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit fot photovoltaic array“)
String diodes (necessity, location, current rating,	Not necessary for only one string. When more strings are connected parallel, string diode is required for every string which has short circuit current rating of each string. (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit fot photovoltaic array“)
DC fuses (necessity, location	Not necessary
Junction box	Must be water proof when installed outside. Must withstand line to line voltage and line to ground voltage. (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit fot photovoltaic array“)
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Mandatory. Must be able to break DC short circuit current from PV. (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit fot photovoltaic array“)
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Only overvoltage relay is required for inverter. (JIS C 8980:1997 „Power conditioner for small photovoltaic power generating system“) For PV array, surge absorver is recommended which has over 1 kA current capacity and maximum voltage is less than twice of maximum circuit voltage. (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit fot photovoltaic array“)

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	Not mentioned in the guideline. Apply for the Japanese guideline for current harmonics from electric equipment (Based on IEC 61000-3-2). No specific reference to multiple inverter systems
EMC: limits regarding conducted	JIS C 8980:1997 „Power conditioner for small photovoltaic

emissions	power generating system“
EMC: limits regarding radiated emissions	JIS C 8980:1997 „Power conditioner for small photovoltaic power generating system“
EMC: limits regarding immunity	JIS C 8980:1997 „Power conditioner for small photovoltaic power generating system“
Requirements regarding power factor	power factor is > 0.85
Limits for DC injection into AC grid	DC injection detection device with inverter disable is required for transformerless inverters. Maximum allowable DC current level is 1% of inverter rated current.
Requirements regarding flicker	Apply for the Japanese standard for flicker voltage limitation
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	Not mandatory but recommended. Place at switching board branch so that it is accessible to maintenance in case of inverter malfunction.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Not specified in the guideline because grid reclosing time in Japanese distribution system is 3 sec or more (typically 60 sec).
Behaviour at startup or at restart after automatic disconnection	Inverter must check grid voltage and frequency for allowable values. Only after all parameters are within the limits re-connection to the grid may occur. At startup, no waiting time is required. At restart after automatic disconnection, waiting time of 150-300 seconds are recommended depends on the utility grid operation procedure at fault. At restart after gate blocking of inverter, waiting time of 5-10 seconds are recommended.
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the guideline
Limits regarding high-frequency capacitive leakage currents	Not mentioned in the guideline
Other safety requirements (yes /no; if yes, specify	Yes-Only DC injection is adressed, see above

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Protection may be either internal to the inverter or an independent device installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	Both active and passive methods should be installed according to the guideline. Any kind of active method and passive method is acceptable. For example: Active method: Frequency shift, power variation, load variation Passive method: voltage phase jump, frequency variation rate, third harmanic voltage detection
AC voltage operating range (may trip points be adjustable in the	100V +20/-20%(Maximum) in case of 100V system 200V +20/-20%(Maximum) in case of 200V system

field e.g. by software? reaction time?)	Reaction time: 0,5 to 2 seconds Field-adjustable trip points, it is however required that the values cannot be changed by the user
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	50Hz +1,5/-1,5Hz(Maximum) 60Hz +1,8/-1.8Hz(Maximum) Reaction time: 0,5 to 2 seconds Field-adjustable trip points, it is however required that the values cannot be changed by the user
External accessible disconnecting switch for utility (mandatory / not necessary)	Not necessary
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Not explicitly specified in the guideline. Depends on the grid operation procedure at the fault. Usually, 150-300 seconds are recommended.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Yes
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	Japan Electrical Safety & Environment Technology Laboratories 5-14-12 Yoyogi, Shibuya-ku, Tokyo, Japan
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	750 V (JIS C 8980:1997 „Power conditioner for small photovoltaic power generating system“)
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Not recommended (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit for photovoltaic array“)
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Recommended Alarm or opening of inverter DC circuit breaker (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit for photovoltaic array“)
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not required
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	Grounding of metal frame of PV module, mounting, measurement equipment etc. DC voltage < 300 V: grounding resistance <100 Ω DC voltage > 300 V: grounding resistance <10 Ω (JIS Technical Report TR C 0005:1997 „Design guide on electrical circuit for photovoltaic array“)
Protection against electric shock on AC side	Not specified. Common grounding requirement for electrical equipment is applied,
Cabling layout (Cabling layout design rules e.g. for lightning protection)	Not specified
Special requirements concerning mechanical fixing / mechanical protection of cables	If the cable has connection, mechanical force should be removed at the connecting point.

Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	Dedicated branch for PV inverter
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Grounding of metal frame of PV module, mounting. DC overvoltage protection device (arrestor, surge absorber) between each DC conductor and ground. On the AC side, no specific rule is given. However, surge absorber between phase to ground is usually used.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Not specified
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Installations are authorised by the local eletric utility. Usually required: - a copy of electrical layout of the system - a copy of the declaration of comfirmation of the requirements for grid interconnection guideline - a copy of the type-testing certification by JET Only a licenced electrician may connect the PV system to the grid Commissioning tests include visual inspection and insulation tests
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are voluntarily buying electricity produced by PV systems. It is not legally regulated. Tariffs paid for electricity fed into the grid vary locally, however, the rate is almost the same as electricity from utility. Rates are around 23 Yen / kWh for low voltage customer. Separate meter for energy fed into the grid is required.
FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

Comment for the basic configuration of standards and guidelines in Japan.

In Japan, we have separated the guideline for grid interconnection of PV system and safety requirements for PV system itself. From the point of grid-interconnection, PV system is considered as a power generating system using an inverter. There is no difference in the requirements of interconnection for inverter systems, no matter if the generating source is PV, fuel cell, micro gas turbine (through DC link). Therefore, grid interconnection requirements for DC sources which utilize inverters are applied for PV systems.
Japanese grid interconnection guidelines consist of several parts, divided by the utility voltage level, (transmission line, high (middle)-voltage distribution line and low voltage distribution line) and type of generation source (DC generating source using inverter for grid interconnection or utility frequency generating source which is directry interconnected to utility system) .
Guideline for DC power sources interconnection to low voltage distribution line grid is applied for small grid-interconnected PV systems up to 50 kW.
Safety requirements of PV system itself are mentioned in other series of PV system specific standards.
These are Japanese Industrial Standards (JIS) and unification of JIS with IEC standard is now proceeding.

Mexico

COUNTRY	Mexico
Person filling in this questionnaire	Oscar Arteaga

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	Especificaciones Técnicas para Pequeños Sistemas Fotovoltaicos Conectados en Paralelo Con la Red Eléctrica (Technical Specifications for Small Grid-connected Photovoltaic Power Systems)
Adress where copies of the standard can be obtained	Instituto de Investigaciones Electricas Division de Energias Alternas Unidad de Energias No Convencionales Av. Reforma No. 113 Col. Palmira 62490 Temixco, Morelos, Mexico www.iie.org.mx
Date of last change	December, 1999
Topics covered by standard	Grid connected PV systems
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	A revision is expected during the first half of 2002
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	Up to 25 kWp
Interconnection voltage mentioned in standard	Low voltage network only
Limitation of max. PV generator power according to standard	AC rating of PV plant, limited to the contracted power with the utility.
Procedure for connection of larger PV systems to the grid	Not determined yet

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required	Must bear a type approval certification
Cables (one cable with two conductors / two independent cables,	Independent cables for each pole of the PV output circuit must be used. The use of separate metal ducts for each pole is recommended.

Quality Insulation strength	Cable operating conditions must be accounted for in the selection of the cable and insulation, specifically maximum system voltage, UV radiation exposure, temperature, moisture and mechanical strength. The PV array conductors Insulation rating must be at least 125% of the rated open circuit voltage at STC.
String diodes (necessity, location, current rating,	Blocking diodes are not necessary they can be installed in addition to overcurrent protection. If they are installed, they must have a current carrying capability equal or greater than 150% of the short circuit current of the string at STC; their blocking voltage must be at least 200% of the open circuit voltage of the array at STC
DC fuses (necessity, location	DC fuses or circuit breakers must be used to protect each string. If the array is floating, overcurrent protection must be installed on each pole of the individual strings. If the array is grounded overcurrent protection must **only** be installed on the ungrounded pole(s) Overcurrent protection rating must be between 125% and 150% of the short circuit current of the protected string at STC
Junction box	All enclosures must be specified for the intended use (waterproof if they are installed outdoors, etc), they must be grounded if they are metallic, the positive and negative conductors must be separated by an insulation barrier
DC disconnecting switch (mandatory / not necessary, Quality of switch: load break capability yes /no	A disconnection means between the PV array and the inverter is required. The load break capability is not specified the device is primarily intended to operate under no load conditions
DC overvoltage protection of inverter (requirements according to standard, local requirements)	According to IEC 61173

INVERTER	
Limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	According to CFE L0000-45 (specification from the Federal Electricity Commission) No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	Not determined yet
EMC: limits regarding radiated emissions	Not determined yet
EMC: limits regarding immunity	Not determined yet
Requirements regarding power factor	Greater than 0.85 (inductive or capacitive) for power output greater than 10% of nominal capacity
Limits for DC injection into AC grid	Either an interconnection transformer or a DC detection circuit is required. No DC injection limit is specified
Requirements regarding flicker	According to CFE L0000-45 (specification from the Federal Electricity Commission)
AC Disconnecting switch for maintenance work (external / internal to the inverter accessibility requirements purpose)	An external disconnecting circuit breaker is required for safety and maintenance purposes.

Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Not determined yet
Behaviour at start-up or at restart after automatic disconnection	The inverter can reconnect to the grid after the voltage and frequency have been within the specified limits for 1 minute
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not addressed in the standard
Limits regarding high-frequency capacitive leakage currents	Not addressed in the standard
Other safety requirements (yes /no; if yes, specify	Not addressed in the standard

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Not mentioned in the standard
Required islanding detection methods (active / passive methods required by standard or electric utilities	Over and under voltage and over and under frequency trips are required. An additional active anti islanding method is recommended
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	± 10% of the nominal grid voltage according to CFE L0000-02 (specification from the Federal Electricity Commission). Reaction time 2 seconds. Field adjustability is not mentioned in the standard
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	60 Hz ± 1 Hz Reaction time and field adjustability have not been determined yet
External accessible disconnecting switch for utility (mandatory / not necessary)	Not necessary
Minimum start-up time after disconnection from the grid (waiting time after normal grid conditions have been restored)	1 minute
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Not determined yet
Authority/ institute authorised to perform such a test and issue a certificate (name, address)?	Not determined yet
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	600 V is the maximum allowable

Grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Either grounded or ungrounded PV systems are allowed. If the PV system is grounded, an isolation transformer between PV system and the grid is mandatory
Ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Recommended where there is a risk of fire due to possible electric arcs caused by ground faults
Automatic PV array disable in case of ground fault (mandatory /recommended / not required If mandatory: how is array disabled?	Recommended where there is a risk of fire due to possible electric arcs caused by ground faults
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	Not determined yet
Protection against electric shock on AC side	No additional measures on top of the already implemented safety measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	Positive and negative conductors within a PV array must be bundled together
Special requirements concerning mechanical fixing / mechanical protection of cables	Cabling tension at connection terminals must be removed by suitable means such as cable glands, etc.
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	Dedicated branch for PV inverter
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	According to IEC 61173 metallic frames and structures must be grounded (under revision)
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	PV array data (rated values) must be shown on junction boxes. The presence of on site generation must be indicated in the main service panel and any other service panels within the dwelling Overcurrent devices and switches must be marked according to electrical diagram
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	The same protection measures must be applied
Difference in installation requirements	Not determined yet
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority	Not determined yet

e.g. CE declaration, anti-islanding test certificate etc.; Tests at commissioning	
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Not determined yet.
FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

Netherlands

COUNTRY	Netherlands
Person filling in this questionnaire	Bas Verhoeven KEMA TDP P.O. box 9035 6800 ET Arnhem Netherlands Email: s.a.m.verhoeven@kema.nl (Date : October 1999)

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems	1: Supplementary Conditions for Decentralized Generators Low-Voltage level 2: Guidelines for the electrical installation of grid connected photovoltaic (PV) systems
Adress where copies of the standard can be obtained	EnergieNed Utrechtseweg 310 P.O. box 9042 6800 Arnhem tel +31 26 3 56 94 44 fax +31 26 4 46 01 46
Date of last change	1: November 1997 2: December 1998
Topics covered by standard	1: Safety provisions and protections required at the point of connection of a generator with the low voltage power network. All conventional and renewable types of generator are covered. 2: Design criteria for safety, fusing, switching, wiring of a PV system and the interconnection with the electrical installation in a building. Comparable with Dutch standard NEN 1010 which is based on the IEC-60364-series and the CENELEC HD 384-series.
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	Not applicable
Energy sources covered by this standard	1: This standard deals with all types of generators connected to the low voltage power network. Simple protection is required for generators below 5 kVA. This class is intended for small generators in residential applications, e.g. PV systems and micro combined heat and power. 2: This standard is intended for grid connected PV systems only. Clauses referring to the AC side may also be used for other small types of generators like micro combined heat and power.
Date of last change	1: November 1997 2: December 1998
Is any change in the standard foreseeable? If yes, please give an	1: changes within the next few years are not foreseen 2: IEC TC 64 is drafting a special standard for the electrical

approximate date for new standard	installation of PV systems. This standard will be adopted as a standard (IEC 60364-7-712) in the year 2000. In Europe CENELEC will probably accept this standard as an EN-standard. EN-standards are mandatory in Europe. Adoption of this EN standard is expected in 2001.
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	1: No power limits are specified. The only restriction is the connection to the low voltage power network. Special standards are applicable for generators connected to the medium or high voltage networks.
Interconnection voltage mentioned in standard	1: Low voltage network only 2: The upper limit of the voltage in the electrical installation is limited to 1000 Vac and 1500 Vdc. NEN 1010 based on IEC 60364 series and the CENELEC HD 384-series.
Limitation of max. PV generator power according to standard	1: The standard has no limitation for power. However the rated power determines the minimum required protections for the supervision of the point of connection with the low voltage network. Generators with a power electronic inverter and a rated power below 5 kVA have simple requirements for the protections. 2: Not applicable.
Procedure for connection of larger PV systems to the grid	The connection of a generator to the power network has to be approved by the network operator. However, people forget to this requirement when dealing with small and medium sized PV systems on dwellings. Permission is asked for all large PV systems. By law, the network operator cannot refuse the connection of a PV system (or any other renewable energy source.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required	PV modules have to comply with the requirements set out in IEC 61215. In addition to these requirements in modules must be capable of conducting continuously a reverse current equal to 2 x $I_{sc\ STC}$ of the string in which the module is included. The module should not be damaged by such a current and should not reach an unacceptably high temperature when such a current passes through it. A module should be fitted with a terminal box and/or a suitable connector of at least IP54. Modules of Class II are required if the open system array voltage exceeds 120 Vdc. At the time of writing, no modules with a class II certificate that is valid for the Netherlands are available. Until this situation changes, modules should satisfy the following conditions: • a voltage test should be carried out with U_{test} =

	4 x $U_{oc\ STC}$ + 2000 [V], in accordance with IEC 60536; • glass front cover of sufficient thickness to provide protection against mechanical loads caused by wind, rain, snow and hail; • a statement should be issued by the supplier, guaranteeing that the module meets the conditions set out above; • the PV system should be designed by a suitably qualified person; • a thorough visual inspection should be made as part of the acceptance testing procedure; • written permission should be obtained from the relevant utility • regular inspections should be carried out by a suitably qualified person
Cables (one cable with two conductors / two independent cables, quality insulation strength	Cables used in the open air should be sufficiently resistant to moisture, chemicals, ultraviolet radiation and temperature. The DC cabling system must be designed according to the fail-safe principle. In other words, it should be impossible for a short circuit to occur between the poles without a connection to earth. The following types of cable may be used in the DC section of a PV system: • wire with a single stranded core and double or reinforced insulation; • cables with basic insulation only and without an armour and/or earthing screen, provided that opposite poles are not in the same cable and that cables with opposite poles are fitted in separate, earthed metal ducts and/or tubes; • cables with basic insulation only and earthed screen or armour, provided opposite poles are not in the same cable. The main DC cable may have both positive and negative conductors, provided that it has an earthed metal screen or armour. Cable armour and/or earthing screens should be connected at both ends to the equipotential bonding conductor. The insulation level of wire or cabling should be determined on the basis of $U_{oc\ STC}$. Attention should be paid to an increased ambient temperature. The DC cabling should be capable of continuously conducting a current of the strength as indicated below. • String cable: $I_{sc\ STC}$ of the string, where there is only one string and 2 x $I_{sc\ STC}$ of the relevant string where two or more strings are connected in parallel • Array cable: 2 x $I_{sc\ STC}$ of the relevant array • Main DC cable: $I_{sc\ STC}$ of the relevant generator When calculating the appropriate cross-sectional area, allowance should be made for increased ambient temperature.

	All cabling should be bundled as far as possible. Where an equipotential bonding conductor is fitted, all DC and/or AC cables should be bundled with the conductor. An equipotential bonding conductor must be bundled with all the cables in the DC and AC sections of the PV system, along their entire length. If the DC and/or AC cables are branched, an equipotential bonding conductor should be bundled with each branch. An equipotential bonding conductor should also be bundled with the AC cables or wires along their entire length beyond the point of transition from the PV installation to the electrical installation. Suitable types of cable should be used for signal and data transmission. Signal and data cabling should be bundled with the DC and/or AC cabling and, where applicable, with the equipotential bonding conductor.
String diodes (necessity, location, current rating,	Blocking diodes are not allowed as safety devices, may only be used in addition to overload protection. If used, the reverse voltage of a blocking diode should be at least 2 x $U_{oc\ STC}$. Blocking diodes should be fitted in the DC junction box, if possible
DC fuses (necessity, location	Where three or more strings or arrays are connected in parallel, each incoming string cable or array cable must be provided with overload protection. The tripping current I_a must be $I_{sc\ STC} < I_a < 2 \times I_{sc\ STC}$, where $I_{sc\ STC}$ equals the maximum current in the relevant string or array. The overload protection must be rated for inductive DC circuits with 1.2 x $U_{oc\ STC}$ and 1.2 x $I_{sc\ STC}$ of the relevant string or array. Fuses or mini-circuit breakers may be used provided that they are suitable for use in inductive DC circuits.
Junction box	The DC junction box should be readily accessible. The following text should be permanently and clearly visible on the cover: THIS BOX CONTAINS LIVE PARTS WHICH CANNOT BE DEACTIVATED The wire, cable, terminals and accessories should be installed in such a way that short circuits between the poles are practically impossible.
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	It should be possible to disconnect each string from the parallel circuit. Circuit breakers, switch-disconnectors, or disconnectors may be used for this purpose, provided that their design is such that it is not possible to touch any live parts. Where disconnectors are used (in combination with fuses or otherwise), the following text should be clearly visible inside the DC junction box: DISCONNECTORS MUST BE OPERATED ONLY UNDER ZERO CURRENT CONDITION A circuit breaker should be fitted, with which the outgoing DC main cable or array cable can be disconnected. This

	breaker must be rated for inductive DC circuits carrying at least 1.15 x $U_{oc\ STC}$ and 1.2 x $I_{sc\ STC}$. Polarity-sensitive breakers should not be used.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Where surge arrestors are used, they should be metal oxide or a comparable type. The use of spark gaps is not allowed. The surge arrestors should be fitted between the positive pole and earth, and between the negative pole and earth. The inception and inclination voltage of the surge arrestor should be at least 1.4 x $U_{oc\ STC;}$

INVERTER	
Limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	Standard European EMC-CE marking is required. For a single inverter EN 61000-3-2
EMC: limits regarding conducted emissions	EN 50081-1
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	Better than ± 0,9.
Limits for DC injection into AC grid	Not allowed, no limits are specified. Under consideration in several EMC standardisation working groups.
Requirements regarding flicker	EN 61686
AC Disconnecting switch for maintenance work (external / internal to the inverter accessibility requirements purpose)	It must be possible to disconnect a PV system from the electrical installation. No requirements are specified for this means of disconnect. There are no requirements for an external accessibility of this disconnect switch.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Not applicable. Reclosing is not used in the Dutch medium and low voltage power networks.
Behaviour at start-up or at restart after automatic disconnection	Instantaneous reconnection is allowed for generators connected with a power electronic inverter and with a rated power below 5 kVA. For all other generators a reclosing delay of 2 minutes has to be obeyed.
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	No special requirements are applicable. The DC-side of a PV system has to be designed as Class II. Requirements are given in NEN 1010. This Dutch standard is based on CENELEC HD 384-series and IEC 60364-series.
Limits regarding high-frequency capacitive leakage currents	No limits are applicable.
Other safety requirements (yes /no; if yes, specify	General clauses prohibit interference between different devices and/or protections.

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Protection may be either internal or external.
Required islanding detection methods (active / passive methods required by standard or electric utilities	Required protection: • Overvoltage • Undervoltage • Overfrequency • Underfrequency • Overload protection or maximum current
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Rated AC voltage in the Netherlands is 230 Vac +6% / -10%. For generators connected with a power electronic inverter and with a rated power below 5 kVA • Overvoltage 1-phase at 106% with a maximum time to trip of 0,1 seconds • Undervoltage 1-phase at 80% with a maximum time to trip of 0,1 seconds For all other generators: • overvoltage 3-phase at 106% with a maximum time to trip time of 2 seconds. • undervoltage 3-phase at 80% with a maximum time to trip of 2 seconds and at 70% with a maximum time to trip of 0,2 seconds Trip points may be adjustable in software by skilled and trained personnel.
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Setting of the over and underfrequency protection is 50 Hz +/- 2 Hz with a maximum time to trip of 2 seconds.
External accessible disconnecting switch for utility (mandatory / not necessary)	No.
Minimum start-up time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Instantaneous reconnection is allowed for generators connected with a power electronic inverter and with a rated power below 5 kVA. For all other generators a reclosing delay of 2 minutes has to be obeyed.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Correct function of the protection and proper settings have to be guaranteed by the manufacturer. For AC Modules a special KEMA-KEUR (K150) safety certification is required. The functioning and settings of the protections are included.
authority/ institute authorised to perform such a test and issue a certificate (name, address)?	KEMA Registered Quality P.O.Box 9035 6800 ET Arnhem The Netherlands
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	The maximum DC-voltage level is according to NEN 1010, 1500 Vdc. The Dutch standard NEN 1010 is based on the international standard IEC 60364-series and the CENELEC HD 384-series.

Grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Not required
Ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Insulation supervision is relevant only for PV systems with a floating DC section (IT systems). The table below indicates whether insulation supervision is obligatory, recommended or not necessary. $U_{oc\ STC} > 120\ V_{DC}$ • Modules complying with class I: Obligatory • Modules complying with class II: Recommended $U_{oc\ STC} \leq 120\ V_{DC}$ • $I_{sc\ STC}$ of string or array > 10 A: Recommended • $I_{sc\ STC}$ of string or array ≤ 10 A: Not necessary
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	When the ground fault detection activates a clear visual and/or acoustic signal must be produced.
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	PV systems with $U_{oc\ STC} \leq 120\ V_{dc:}$ Additional protection to prevent direct or indirect electrical shock should be provided as follows: • active components should be entirely enclosed within a casing of suitable insulating material; • if the inverter is equivalent to a safety transformer, all components in the DC section of the PV system should at least comply with class III; • if the inverter is not equivalent to a safety transformer, all components in the DC section of the PV system should at least comply with class I, but preferably with class II. An inverter should be considered equivalent to a safety transformer if it complies with NEN 10742. PV systems with $U_{oc\ STC} > 120\ V_{dc:}$ Additional protection to prevent direct or indirect electrical shock should be provided as follows: • active components should be entirely enclosed within a casing of insulating material; • all components in the DC section of the PV system should comply with class I or class II. Ideally, modules should comply with class II, while class I is generally more used for inverters. Metal frames and external conductive (metal) parts of class I components should be earthed. External conductive (metal) parts of class II components do not need to be earthed. However, if the surface area of such external conductive (metal) parts is large, earthing is recommended.
Protection against electric shock on AC side	The AC voltage at the inverter's AC terminals should be reduced to ≤ 50 V_{AC} in the event of a fault in the electrical installation. The reaction speed of the protection that effects this reduction should be as indicated in table 41A of NEN 1010. (The limit at 230 V_{AC} is 0.4 seconds.)

	PV systems (including AC modules) are categorised as small generators. A grid connected PV system (inverter) must therefore comply with the Supplementary conditions for decentralized generators low-voltage level. This document includes requirements regarding the protection of the point of connection of the inverter and the electrical installation. In principle, any system which meets these requirements should automatically comply with the above requirement
Cabling layout (Cabling layout design rules e.g. for lightning protection)	An equipotential bonding conductor must be bundled with all the cables in the DC and AC sections of the PV system, along their entire length. If the DC and/or AC cables are branched, an equipotential bonding conductor should be bundled with each branch. An equipotential bonding conductor should also be bundled with the AC cables or wires along their entire length beyond the point of transition from the PV installation to the electrical installation. The cross-sectional area of the equipotential bonding conductor should at least be equal to the cross-sectional area of the largest active conductor used in the DC or AC section of the PV system. The cross-sectional area of the equipotential bonding conductor (excluding protection against mechanical damage) should be at least 4 mm^2. Non-insulated equipotential bonding conductors may be used.
Special requirements concerning mechanical fixing / mechanical protection of cables	No special requirements.
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	The PV inverter should be connected to the main service panel with a dedicated feeder. One or more PV systems may be connected to feeder(s) to which power-consuming appliances are connected, provided that the total current of the PV systems connected to the whole electrical installation does not exceed 2.25 A.
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Principally a building does not automatically require lightning protection when a PV system is installed. The necessity of such protection should be determined by reference to section 4 of NEN 1014. Most houses in the Netherlands are not fitted with external lightning protection and the increased risk associated with the installation of a PV system is very small. However, where PV systems are used on a particularly large scale or in special situations, e.g. on baffle screens along motorways or tall structures that rise above neighbouring buildings, lightning protection is recommended. Where external lightning protection is provided, the PV system's metal support structure must be bonded to the lightning protection system, provided that the latter is within a few metres of the support structure. The number of connections with the external lightning protection system should comply with subsection 6.4 of NEN 1014. The cross-sectional area of these connections should be at least

	10 mm². Where a PV system is connected to an external lightning protection system, an equipotential bonding conductor must also be fitted. Under such circumstances, the cross-sectional area of the equipotential bonding conductor should be at least 6 mm². It is particularly important that the equipotential bonding conductor is bundled with the DC <u>and</u> AC cabling along its entire length and connected to the main earthing-terminal or bar of the electrical installation. In this way, a metallic earth loop is deliberately created. The loop should not be interrupted at any point and should not include spark gaps or other kinds of surge arrestors.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	DC Junction box: • This box contains live parts which cannot be deactivated • Disconnectors must be operated only under zero current condition Main service panel • Before carrying out work on this installation, all PV systems should be disconnected
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	Yes.
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	An AC Module is considered as an electrical product. Certification according to K150 of KEMA is required for AC Modules. The K150 document includes all mechanical and electrical safety aspects.
Difference in installation requirements	PV systems may be connected to feeder(s) to which power-consuming appliances are connected, provided that the total current of the PV systems connected to the electrical installation does not exceed 2.25 A. This applies only to feeders whose cross-sectional wire area is 2.5 mm², and protected with 16 A overload protection device. This general clause is often used for AC Modules.
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorising body; documentation required by authority e.g. CE declaration, anti-island test certificate etc. ; Tests at commissioning	All PV systems have to comply with regular and special standards mentioned in this section of the document. Official procedures for commissioning are not available. Specialised Consultancy firms often assist owners of large and/or special PV system in authorisation and acceptance testing.
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities normally accept decentralised generators in their networks. The new Dutch legislation on electrical energy requires a zero-obstruction policy from network operators towards renewable energy. Pay back rates and the necessity of a net-export kWh-meter are subject to the contract between the network operator and the owner of the PV-system.

FURTHER LITERATURE, NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

Portugal

COUNTRY	Portugal
Person filling in this questionnaire	António Venâncio

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	There is no specific standard for grid connected PV systems
Date of last change	- - - -
Topics covered by standard	- - - -
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	Law 168/99 (last revision of all the legal and technical framework to Independent Power Producers), first introduced in 1988.
Adress where copies of the standard can be obtained	
Energy sources covered by this standard	All renewable sources: • Biomass, • Geothermal, • Small scale hydro-electric (up to 10 MVA), • Landfill gas, • Solar (thermal and photovoltaic), • Waves, • Wind. Non imported fuels. Energy from waste (industrial, agricultural and urban).
Date of last change	18 May 1999
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	- - - -
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	• When the connection to the grid is made at the low voltage level (up to 1kV), the power cannot exceed 4% of the minimum short-circuit power at the interconnection point, with an upper limit of 100kW. • For higher voltage levels: 1. The synchronous generators are limited to 8% of the minimum short-circuit power in the interconnection point. 2. The asynchronous generators systems are limited to 8% of the minimum short-circuit power in the interconnection point if the maximum power for an individual machine do not exceed 2000kW and 5% of the minimum short-circuit power. 3. The asynchronous generators systems are limited to 5% of the minimum short-circuit power in the interconnection point in all the other cases not covered by point 2 and the maximum power for an individual machine is limited by 4500kW.
Interconnection voltage mentioned in	No specific interconnection voltage.

standard	The law deals with interconnection to low, medium and high voltage grid.
Limitation of max. PV generator power according to standard	There is no specif reference to PV generators, but for systems interconnected to the low voltage, the max power is 100kW.
Procedure for connection of PV systems to the grid (is the same to all the other sources covered by this law)	• The licensing of an IPP plant requires the following documents to be submitted to the Government's Directorate General of Energy (DGE): 1. Normalised formal request to the Ministry of Economy (Energy) 2. Liability term, by which the installation conforms to the regulations in force. 3. Technical information provided by the utility (grid company) regarding: ♦ Interconnection point ♦ Maximum and minimum short circuit power at the interconnection point ♦ Type of neutral connection ♦ Automatic reclosing devices available or to be installed 4. Detailed design of the whole system (generators, transformers, protective devices, connection line, local grid, etc.). • The final decision (approval) is due to the Minister of Economy or the General Director of Energy, depending on the system installed power (P>1MVA or P<1MVA, respectively). • Before starting its regular operation, the power plant must be inspected by the DGE (P>10 MVA) or the Ministry's Regional Delegation (P<10 MVA), which will deliver an "Operating Licence".

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	Not explicitly specified.
Cables and wires (one cable with two conductors / two independent cables, quality insulation strength	• **AC side**: the system must comply with the technical condition required for electric systems. • **DC side**: no specific reference is made in the IPP law neither in the "Technical Guide"
String diodes (necessity, location, current rating,	Not explicitly specified.
DC fuses (necessity, location	Not explicitly specified.
Junction box	Not explicitly specified.
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Not explicitly specified.
DC overvoltage protection of inverter	Not explicitly specified.

(requirements according to standard, local requirements)	

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	• The produced energy must be as free as possible from harmonic distortion. • The utility must identify the harmonic sources and impose to the IPP the necessary solutions, whenever its harmonics may cause trouble to other consumers. • The charges with these arrangements will be supported by the IPP if the distortion is caused by his power plant. • The IPP is submitted to the legal framework regarding the quality of the service in the electrical grids (EN 50160).
EMC: limits regarding conducted emissions	No reference is made about this subject (in the IPP law). It is assumed that the European Standards for high frequency emission/immunity EN 50081-1&2 EN 50082 -1&2 are applied.
EMC: limits regarding radiated emissions	No reference is made about this subject (in the IPP law). It is assumed that the European Standards for high frequency emission/immunity EN 50081-1&2 EN 50082 -1&2 are applied.
EMC: limits regarding immunity	No reference is made about this subject (in the IPP law). It is assumed that the European Standards for high frequency emission/immunity EN 50081-1&2 EN 50082 -1&2 are applied.
Requirements regarding power factor	• If asynchronous generators are used, the power factor cannot be less than 0,85 inductive during full and peak load hours. • If synchronous generators are used, the power factor must be between 0,8 inductive and 0,8 capacitive. • During the off-peak load hours, is not permitted to supply reactive energy to the grid. • In the peak and full load hours, the Independent Power Producers must ensure the supply of reactive energy (at least 40% of the total active energy generated). • No special limits are mentioned for static converters interface systems (inverters in PV systems, for instance) but this type of systems are considered equivalent to synchronous generators.
Limits for DC injection into AC grid	No absolute limit for maximum allowable DC current level is

	given in the law.
Requirements regarding flicker	No reference is made about this subject (in the IPP law). The local utility may specify levels in accordance with the local grid requirements.
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	Mandatory. External, accessible by the utility personel.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	There is no specific reference to fast reclosing.
Behaviour at startup or at restart after automatic disconnection	The IPP reclosing can only be done: 1. 3 minutes after the grid reclosing; 2. When the grid voltage is 80% Un or superior; 3. In case of multiple generators a 15 s gap between each one reposition is mandatory.
TRANSFORMERLESS INVERTERS	There is no specific reference to Transformerless Inverters
Special protection against electric shock (e.g. DC sensitive residual current device)	- - - - -
Limits regarding high-frequency capacitive leakage currents	- - - - -
Other safety requirements (yes /no; if yes, specify	SEE Other Protection Devices

ISLANDING PROTECTION	No reference is made (in the IPP law) for this phenomenon. The co-ordination between the IPP and the electrical grid must consider situations of grid disconnection, for maintenance and repair, in order to ensure the necessary safety conditions.
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	- - - -
Required islanding detection methods (active / passive methods required by standard or electric utilities	- - - -
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	The transient voltage drop in the grid caused by the connection of asynchronous generators will not exceed: • 5% in case of hydroelectric or thermoelectric plants • 2% in case of wind generators. No special reference is made for PV inverters. The grid quality levels for Voltage are • Over Voltage: 1,15 Un • Under Voltage: 0,85 Un Un = Nominal Voltage

	• LV - 230/400 V • MV - 15 and 30 kV • HV - 60 kV (distribution) • VHV - 150, 220 or 400 kV (transmission)
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	50Hz more or less 0.25Hz (0,5%)
External accessible disconnecting switch for utility (mandatory / not necessary)	Mandatory
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	The IPP reclosing can only be done: 1. 3 minutes after the grid reclosing; 2. When the grid voltage is 80% Un or superior; 3. In case of multiple generators a 15 s gap between each one reposition is mandatory.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	- - - --
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	- - - - -
SYSTEM DESIGN	The Law as well as the Technical Guide published by the Governement's General Directorate of Energy, define some rules applicable to all Independent Power Producers Systems.
DC voltage level (max. allowable open circuit voltage according to standard)	Not explicitly limited.
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Not explicitly limited.
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Besides the specific rules mentioned in the Technical Guide, the IPP must comply with the general rules applicable to protection and safety (eg. ground fault protection devices). In the case of interconnection with the low voltage grid, the generators neutral conductor should be connected to the low voltage grid neutral conductor.
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not explicitly limited.
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	Not explicitly mentioned.
Protection against electric shock on AC side	The general protection devices usually installed in the electrical systems should also be installed in the IPP systems.

Cabling layout (Cabling layout design rules e.g. for lightning protection)	Not mentioned
Special requirements concerning mechanical fixing / mechanical protection of cables	Not mentioned
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	All the IPP systems should use dedicated branches or branches only used by other IPP systems (eg.a dedicated branch can be used by two wind farms if the cable section is able to support the injected power).
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Safety devices and procedures should be implemented, envisaging the equipment and people protection. There is no specific requirements in the law.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Not mentioned.
Other Protection Devices	The IPP must be equipped with protective devices which ensure its fast disconnection when troubles occur. The "Technical Guide" indicates a possible group of protective devices for Low (LV) and Medium Voltage (MV) connections: • LV (fuses are commonly used): · Over Voltage 1,15Un; ≤ 0,1s · Under Voltage 0,85Un; ≤ 0,1 - 1,0s · Over Frequency 50,25Hz; ≤ 0,1s · Under Frequency 49,75Hz; ≤ 0,1s . Time Overcurrent 1,3In 1,0s • MV (normally relays and switchgears) · Over Voltage 1,15Un; ≤ 0,1s · Under Voltage 0,85Un; ≤ 0,1 - 1,0s · Over Frequency 50,25Hz; ≤ 0,1s · Under Frequency 49,75Hz; ≤ 0,1s . Time Overcurrent 1,3In 1,0s . Zero Sequence Over Voltage 3 - 36% Un ≤ 0,1 - 1,0s If the grid has automatic reclosing, a co-ordination must be established between the two systems.
AC MODULES	There is no specific mention to AC MODULES
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules
Difference in installation requirements	Nothing mentioned.
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body;	SEE: Procedure for connection of PV systems to the grid

documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems and all the other IPP systems according to the Law 168/99, providing the technical conditions are met. Tariffs paid for electricity fed into the grid are specified in the Law 168/99: • Rates are between 0,055 and 0,065 Euro / kWh. Different meters for the energy supplied by the IPP and for the energy consumed from the utility grid are mandatory.
FURTHER LITERATURE **NORMATIVE REFERENCE**	The Law 189/88 and the Law 313/95 (IPP law) were recently revised to conform to the new national electric system legal framework and some articles were modified. The new IPP law is the 168/99 and the major difference is in the calculation of buy-back rates, which include now the environmental benefits of Renewables (green tariff). The specific technical requirements for grid connection are also detailed in the "Technical Guide for Independent Electric Producer Power Plants", published by the *Direcção Geral de Energia* (DGE), the Government's General Directorate for Energy. In all the aspects not specifically mentioned in these documents, the European Standards are applied.
Figure of a typical small grid-connected PV system in your country	

Switzerland

COUNTRY	Switzerland
Person filling in this questionnaire	Daniel Ruoss / Sergio Taiana
STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	• ESTI Nr. 233.0690 'Photovoltaische Energieerzeugungsanlagen – Provisorische Sicherheitsvorschriften' ("Photovoltaic power generating systems – safety requirements draft") • VSE Sonderdruck Abschnitt 12 'Werkvorschriften über die Erstellung von elektr. Installation' Elektrische Energieerzeugungsanlagen Completes VSE 2.8d-95
Adress where copies of the standard can be obtained	Eidgn. Starkstrominspektorat ESTI Luppmenstr. 1 8320 Fehraltorf Tel: 01 956 12 22 Fax: 01 956 11 22 Verband Schweizerischer Elektrizitätswerke VSE Gerbergasse 5 Postfach 6140 8023 Zürich Tel: 01 211 51 91 Fax: 01 221 04 42
Date of last change	ESTI: June 1990 VSE: 1997
Topics covered by standard	PV systems – both stand alone and grid connected
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	Yes, for the ESTI guidelines. An update is in work and should update the lightning protection and also include AC- modules.
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	No actual limit is specified. The standard only deals with interconnection to the low voltage grid, so that the maximum size of PV systems is limited by local grid capacity. Although for the ESTI approval the power range is being separated as followed: • PV installations up to 3.3 kVA on one phase or up to 10 kVA on three phase do not require an approval of the

	ESTI. • Higher than 3.3 kVA on one phase or 10 kVA on three phase do require an approval of the ESTI.
Interconnection voltage mentioned in standard	Low voltage grid only
Limitation of max. PV generator power according to standard	Without specific approval the maximum power is limited to 3.3 kVA on one phase (changing, nowadays a lot depending on the local power utility) or up to 10 kVA on three phase for small installations. If grid conditions permit, larger systems may be connected to the low voltage grid with the approval of the ESTI (federal high current inspectorate).
Procedure for connection of larger PV systems to the grid	Request at ESTI, which then determines if grid is suitable for suggested power.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules (test certificate required)	EN 61215 (IEC 1215), ISPRA 503
cables (one cable with two conductors / two independent cables, quality insulation strength	Not explicitly specified. In Switzerland it is common practice to use two independent DC cables from the PV generator to the inverter. Each cable is in isolation class II (double insulation). Cables have to be selected according to local environmental conditions. Special care has to be taken to use UV resistant cables with high mechanical strength. A Swiss cable manufacturer (Huber & Suhner) introduced several years ago a so called 'Solarcable' available with 2.5 mm^2 or 4 mm^2, which is in almost all installation applied.
String diodes (necessity, location, current rating,	String diodes are not necessary for installations with only one string. When more strings are connected in parallel, string diodes may be omitted if - only modules of the same type are used - modules are of protection class II type - manufacturer certifies that modules can withstand 50% of the module short circuit current in the direction opposite to normal current flow => similar to the regulations in Austria
DC fuses (necessity, location	DC fuses are not necessary for installations with only one string. If more strings are connected in parallel then - each string has to be protected by fuses - OR each string must be able to carry the total maximal short circuit of the generator
Junction box	Must be isolation class II
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Mandatory for one and three phase inverters. DC circuit breaker must be capable of being operated under load, i.e. must be able to switch DC short circuit current of PV generator. Exception: not required for AC modules and string inverter. In connection with Multi- contact connectors the string inverters have to be labelled as followed: 'Before disconnecting with the Multi-connectors please switch

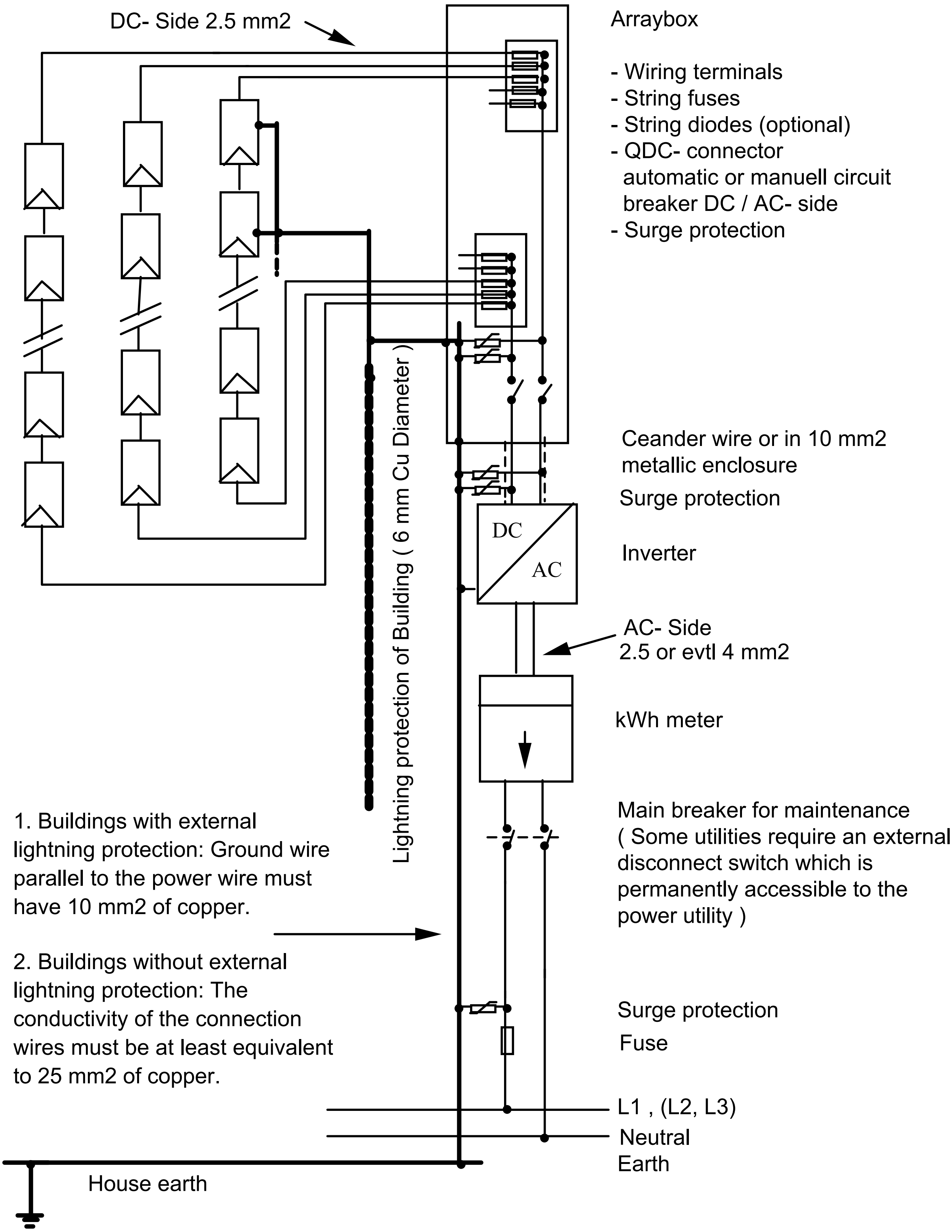
	off the AC side!'
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Overvoltage protection devices have to be installed directly at inverter terminals. Most inverter manufacturer did include an overvoltage protection into the inverter.
INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter: EN 61000-3-2 No specific reference to multiple inverter systems
EMC: limits regarding conducted emissions	EN 50081-1 / EN 55014
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	Not mentioned in the standard Usually requirement by local utility that power factor is between 0.9 and 1 inductive. If P_{AC} > 10% of $P_{nominal}$ then power factor > 0.9
Limits for DC injection into AC grid	No absolute limit for maximum allowable DC current level is given in the standard. A recommended value for the DC component on the AC side would be 1% of $I_{Nominal\ AC}$.
Requirements regarding flicker	Not mentioned in the standard. But a recommendation is being used 'Empfehlung für die Beurteilung von Netzrückwirkungen' issued by the SEV and VEÖ
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	A disconnector (not external accessible!) is mandatory for one or three-phase inverters feeding into the grid. But the device can be built in (electrical main frame) before the net meter and some utilities require also one after the net meter.
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Not specified in the standard
Behaviour at startup or at restart after automatic disconnection	Inverter must check grid voltage, frequency and impedance for allowable values. Only after all parameters are within the limits re-connection to the grid may occur. No waiting time is specified in the standard; however, all utilities require a waiting period of minimum 20 seconds.
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the standard
Limits regarding high-frequency capacitive leakage currents	Not mentioned in the standard
Other safety requirements (yes /no; if yes, specify	Not mentioned in the standard
ISLANDING PROTECTION	
Location of protection device (external / internal to inverter	Protection may be either internal to the inverter or an independent device (over- under voltage and frequency

may it be part of inverter electronics / must it be an independent device)	detection device controlling a switch, either manually or automatically reclosing) installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	Currently two methods are used but both methods are not recommended: 1) ENS (impedance measurement method): if grid impedance is > 1,75Ω OR grid impedance jump > 0,5Ω is detected then inverter must disconnect within 5 seconds. Voltage and frequency limits see below. 2) In case of single phase inverter feeding into a three-phase grid: measurement of phase-to-phase voltages (400V) and shutdown in case of undervoltage (any phase-to-phase voltage below 80% of nominal) AND measurement of phase-to-neutral voltage with shutdown in case of overvoltage (> 110% of nominal) Especially method no. 1 (impedance measurement method) is not absolutely secured and it has been shown, that 100% safety cannot achieved. Several measurements on the same phase can influence eachother. The ENS (impedance measurement) test method is nationally not accepted. Switzerland recommends: Measurement of net voltage (one phase) and shutdown in case of frequency shift. (E.g. in the US, Japan and Holland)
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	230V +15%/ -15% Reaction time: 0,2 seconds
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Frequency range is 50Hz +/- 1Hz Reaction time: 0,2 seconds
External accessible disconnecting switch for utility (mandatory / not necessary)	Varies from one power utility to another. In most case not required anymore, some still do order an external accessible disconnector. A disconnector (not external accessible!) is mandatory for one or three-phase inverters feeding into the grid. But the device can be built in (electrical main frame) before the net meter and some utilities require also one after the net meter (usually built in the inverter).
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	Not specified in the standard. Utilities usually require over 20 seconds.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	The ENS (impedance measurement) test method is nationally **not** accepted.
Authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	Berufsgenossenschaft für Feinmechanik und Elektrotechnik, Cologne, Germany TÜV Rheinland, Cologne, Germany Bundesforschungs- und Prüfzentrum Arsenal, Vienna, Austria
SYSTEM DESIGN	
DC voltage level	The open circuit voltage of an array is limited by following

(max. allowable open circuit voltage according to standard)	formula: $V_{open\ array} = (V_{module\ test} – 1000\ V) / 2$ The test voltage of a module minus 1000 V divided by 2.
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Plus and minus connector are not grounded! (The PV array is with the resistor of the varistor symmetrical.) By PV arrays with transformerless inverters grounding is forbidden.
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	A ground fault detection device can be installed. But in most installation it was not applied yet.
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not required
Protection against electric shock on DC side (e.g. Safety Extra Low Voltage / Insulation class II modules)	DC voltage < 120V: no special measures required DC voltage > 120V: - use of solar modules with protection class II and consequent use of class II equipment for the DC side (cables, switches, junction box, etc) => grounding on the DC side is mandatory if applicable (e.g. laminates) otherwise just the inverter and the rest of the electrical installation
Protection against electric shock on AC side	No additional measures on top of the already implemented safety measures
Cabling layout (Cabling layout design rules e.g. for lightning protection)	No, the responsibility of the consulted engineer
Special requirements concerning mechanical fixing / mechanical protection of cables	No, the responsibility of the consulted engineer
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	May be connected to any existing branch if equipped with ENS or with an automatically disconnector (over-undervoltage, frequency detection relay equipped)
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	If the building is equipped with a external lightning protection system (6 mm CU) all exposed dead metal parts of the PV system (mounting structures, frames etc.) must be connected to it. Then a 10 mm^2 CU cable can be connected to the main equipotential conductor. If no external lightning protection system is available a 25 mm^2 CU cable has to be connected to the main equipotential conductor. On the DC side class C overvoltage protection devices have to be installed between each DC conductor and ground. On the AC side overvoltage protection devices (phase to ground) are recommended, depending on the cable length form the inverter to the grid connection.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Fuses and switches on the DC and AC side which must not be removed/ operated under load must be marked accordingly to the ESTI and local power utility guidelines.
AC MODULES	
Reference to AC modules	No
Differences in required protection	No; this means that all protection measures described above

measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	are also necessary for AC modules. Although some power utilities are simplify more and more their regulation concerning very small installations (e.g. AC- module)
Difference in installation requirements	Nothing mentioned; in practice some measures on the DC side are not being applied anymore (e.g. disconnecting switch, overvoltage protection on the DC side)
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	All installations have to be authorised by the local electric utility. Usually required: - a description of the inverter and the solar modules - a form for grid connection of the electric power utility Only a licensed electrician may connect the PV system to the grid. Commissioning tests include visual inspection and tests of the anti-islanding measures! If an installation exceeds 3.3 kVA on one phase or 10 kVA on three phase an approval of the ESTI is required. Usually required: - a description of the inverter and the solar modules - a form for grid connection of the ESTI Commissioning tests include visual inspection of the lightning protection and the grid connection. Tests of the anti-islanding measures!
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems. Tariffs paid for electricity fed into the grid vary locally; the minimum rate for the produced electricity is 0.15 SFr. / kWh (around 0.10 EURO / kWh). Separate net meter is in most installation applied. Over 100 power utilities in Switzerland offer their clients the possibility to buy solar power. If a PV plant is installed within a green pricing model, tariff are paid from 0.80- 1.20 SFr. / kWh (around 0.50- 0.75 EURO / kWh). Separate net meter is in mandatory.
FURTHER LITERATURE NORMATIVE REFERENCE	Each power utility has its 'Werkvorschriften' (Utility regulation), which vary slightly to the national guidelines due to local standard. Most are called: 'Richtlinien für den Anschluss und Parallelbetrieb von Erzeugungsanlagen (EEA) mit dem Netz der .....' ("Technical Guidelines for the grid connection and parallel operation of a generation systems with the net of a power utility")
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	PV installation up to 3.3 kWp If only one inverter is applied, no additional and automatic islanding protection device is necessary.

PV residential wiring diagramm for grid connection (<= 3.3 kWp)



Enecolo AG, D. Ruoss
January 23th 2000

United Kingdom

COUNTRY	United Kingdom
Person filling in this questionnaire	Alan Collinson

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	G77 – Recommendations for the Connection of Inverter-Connected Single-Phase Photovoltaic (PV) Generators up to 5kVA to Public Distribution Networks.
Adress where copies of the standard can be obtained	Electricity Association 30 Millbank London SW1P 4RD Tel +44 (0) 207 963 5801
Date of last change	09-02-2000
Topics covered by standard	PV inverters for grid connected systems
If no PV specific standard available: other, more general standard which is applicable for dispersed PV generators [1]	- - - -
Energy sources covered by this standard	- - - -
Date of last change	- - - -
Is any change in the standard forseeable? If yes, please give an approximate date for new standard	- - - -
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	Up to 5kVA, single phase only.
Interconnection voltage mentioned in standard	Low voltage grid only.
Limitation of max. PV generator power according to standard	Up to 5kVA, single phase only for a single installation.
Procedure for connection of larger PV systems to the grid	Larger installations are covered by standard G59, which governs all embedded generators up to 5MW.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules	Not covered by G77
cables (one cable with two conductors / two independent cables, quality insulation strength	Electrical wiring covered by IEE Wiring Regulations. Revisions to these regulations are being considered to include more on PV-specific issues.

String diodes (necessity, location, current rating,	Not covered by G77.
DC fuses (necessity, location	Not covered by G77.
Junction box	Not covered by G77.
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability yes /no	Not covered by G77.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	Not covered by G77.

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter, or single installation: EN 61000-3-2 (up to 16 Amps) and IEC 61000-3-4 (>16 Amps). G5/3 also applies (limits for harmonics in the UK electricity supply system.
EMC: limits regarding conducted emissions	EN 50081-1
EMC: limits regarding radiated emissions	EN 50081-1
EMC: limits regarding immunity	EN 50082-1
Requirements regarding power factor	G77: 0.95 leading (i.e. VARs absorbed by the inverter) to unity
Limits for DC injection into AC grid	Use of an isolation transformer is recommended. A DC injection detection device with inverter disable is required for transformerless inverters, the maximum DC current limit is 5mA.
Requirements regarding flicker	In accordance with EN 61000-3-3 and Engineering Recommendation P28.
AC Disconnecting switch for maintainance work (external / internal to the inverter accessibility requirements purpose)	Covered by IEC 1727 (1995) Characteristics of the Utility Interface (section 5.8).
Requirements for inverter behaviour in case of fast reclosing (i.e. reclosing within 300ms or less)	Disconnect within 5 seconds of loss of supply. Also, capable of withstanding an out-of-sync reclosure taking place within 5 seconds of loss of supply.
Behaviour at startup or at restart after automatic disconnection	Inverter must check grid voltage and frequency for allowable values. Only after all parameters are within the limits can re-connection to the grid occur after a further delay of at least 3 minutes.
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned specifically in G77
Limits regarding high-frequency capacitive leakage currents	Not mentioned specifically in G77
Other safety requirements	DC monitoring to limit injected DC to less than 5mA.

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Protection may be either internal to the inverter or an independent device installed between inverter and connecting point to the grid
Required islanding detection methods (active / passive methods required by standard or electric utilities	A recognised loss of mains technique is required, such as vector shift or frequency shift. Active techniques that distort the voltage waveform beyond harmonic limits or that inject current pulses are not allowed.
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Fixed (i.e. non-adjustable by the user) 230V +10% 230V -10%
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Fixed (i.e. non-adjustable by the user) 50Hz +1% 50Hz – 6%
External accessible disconnecting switch for utility (mandatory / not necessary)	Not covered in G77.
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	At least 3 minutes.
Accepted standardised Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	Yes. Part of the G77 Type Approval tests in G77 Appendix.
authority/ institute authorised to perform such a test and issue a certificate (name, adress)?	University of Southampton (Dr Tom Markvart)
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	Not covered by G77
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	Not covered by G77
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	Not covered by G77
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	Not covered by G77
Protection against electric shock on DC side	Not covered by G77

(e.g. Safety Extra Low Voltage / Insulation class II modules)	
Protection against electric shock on AC side	Not Covered by G77. Covered by IEE Wiring Regulations.
Cabling layout (Cabling layout design rules e.g. for lightning protection)	Not covered by G77
Special requirements concerning mechanical fixing / mechanical protection of cables	Not covered by G77
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	Not explicitly stated in G77, although diagram shows connection between import/export meters and consumer unit.
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Earthing requirements in accordance with BS 7430 (1991) Code of Practice for Earthing and BS 7671 Requirements for Electrical Installations.
Labelling, Warning Messages (at which points are warning messages required; what is their purpose	Labelling at service termination, meter position and isolation switch to indicate the presence of on-site generation and the point of isolation. Also, a circuit diagram showing the relationship between the inverter equipment and the supply, summary of protection settings, contact telephone number of equipment installer/supplier/maintainer.
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	No
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	No; this means that all protection measures described above are also necessary for AC modules.
Difference in installation requirements	No
AUTHORISATION PROCEDURE	
Authorisation procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islandig test certificate etc. ; Tests at commissioning	Installations need to be authorised by the local distribution network operator, who will agree on-site commissioning tests and who may also want the opportunity to witness the commissioning tests. The use of a type approved inverter simplifies the authorisation process. A connection agreement also needs to be in place with the local Distribution Network Operator and an appropriate supply agreement with an electricity supplier if any export settlement is required.
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Electricity suppliers are not obliged to buy electricity produced by PV systems. Note: The cost of two-way metering normally negates any benefits in exporting units. Meter fraud is also an issue for two-way metering

FURTHER LITERATURE NORMATIVE REFERENCE	
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

USA

COUNTRY	United States of America
Person filling in this questionnaire	Ward Bower

STANDARDS AND GUIDELINES	
Title of relevant national standard for small grid-connected PV systems [1]	_Note there is not a single national standard._ *These apply.* *National Electrical Code®*, NFPA 70; IEEE Std 929-2000 "Recommended Practice for Utility-interface of Photovoltaic Systems." IEEE Std 519-1992 "Recommended Practices for Harmonic Control in Electrical Power Systems.' UL1741 "UL Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems." UL1703 "UL Standard for Flat-plate Photovoltaic Modules and Panels." ANSI C84.1-1995, "Electric Power Systems and Equipment - Voltage Ratings (60 Hertz) Accredited Standards Committee C2-1997, "National Electrical Safety Code® (NESC®) Also others for related equipment and hardware
Address where copies of the standard can be obtained	IEEE Standards can be purchased from Institute of Electrical and Electronics Engineers Customer Service; 445 Hoes Lane, PO Box 1331; Piscataway, NJ 08855-1331; Telephone 908-981-0060. UL Standards can be purchased from Underwriters Laboratories Inc. at 333 Pfingsten Road; Northbrook, IL 60062-2096; Telephone 847/272-8800 The National Electrical Code can be purchased form most bookstores or from the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269; Telephone 617/770-3000. ASCI Standards may be purchased from ASTM at 1916 Race Street; Philadelphia, PA 19103-1187; Telephone 215/299-5400.
Date of last change	1999-01-01 (*NEC®);* Approved 01-01-2000 (IEEE Std 929-2000); Published 1999-05-07 (UL1741) [Currently being updated] 1993- - (1999-12-10 latest) but now under revision (UL1703)
Topics covered by standard	*NEC®* Covers all electrical installations. Article 690 is specific to PV. IEEE Std 519-1992 covers harmonic requirements. IEEE Std 929-2000 covers utility interconnection requirements. The UL documents are used to test and list modules and hardware for safety. {List is a term used that designated tested according to a specific standard and then included on the list of certified hardware.
If no PV specific standard available: other, more general standard which is applicable for distributed PV	Some utilities still use their own internally-generated distributed generation interconnection requirements. Some utility-installed systems installed in fenced areas follow the

generators [1]	National Electrical Safety Code® (C2-1997) that is specific to "behind the fence" utility-controlled installations.
Energy sources covered by this standard	The *NEC*® now covers conventional installations and generation for uninterruptible power supplies, battery storage, and PV. The *NEC*® is being revised for the 2002 edition and a new Article 691 is proposed for fuel cells. Other Articles for fuel cells, micro-turbines, etc. are expected to follow. The IEEE Std 929-2000 is specific to PV but is expected to be superceded in the future by a new IEEE (1547) standard for all distributed generation.
Date of last change	- - - -
Is any change in the standard foreseeable? If yes, please give an approximate date for new standard	The NEC® is revised on a three-year cycle. All proposals have already been submitted and panel actions initiated for the 2002 edition. IEEE documents are updated every 5 years. A new IEEE Par 1547 has been prepared to cover all distributed generation and the document is being written. UL standards are amended as needed. UL1741 is currently being amended to correlate with the IEEE Std 929-2000 standard. Also UL1741 will be modified to cover inverters for all distributed generation. UL1703 is being revised to be correlated with NEC (expected 2000-05-05)
FRAMEWORK OF STANDARD	
Power range of individual systems covered by standard	(NEC®) No limits are specified. The code deals with installation requirements and safety and has requirements for several voltage categories. IEEE Std 929-2000 deals with all systems, but defines small systems at 10kW and less and intermediate-size at 10kW through 500kW. UL standards can be adapted or modified for any size hardware.
Interconnection voltage mentioned in standard	No limits for NEC or IEEE Std 929-2000. Generally residential systems connect to the low voltage distribution at 120/240 volts. Commercial systems may connect in a variety of single- an three-phase configurations. Commercial voltages are generally 120/240V-1-phase, 208V-3-phase, 480V-3-phase but others may be used. ANSI C84.1-1995, "Electric Power Systems and Equipment - Voltage Ratings (60 Hertz)" applies for voltage limits in each of the operating ranges.
Limitation of max. PV generator power according to standard	US standards do not specify a generated-power maximum, but utilities may impose limits based on feeder and transformer sizes. All standards are superceded and the utility may disconnect when generation begins to affect stability or regulation of the utility grid.
Procedure for connection of larger PV systems to the grid	This depends on the utility. Generally a project or application is submitted to the utility. After review and approval, and determination of suitability for distributed power on the grid, the installer and utility work to meet requirements. Utility may require special protection equipment on any system, but net metering laws are now altering that to be limited to larger (e.g.>100kW) systems.

ELECTRICAL REQUIREMENTS	
EQUIPMENT	
PV modules	(Listing is generally required by the NEC for grid connected systems.) Both IEEE1262 "IEEE Recommended Practice for Qualification of Photovoltaic Modules and UL1703 "UL Standard for Flat-plate Photovoltaic Modules and Panels." apply. Both are currently being reviewed for correlation. Also IEC61215 " Design and Type Approval of Crystalline Silicon Terrestrial PV Modules" is used for qualification of modules with non-domestic requirements.
cables (one cable with two conductors / two independent cables, quality insulation strength	All external, exposed cables, cable sizes, insulation types and routing are specified in the NEC. One of the current-carrying conductors is required to be grounded and special rules apply for switching or disconnecting the grounded conductor. Internal cables (in listed hardware) are specified by UL standards. Multi-conductor cables are allowed but it is common practice to use two independent DC cables from the PV generator to the inverter. The cables are run parallel and near to each other in a common conduit or tray. Flexible cables are allowed on tracking systems. Sunlight resistant insulation on cables is required when exposed to UV even when shaded by the PV.
String diodes (necessity, location, current rating,	String diodes are not required for installations. The NEC allows the use of string (blocking) diodes but does not require them. When strings are connected in parallel, string diodes may be omitted if: - modules and conductors are protected by fuses or overcurrent devices, (the smallest required fuse applies) - the UL listing label indicates maximum reverse current through the PV module and that value cannot be exceeded. Note that overcurrent protection for conductors, connectors, and other devices are calculated independently and the lesser value applies.
DC fuses (necessity, location	DC overcurrent protection is not necessary for installations with only one string and when there are no energy storage devices or other sources that may backfeed. If strings are connected in parallel then - each string or module must be protected by overcurrent devices according to the listing label or *NEC* requirements for cable ampacity. - each unprotected module or string must be able to carry the total maximum short circuit of the remainder of the array and any backfeed from other sources. DC fuses may be located near the PV array but must be in an accessible location.
Junction box	Required per *NEC* for wiring requirements. Must be accessible.
DC disconnecting switch (mandatory / not necessary, quality of switch: load break capability	Required for conventional systems with exposed dc wiring. Exception: AC PV modules have no dc fusing or disconnect requirements.

yes /no	The DC disconnecting device may have an interrupting rating less than the current-carrying capacity if it cannot be opened under load. A listed and properly rated connector may be installed as a disconnecting switch.
DC overvoltage protection of inverter (requirements according to standard, local requirements)	All wiring, terminals and devices are required to be rated at or above the maximum system voltage. There is no tolerance when dc voltages are involved. Nominal voltage and ANSI C84.1-1995 ranges apply to ac voltages.

INVERTER	
limits regarding current harmonics (different limits in case of multiple inverters feeding into the grid at a given point? if yes, specify)	For single inverter: IEEE Std 519-1992 and IEEE Std 929-2000. Total harmonic current distortion <5% at rated inverter output. Odd harmonics 3-9 <4% Odd harmonics 11-15 <2% Odd harmonics 17-21 <1.5% Odd harmonics 23-33 <0.6% Odd above 33 <0.3% Even harmonics shall be <25% of odd harmonics listed in each range The reference may be applied to multiple inverter systems but listings use single inverters.
EMC: limits regarding conducted emissions	FCC Chapter 15 Part B
EMC: limits regarding radiated emissions	FCC Chapter 15 Part B
EMC: limits regarding immunity	FCC Chapter 15 Part B
Requirements regarding power factor	IEEE Std 929-2000 specifies > 0.85 (leading or lagging) when inverter output is >10% of rating. Specially designed system may operate outside this limit with utility approval.
Limits for DC injection into AC grid	IEEE Std 929-2000 recommends dc current not greater than 0.5% of the maximum rated output current into the ac interface.
Requirements regarding flicker	The Maximum Borderline of Irritation Curve" is specified in IEEE519.
AC Disconnecting switch for maintenance work (external / internal to the inverter accessibility requirements purpose)	AC Disconnect required per NEC. Must be rated to interrupt the maximum circuit current.
Requirements for inverter behavior in case of fast reclosing (i.e. reclosing within 300ms or less)	IEEE Std 929-2000 and UL1741specifies non-islanding inverter requirements for loss of utility under various conditions of utility voltage. V<50% 6 cycles 50%≤V<88% 120 cycles 88%≤V≤110% Normal Operation 110%<V<137% 120 cycles V>137% 2 cycles
Behavior at startup or at restart after automatic disconnection	IEEE Std 929-2000 specifies the inverter must check grid voltage and frequency for allowable values. Only after all parameters are within the limits for 5 minutes may automatic re-connection to the utility grid occur.

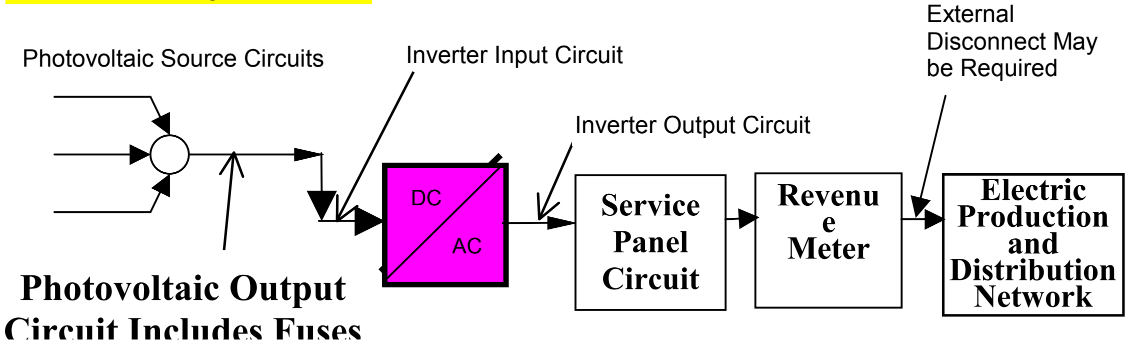
TRANSFORMERLESS INVERTERS	
Special protection against electric shock (e.g. DC sensitive residual current device)	Not mentioned in the standards but grounding requirements of the NEC apply.
Limits regarding high-frequency capacitive leakage currents	Not mentioned in the standards
Other safety requirements (yes /no; if yes, specify	Grounding and DC injection is addressed in IEEE Std 929-2000. A PV system should not inject dc current >0.5% of rated output current into the ac interface under normal or abnormal operating conditions.

ISLANDING PROTECTION	
Location of protection device (external / internal to inverter may it be part of inverter electronics / must it be an independent device)	Generally IEEE Std 929-2000 and UL1741 specify anti-islanding in listed inverters. Wavers for protection may to allow an independent device to be installed between inverter and connecting point to the grid are permitted by some utilities.
Required islanding detection methods (active / passive methods required by standard or electric utilities	Methods are not specified. Requirements for allowable „ "Anti-Islanding" are given in IEEE Std 929-2000 and UL1741. (See above)
AC voltage operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	Specified by IEEE Std 929-2000 and ANSI C84.1-1995, "Electric Power Systems and Equipment - Voltage Ratings (60 Hertz). See above standards for allowable set points and reaction times.
AC frequency operating range (may trip points be adjustable in the field e.g. by software? reaction time?)	IEEE Std 929-2000 recommends 59.3 to 60.5 Hertz where the end points are the set points for tripping the inverter off within 6 cycles. Frequency limits are normally not allowed to be field-adjustable.
External accessible disconnecting switch for utility (mandatory / not necessary)	Required by *NEC*. Recommended by IEEE Std 929-2000 for installations on buildings.
Minimum startup time after disconnection from the grid (waiting time after normal grid conditions have been restored)	IEEE Std 929-2000 requires 5 minutes after proper utility voltage and frequency is established for reconnect after a utility out-of-specification trip.
Accepted standardized Islanding test (is there a nationally approved anti-islanding test whose results are accepted by utilities and authorities)	IEEE Std 929-2000 and UL1741 contain test setup and requirements for listing and utility interconnection recommended practices. The procedure was written so tests conducted on single inverters would apply to multiple inverters connected together.
Authority/ institute authorized to perform such a test and issue a certificate (name, address)?	Qualified electrical testing laboratories that are recognized as having the facilities to test as required by the *NEC.*
SYSTEM DESIGN	
DC voltage level (max. allowable open circuit voltage according to standard)	Not explicitly limited. PV modules are generally listed for operation up to 600 Vdc. Some have been listed to operate at 1000 Vdc. The NEC requires a different class of

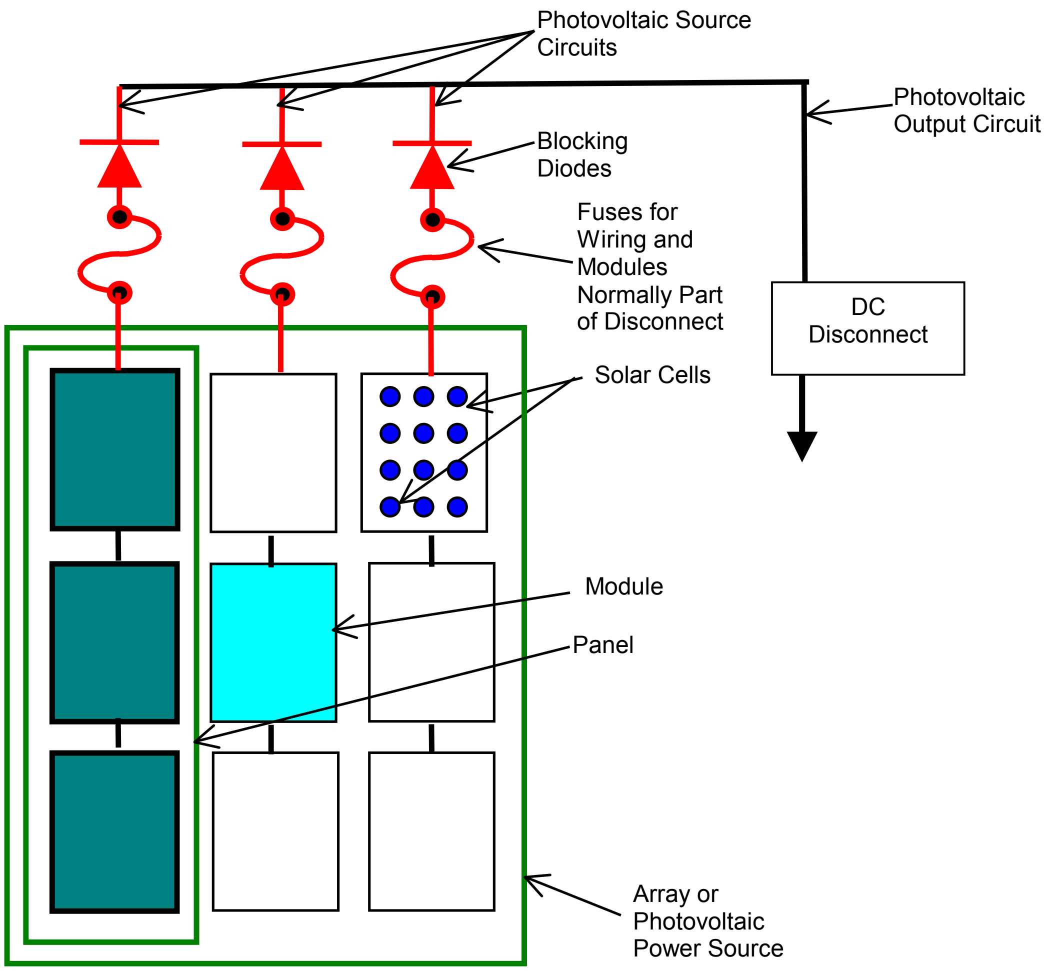
	equipment and installations when voltage exceeds 600 V.
grounding of active conductors on the DC side (mandatory / recommended / forbidden)	If DC voltage is >50V then grounding or "equivalent means" of grounding on the DC side is required by the NEC.
ground fault detection (mandatory / recommended; required reaction in case of ground fault)	A dc ground fault detection device is required for installations on 1 and 2 family roof-mount installations. AC ground fault protection is permitted for AC module installations.
automatic PV array disable in case of ground fault (mandatory /recommended / not required if mandatory: how is array disabled?	For 1 and 2 family roof-mount installations the faulted section of the array must be disabled and the ground fault interrupted per the NEC. It is permitted to disconnect both lines of the faulted array and lift the ground connection as long the condition is indicated.
Protection against electric shock on DC side	DC voltage >50 V the system must be grounded per the NEC. Terminals must be protected and not readily accessible. Connectors must be constructed so that exposed terminals are not energized.
Protection against electric shock on AC side	No additional measures for PV systems other than requirements of the NEC. Requirements include bonding and grounding all non-current-carrying conductive mounting structures, frames, conduit, junction boxes, cabinets, etc.
Cabling layout (Cabling layout design rules e.g. for lightning protection)	Yes. Inductive loops are to be minimized. Grounding requirements provide for a single point of system ground.
Special requirements concerning mechanical fixing / mechanical protection of cables	Cables must be supported per NEC requirements for installation. Conduit is required in some locations. Exposed cables must be protected against accidental damage.
Connecting point to AC grid (dedicated branch for PV inverter / inverter may be connected to existing branch with other loads)	Point-of-interconnection is typically at the service entrance of the utility service. Supply side or load side is permitted by the NEC. Dedicated branch circuits are also required. These circuits are treated as fed from more than one point and are not allowed to include receptacles, lamp holders or other loads..
Lightning protection (earthing requirements, overvoltage protection devices on DC and AC side, external lightning protection system)	Not required in codes and standards for installation but good practice. All exposed dead metal parts of the PV system (mounting structures, frames, conduit, junction boxes, cabinets, etc.) are required to be bonded and connected to the equipment grounding conductor.
Labeling, Warning Messages (at which points are warning messages required; what is their purpose	Fuses and switches on the DC side that must not be removed/operated under load must be marked accordingly. Automatic ground-fault protection systems must be properly labeled per the NEC. Terminals that may be energized from more than one source must be labeled accordingly.
AC MODULES	
Reference to AC modules (yes / no; if yes: specify	Yes. NEC requires specific labeling on the AC module and allows multiple AC modules to be connected on a properly sized dedicated branch circuit.
Differences in required protection measures (if yes, specify; e.g. no mechanical relay required for disconnection etc.)	Yes. Only AC side protective devices are required. The use of an AC ground-fault protection device is permitted in the NEC. Changes are proposed that will eliminate the permissive language for this ground-fault protection.
Difference in installation requirements	AC Modules are to be listed as contained devices with no exposed dc voltages or wiring.

AUTHORISATION PROCEDURE	
Authorization procedure for PV installation (Authorizing body; documentation required by authority e.g. CE declaration, anti-islanding test certificate etc. ; Tests at commissioning	Permits for installation are required. Drawings, schedules, specifications, equipment lists and layout are normal. The local authority having jurisdiction (AHJ) inspects installations. Utility-interactive systems are required to use listed hardware and components. Generally, only a licensed electrician may wire and connect the PV system to the grid. Some states now certify PV installers. Inspections include visual checks for workmanship, materials, components and wiring. Some utilities require a utility inspection before interconnection is approved.
LEGAL SITUATION	
Conditions for feeding energy into the grid (legal requirement for utilities to buy PV electricity? Tariffs for electricity from PV Separate meter for energy fed into the grid?	Utilities are obliged to buy electricity produced by PV systems but net metering laws are only recently providing guidelines for protection equipment required by the utilities, insurance requirements imposed on the PV owner, etc. Tariffs paid for electricity fed into the grid vary widely and depend on state laws and the local utility.
FURTHER LITERATURE NORMATIVE REFERENCE	Various net metering laws that vary from state to state.
Figure of a typical small grid-connected PV system in your country (include information about grounding, required components, protection against electric shock, islanding	

Interactive PV System



DC Component Identification



Conclusions

Generally speaking it can be said that building a PV system and connecting it to the grid has become a more or less standard procedure in many countries. Most safety issues are well-defined and solved and electric utilities have become used to the procedure. Although islanding and islanding prevention are still major topics in many countries, there is a growing realisation that the dangers of islanding were over-estimated in the past. There is a tendency to deal with this problem by establishing standardised islanding tests in which inverters are subjected to a near worst-case situation regarding the likelihood of islanding. If the inverter passes this test successfully, a type test approval is issued, authorising the use of this type of inverter for grid-connected systems.

In the future international harmonisation of standards will be the next challenge. Even as the principal issues are recognised and dealt with, there are many fine details in which the national standards are different. For example, there are hardly two countries, which define identical frequency or voltage windows of operation even if the nominal grid parameters are the same. No sound technical reason can be given for such discrepancies, which are obstacles to easy and cost-effective growth in total PV system capacity around the world.

The past five years have seen tremendous change in technical standardisation on a national level. It seems only natural that the next step should be to harmonise the national regulations on an international level as far as technical boundary conditions allow.

List of Task V participants

The participants of Tasks V are listed below (in alphabetic order and per 2000):

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