

**NRS 097-2-1:2017**

Edition 2.1

# **GRID INTERCONNECTION OF EMBEDDED GENERATION**

## **PART 2: SMALL-SCALE EMBEDDED GENERATION**

### **SECTION 1: UTILITY INTERFACE**

**This document is not a South African National Standard**



## NRS 097-2-1:2017

This rationalized user specification is issued by  
the Technical Governance Department, Eskom,  
on behalf of the  
User Group given in the foreword  
and is not a standard as contemplated in the Standards Act, 1993 (Act No. 29 of 1993).

### Table of changes

Change No.	Date	Text affected
1	July 2020	Changed EMC/EMI requirements in 4.1.13
2	July 2020	Insertion of new Figure 4 (NRS 097-2-1 emission limits)
3	July 2020	Updated normative references to include SANS 216 and SANS 61000-2-2

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## NRS 097-2-1:2017

### Foreword

This section of NRS 097-2 was prepared on behalf of the NRS Association and approved by it for use by supply authorities and other users.

This section of NRS 097-2 was prepared by a working group which, at the time of publication, comprised the following members:

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A Manufacturers' Interest Group (MIG) was consulted on the contents of this section of NRS 097-2 and its comments were incorporated where the working group was in agreement. The MIG comprised the following members:

Anderson A	Energyneering
Bekker B Dr	MLT Drives
Candy R Dr	EON Consulting
de Lange N	Microcare
Dilchert D	Solarcon
Hunkin H	SMA
Lipjes L	SolarEdge
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Monk L	Schneider-Electric
Rahme A	SMA
Schutz A	MLT Drives
Yeshaya A	SolarEdge

NRS 097 consists of the following parts and sections, under the general title Grid interconnection of embedded generation:

Part 1: Distribution standard for the interconnection of embedded generation.

The specification sets out the minimum technical and statutory requirements for the connection of embedded generators to medium-voltage and high-voltage utility distribution networks. The specification applies to embedded generators larger than or equal to 100 kVA. (In course of preparation.)

Part 2: Small-scale embedded generation.

The specification sets out the technical requirements for the utility interface, the embedded generator and/or system and the utility distribution network with respect to embedded generation. The specification applies to embedded generators and or embedded generator systems smaller than or equal to 1000 kVA connected to low-voltage networks.

## **NRS 097-2-1:2017**

Section 1: Utility interface

Section 2: Embedded generator requirements. (To be developed in the future.)

Section 3: Simplified utility connection criteria for low-voltage connected generators.

Section 4: Procedures for implementation and application. (To be developed in the future.)

In the definition of “utility”, reference is made to the “electricity distribution supply authority”. In South Africa this may be Eskom, or the municipal electricity service provider, or any legal entity that distributes electricity to a group of users.

This edition of the specification contains significant updates based on VDE-AR-N 4105 (edition 2011-08). Annexes D, E and F in this specification are parts of the original publication of the German application guide VDE-AR-N 4105 (edition 2011-08) (Annexes A, B and C). The NRS and SABS standards are based on VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V. and licensed under permit number 212.013.

Annexes A and B form an integral part of this document.

## NRS 097-2-1:2017

### Introduction

This section of NRS 097-2 aims to be technology neutral and focuses on the interface between the embedded generator and the utility, although it is expected that the specification will mainly apply to photovoltaic grid connected systems interfaced through static power converter technology. Static power converters are also utilized to convert for example, wind power, micro-hydro power, pico hydro power, battery storage energy and fuel cells to grid compatible electricity. Other conversion technologies are considered where the requirements deviate from those of static power converters. These include induction generators (where the primary resource may for example be wind or hydro) and synchronous generators (where the primary resource may for example be wind, micro-hydro or diesel).

If utilities can allow embedded renewable energy generation to feed into their networks, this provides a relatively easy way for private sector companies, institutions, and individuals to invest their own resources in renewable generation, without having to undertake detailed own load and storage requirement analysis. The grid acts as a storage facility. This allows considerable leverage of financial resources into the overall renewable energy generation capacity development process.

Where national or local governments define renewable energy objectives, and decide to financially incentivize these through attractive feed-in-tariffs or renewable energy certificates or similar trading systems, small-scale grid-connected options have become a very important component of the overall renewable electricity market.

In South Africa, utilities are receiving an increasing number of requests from customers to allow small-scale embedded generation. As given in the South African Distribution Network Code, the utility is obliged to provide an offer to connect the embedded generator under the conditions in "Application for Connection", referred to in 3.2 of the Distribution Network Code. The reader is also referred to the Grid Connection Code Requirements For Renewable Power Plants (RPPS) Connected To The Transmission System (TS) Or The Distribution System (DS) In South Africa.

Licensing / registration requirements shall be in line with the relevant electricity regulation act or applicable NERSA requirements. The onus rests on the customer to ensure that all relevant legislation is adhered to.

A key constraint to the implementation of grid-connected small-scale renewable energy activities in South Africa is the lack of pre-approved, generic standards for utility engineers and system promoters to apply in designing and approving the utility interface. This section of NRS 097-2 and its accompanying parts address this need.

The work on "*Grid interconnection of embedded generation: Small-scale embedded generation*" is based on the following (three key documents):

- a) utility interface (*this document*);
- b) embedded generator requirements, which deal with product type approval, installation requirements and certificate of compliance on the EG customer's side of the meter (a future document); and
- c) simplified utility connection criteria, which deals specifically with the commonly designed unidirectional flow of energy in LV networks, with cumulative impacts of EGs, with substation configuration and metering arrangements (NRS 097-2-3:Edition 1 published in 2014).

In addition, a specification will in the future be developed to provide informative guidelines on the implementation procedures, the application form, the license requirements, the certificate of compliance procedures, the commissioning procedures, where applicable, and documentation requirements for the embedded generator. The document will address legal issues such as agreements and ownership, and also metering and revenues from feed-in tariffs. In the case of the utility, it will provide guidelines for the registration process and the record keeping of embedded generators within utility networks and network spurs.

## **NRS 097-2-1:2017**

NOTE Edition 1 included a clause on uninterruptible power supplies (UPS). However, apart from UPSs connected so that a possibility exists of feeding back into the grid, UPSs falls outside the scope of this document. The clause has therefore been removed. A UPS that is connected such that the possibility exists of feeding back into the grid, i.e. in parallel to the grid, must comply with all the requirements of this document. This requirement is provided in 4.1.

### **Keywords**

alternative supply, embedded generation, metering, utility interface.

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## GRID INTERCONNECTION OF EMBEDDED GENERATION

### Part 2: Small-Scale embedded generation

#### Section 1: Utility interface

##### 1. Scope

This section of NRS 097-2 defines standards for the utility interface for the interconnection of small-scale embedded generation systems to a utility network.

This section of NRS 097-2 applies to embedded generators or embedded generator systems of nominal capacity less than 1000 kVA, connected to a single-phase, dual phase, or three-phase low-voltage networks.

This section of NRS 097-2 aims to provide a practical specification for utilities to facilitate the incorporation of embedded generation on low-voltage networks while ensuring compliance of the utility interface with the requirements documented in this specification. This document does not guarantee that the respective utilities will allow connection of the EG at the customer's preferred location and current terms and conditions; additional requirements may be set by the utility to ensure safety and quality of supply on the network.

This part of NRS 097 does not look at or specify any requirements for the fuel source and or converters of alternate energy sources, i.e. it does not cover specifications for e.g. the following:

- a) PV panels or the installation thereof;
- b) fuel sources, e.g. fuel cells, biogas; and
- c) interfaces (mechanical, electrical or different) between the primary fuel source and the inverter or generator, e.g. batteries, gearbox, clutch etc.

The *Grid Connection Code Requirements For Renewable Power Plants (RPPS) Connected To The Transmission System (TS) Or The Distribution System (DS) In South Africa* version 3.0 was approved by NERSA and published in August 2019. The Grid Code documents are also dynamic documents that may change as requirements in the industry evolves, i.e. updated documents will become available at times and are published on the NERSA website.

The Grid Code defines the minimum requirements for any renewable power plant (embedded generator system) in order to connect to the grid or network. Wherever conflict exists between this set of documents and the applicable Grid Code(s) in terms of more strict requirements, the applicable Grid Code(s) will take preference.

NOTE 1 The 1000 kVA value will be revisited and reviewed as the industry evolves.

NOTE 2 This document provides a standard set of specifications for small embedded generators. Compliance with this document does not guarantee that a utility will or can allow connection to the utility network.

NOTE 3 The customer is advised to contact the utility to discuss potential further connection requirements.

##### 2. Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this section NRS 097-2. All documents are subject to revision and, since any reference to a document is deemed to be a reference to the latest edition of that document, parties to agreements based on this specification are encouraged to take steps to ensure the use of the most recent editions of the documents listed below. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems.*

IEC 61727, *Photovoltaic (PV) systems – Characteristics of the utility interface.*

SANS/IEC 62109-1, *Safety of power converters for use in photovoltaic power systems Part 1: General Requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems Part 2: Particular requirements for inverters (To be adopted by SABS)*

Transmission Grid Code, *All parts*, available online, [www.nersa.org.za](http://www.nersa.org.za), (Menu links: *Electricity > Technical Standards > Transmission Grid Code*).

Distribution Grid Code, *All parts*, available online, [www.nersa.org.za](http://www.nersa.org.za), (Menu links: *Electricity > Technical Standards > Distribution Grid Code*).

RPP Grid Code, *Grid connection code for renewable power plants (RPPs) connected to the electricity transmission system (TS) or the distribution system (DS) in South Africa*, available online, [www.nersa.org.za](http://www.nersa.org.za), (Menu links: *Electricity > Technical Standards > Transmission Grid Code OR Electricity > Technical Standards > Distribution Grid Code*).

SANS 211, *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement*.

SANS 50065-1, *Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz Part 1: General requirements, frequency bands and electromagnetic disturbances*.

SANS 216-1-1/CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

SANS 216-1-2/CISPR 16-1-2, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements*

SANS 216-2-1/CISPR 16-2-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

SANS 61000-2-2, *Electromagnetic compatibility (EMC) Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

SANS 60947-2/IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*.

SANS 10142-1, *The wiring of premises – Part 1: Low-voltage installations*.

*Act No. 85 of 1993 of Occupational Health and Safety Act, as amended by, Occupational Health and Safety Amendment Act, No. 181 of 1993.*

*Electrical Installation Regulations, 2009: Government Notice. R: 243, Government Gazette, 6 March 2009.*

*Electrical Machinery Regulations, 2011: Government Notice. R: 250, Government Gazette, 25 March 2011.*

SANS 474:2009/NRS 057, *Code of practice for electricity metering*.

SANS 473:2013/NRS 071, *Automated meter reading for large power users*.

SABS 1186-1, *Symbolic safety signs Part 1: Standard signs and general requirements*.

NRS 071, *Code of smart metering*

NRS 048-2, *Electricity supply – Quality of supply – Part 2: Voltage characteristics, compatibility levels, limits and assessment methods.*

NRS 048-4, *Electricity supply – Quality of supply – Part 4: Application practices for licensees.*

EN 50438, *Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks.*

CLC/TS 50549, *Requirements for generating plants to be connected in parallel with distribution networks.*

EA Engineering Recommendation G83/1-1: Amendment 1-June 2008, *Recommendation for the connection of small-scale embedded generator systems (up to 16 A per phase) in parallel with the public low-voltage distribution networks.* Available for purchase from the World Wide Web at <[www.ena-eng.org/ENA-Docs](http://www.ena-eng.org/ENA-Docs)>.

IEEE 1547, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.*

IEC 62116:2008 (ed. 1), *Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.*

VDE-AR-N 4105:2011-08, *Power generation systems connected to the low-voltage distribution network.*

### 3. Terms, definitions and abbreviations

For the purposes of this specification, the following terms, definitions and abbreviations apply.

#### 3.1 Terms and definitions

**alternative supply (often called backup supply):** power system that operates as a backup supply during loss-of-grid conditions, consists of storage (in the form of batteries, fossil fuels or fuel cells) and a synchronous static power converter or a generator which is able to operate in stand-alone mode

NOTE Examples of a generator that operates in stand-alone mode are a UPS or a diesel generator.

**asynchronous generator,** induction generator: type of rotating electrical generator that operates at a speed not directly related to system frequency, the machine of which is designed to be operated in parallel with a network that contains other generation as the output voltage, and frequency is determined by the system to which it is connected

NOTE A mains-excited asynchronous generator will cease generation on disconnection of the parallel connection. Power-factor corrected and self-excited asynchronous generators are derivatives of the mains-excited generator.

**bi-directional meter:** meter that measures the active energy (Wh) flow in both directions (import and export) and either displays the balance of the imported and exported energy in a single register meter (net metering) or displays both imported and exported energy in separate registers

NOTE Active energy flow in a meter is measured in watt-hours (Wh).

**central disconnection device:** separate device that disconnects all phases and neutral of the embedded generator or group of generators operating in parallel with the utility network from the network in response to an out-of-bounds condition

**controllable generator:** in this part of NRS 097, a controllable generator is a generator that shall be capable of receiving signals and act accordingly

NOTE 1 Reactive power control requirements are standard requirements in accordance with this specification and does not imply a controllable generator.

**customer network:** electrical installation downstream of the electricity consumption meter, usually

on the customer premises

**NOTE** This network can be backed up and operated as an island behind the customer breaker, provided that it complies with the safety and protection requirements of this specification as well as all parts of NRS 052 or other specifications for stand-alone generator systems.

**disconnection device:** device that disconnects all phases and neutral of the embedded generator operating in parallel with the utility network from the network in response to an out-of-bounds condition

**NOTE 1** This device incorporates the controls, relays and breakers.

**NOTE 2** For static power converter generators, these are often incorporated in the generator.

**electromagnetic compatibility (EMC):** the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. [IEC 61000-1-1]

**embedded generator, EG:** one or more energy generation sources that includes the energy conversion device (devices), the static power converter (converters), if applicable, and the control and protection gear within a customer's network that operate in synchronism with the utility's supply

**NOTE 1** Examples of energy conversion devices are photovoltaic modules, fuel cells, induction generators or synchronous generators.

**NOTE 2** Embedded generation is also referred to as "distributed" or "dispersed generation" in other documents.

**NOTE 3** The embedded generator may include storage devices, such as lead-acid batteries in which case the size of the generator (typically inverter) is defined as the maximum change in apparent power flow at the point of utility connection for a generator trip (or rapid reduction in output) when generating at full active power output. This means that a part of the generator's size is effectively hidden from the network (behind the meter) by the same size load that will be removed from the grid along with a trip of the generator.

**feed-in tariff (renewable energy); (RE); FIT:** mechanism to promote the deployment of renewable energy that places an obligation on specific entities to purchase the output from qualifying renewable energy generators at pre-determined premium prices

**NOTE** The tariffs are structured according to the renewable energy technology employed and allow the owner to incur reasonable profits from investing into renewable energy generation.

**generator size:** the maximum capacity of a generator unit or group of generator units in an installation in volt-ampere [VA]

**installation:** the same as "electrical installation" as defined in SANS 10142-1

**island:** state in which a portion of the utility's or customer's network, containing load and generation, continues to operate isolated from the rest of the grid; the generation and loads may be any combination of customer-owned and utility-owned

**loss-of-grid:** condition in which supply from the utility network is interrupted for whatever reason

**low voltage; LV:** nominal voltage levels up to and including 1 kV

**NOTE** For the purposes of this specification, the focus is on systems connecting to 230 V a.c. for single phase, 460 V a.c. line-to-line for dual phase and 400 V a.c. line-to-line for three-phase.

**parallel operation;** operation of the embedded generator which is synchronized to the grid and operates in parallel to the network

**photovoltaic; PV:** method of generation of d.c. electricity by a device when exposed to solar radiation

**point of common coupling; PCC:** electrical node that is closest to a customer where other customers are or can be connected

**point of connection; POC:** interconnection between the embedded generator and the utility distribution network, referring to the customer side of the meter between the utility network and the customer's installation

**power factor:** ratio of the r.m.s. value of the active power to the apparent power, measured over the same integrating period

NOTE Active power is measured in watts and apparent power in volt-amperes.

**prevention of islanding:** embedded generator's ability to detect loss-of-grid and prevent the condition of unintended islanding

**reference current;  $I_{ref}$ :** value of the r.m.s. input current of the equipment determined according and used to establish emission limits

**rated current of the equipment;  $I_{equ}$ :** input current of the piece of equipment as declared by the manufacturer and marked as such on the rating plate of the piece of equipment or stated in the product documents

**safety disconnect:** independent control system that monitors the utility network conditions and disconnects the a.c. output of the embedded generator from the network for out-of-bounds conditions

**short-circuit ratio;  $R_{sce}$ :** ratio of the network short-circuit level at the POC to the rated apparent power of the equipment

IEC 61000-3-12 definition: characteristic value of a piece of equipment defined as follows:

- a)  $R_{sce} = S_{sc} / (3 V_{LN} I_{equ})$  for single-phase equipment and the single-phase part of hybrid equipment;
- b)  $R_{sce} = S_{sc} / (2 V_{LL} I_{equ})$  for interphase equipment; and
- c)  $R_{sce} = S_{sc} / (V_{LL} I_{equ})$  for all three-phase equipment and the three-phase part of hybrid equipment.

**simple separation:** separation between electric circuits or between an electric circuit and local earth by means of basic insulation

[IEV 826-12-28]

**small-scale embedded generator; SSEG:** embedded generator rated at up to 1 MVA which includes the energy conversion device (devices), the static power converter (converters), if applicable, and the control and protection gear within a customer's network that operates in synchronism with low-voltage networks

NOTE 1 Examples of energy conversion devices are photovoltaic modules, fuel cells, induction generators or synchronous generators.

NOTE 2 Embedded generation is also referred to as "distributed" or "dispersed generation" in other documents.

NOTE 3 The embedded generator may include storage devices, such as lead-acid batteries in which case the size of the generator is limited to the maximum change in active power flow at the point of utility connection for a generator trip (or rapid reduction in output) when generating at full active power output.

**static power converter:** power electronic device that converts variable d.c. or a.c. to grid compatible a.c. either synchronously (able to operate in stand-alone mode) or asynchronously (requires utility interconnection)

**synchronous generator:** type of rotating electrical generator that operates at a speed which is directly related to system frequency and is capable of operating in isolation from other generating plants

**total harmonic distortion; THD:** ratio of the r.m.s. value of the harmonics to the r.m.s. value of the fundamental and is defined as:

$$THD_x = \frac{\sqrt{\sum_{n=2}^{\infty} x_n^2}}{x_1}$$

where

$x_n$  is the r.m.s. harmonic voltage or current of harmonic order  $n$ ;

$x_1$  is the r.m.s. fundamental voltage or current.

**uni-directional meter:** meter that measures the active energy flow in one direction only and ignores the active energy flow in the reverse direction

NOTE Active energy is measured in watt-hours (Wh).

**unsymmetrical voltage:** voltage between any mains conductor (phase or neutral) and the earth. [IEC 61000-2-2]

**uninterruptible power supply system; UPS:** power system that comprises a synchronous static power converter, a charger, switchgear, control circuitry and a means of energy storage (e.g. batteries) for maintaining continuity of electricity supply to a load in the case of a disruption of power supply from an electricity distribution network

**utility:** electricity distribution supply authority (see foreword), in the area of the installation responsible for the electricity network infrastructure

**utility-interconnected inverter:** static power converter connected in parallel to the utility network

**utility network:** electricity distribution infrastructure operated and controlled by the utility

## 3.2 Abbreviations

**a.c.:** alternating current

**AMN:** Artificial Mains Network

**LISN:** Line Impedance Stabilization Network

**CB:** circuit-breaker

**COC:** certificate of compliance

**DB:** distribution board

**d.c.:** direct current

**EA:** electricity association

**E/L:** earth leakage

**EG:** embedded generator

**FIT:** feed-in tariff

**I<sub>ref</sub>:** reference current

**I<sub>equ</sub>:** equivalent current

**I<sub>SC</sub>:** short-circuit current

**PCC:** point of common coupling

**POC:** point of connection

**PV:** photovoltaic

**QOS:** quality of supply

**RCD:** residual current device

**r.m.s.:** root mean square

**RPP:** renewable power plant

**R<sub>SCE</sub>**: short-circuit power to rated power ratio  
**S<sub>SC</sub>**: short-circuit power of the source or fault level  
**SSEG**: small scale embedded generator  
**THD**: total harmonic distortion  
**UPS**: uninterruptible power supply

## 4. Requirements

In South Africa, safety is regulated via the Occupational Health and Safety (OHS) Act, calling on amongst others the electrical installation regulations, which invokes other standards such as SANS 10142-1.

Performance aspects are regulated via international standards, industry specifications and licensing conditions, which include relevant parts of the grid code(s).

In this part of NRS 097, 4.1 deals with performance aspects, 4.2 deals with safety aspects and 4.3 deals with metering.

### 4.1 Utility compatibility (Performance aspects)

#### 4.1.1 General

**4.1.1.1** This clause describes the technical issues and the responsibilities related to interconnecting an embedded generator to a utility network.

**4.1.1.2** The quality of power provided by the embedded generator in the case of the on-site a.c. loads and the power delivered to the utility is governed by practices and standards on voltage, flicker, frequency, harmonics and power factor. Deviation from these standards represents out-of-bounds conditions. The embedded generator is required to sense the deviation and might need to disconnect from the utility network.

**4.1.1.3** All power quality parameters (voltage, flicker, frequency and harmonics) shall be measured at the POC, unless otherwise specified (see annex A).

The power quality to be supplied to customers and influenced by SSEG shall comply with NRS 048-2. This implies that the combined voltage disturbances caused by the specific EG and other customers, added to normal background voltage disturbances, may not exceed levels stipulated by NRS 048-2. The maximum emission levels that may be contributed by SSEG are provided in this document (see 4.1.5 to 4.1.10).

The customer can expect power quality at the POC in line with NRS 048-2. As such, the generator may not contribute significant disturbances to the voltage supplied at the POC. Typical contributions for small customer installations (total installation) are provided in Annex D of NRS 048-4.

NOTE 1 The frequency cannot be changed by a SSEG.

NOTE 2 The utility is responsible for the power quality at the POC, however, the EG is responsible to mitigate power quality exceedances should it be shown to cause excessive power quality levels.

**4.1.1.4** The embedded generator's a.c. voltage, current and frequency shall be compatible with the utility at the POC.

**4.1.1.5** The embedded generator shall be type approved, unless otherwise agreed upon with the utility (see annex A).

**4.1.1.6** The maximum size of the embedded generator is limited by the rating of the supply point on the premises.

NOTE Also see NRS097-2-3.

**4.1.1.7** The utility will approve the size of the embedded generator and will decide on the connection point and conditions. In some cases it may be required to create a separate supply point.

**4.1.1.8** Embedded generators larger than 13,8 kVA shall be of the balanced three-phase type unless only a single-phase network supply is available, in which case NRS 097-2-3 recommendations can be applied based on the NMD.

NOTE 1 This value refers to the maximum export potential of the generation device/system.

NOTE 2 In the case of long feeder spurs the maximum desired capacity of the EG might require approval by the utility and might result in the requirement for a three-phase connection for smaller units.

**4.1.1.9** A customer with a multiphase connection shall split the embedded generator in a balanced manner over all phases if the EG is larger than 4,6 kVA.

NOTE Balancing phases in a multiphase embedded generator is deemed desirable.

**4.1.1.10** Embedded generators or generator systems larger than 100 kVA may have additional requirements, for example, they must be able to receive communication signals for ceasing generation/disconnection from the utility supply, if the utility requires such. Communication facilities shall be provided to utility at no charge for integration with SCADA or other system when required. See Annex G (G.1).

NOTE The RPP Grid Code requires category A3 units to be able to interface with the utility in order to receive stop and start signals.

**4.1.1.11** In line with the current Renewable Power Plant Grid Code, embedded generators smaller than 1000 kVA connected to low-voltage form part of Category A generators, with the following sub-categories:

a) Category A1: 0 – 13,8 kVA;

This sub-category includes RPPs of Category A with rated power in the range from 0 to 13,8 kVA, inclusive of 13,8 kVA.

b) Category A2: 13,8 kVA – 100 kVA; and

This sub-category includes RPPs of Category A with rated power in the range greater than 13,8 kVA but less than 100 kVA.

c) Category A3: 100 kVA – 1 MVA.

This sub-category includes RPPs of Category A with rated power in the range from 100 kVA but less than 1 MVA.

NOTE 1 These sub-categories must be cross-checked with the Renewable Power Plant Grid Code (or other part of the Grid Code where applicable); where applicable, requirements will apply per sub-category and not per sizes defined here.

NOTE 2 Until a separate Grid Code for non-renewable technologies have been compiled and published, relevant categories from this document will apply to non-renewable SSEG.

**4.1.1.12** In accordance with SANS 10142-1, all generators shall be wired permanently.

NOTE 1 Some international companies are distributing so-called “plug-in” generators, where a small PV panel and inverter is connected to the supply circuit via a standard (load) plug. At present such installations are not regarded as safe and in contravention of SANS 10142-1.

NOTE 2 This option will be reviewed when internationally accepted norms are finalised to ensure plugs and plug points are safe when feeding power into the grid as well as additional requirements for such generators or plugs.

**4.1.1.13** Any UPS/generating device that operates in parallel with the grid may only connect to the grid when it complies fully with the requirements of this part of NRS 097. This includes UPS configurations with or without EG.

NOTE The requirement is applicable irrespective of the duration of parallel operation.



**4.1.1.14** Standby-generators are covered by SANS 10142-1.

**4.1.1.15** All generators larger than 100 kVA will be controllable, i.e. be able to control the active output power dependent on network conditions/abnormal conditions. This includes several smaller units that totals more than 100 kVA at a single POC.

**4.1.1.16** Maximum DC Voltage may not exceed 1000V. This is the voltage on the DC side of the inverter, for example when no load is taken and maximum source energy is provided, e.g. peak solar radiation occurs on the solar panels.

#### **4.1.2 Normal voltage operating range**

**4.1.2.1** In accordance with IEC 61727, utility-interconnected embedded generators do not normally regulate voltage, they inject current into the utility. Therefore the voltage operating range for embedded generators is designed as protection which responds to abnormal utility network conditions and not as a voltage regulation function.

**4.1.2.2** The embedded generator shall synchronise (see 4.1.12) with the utility network before a connection is established. The embedded generator shall not control the voltage, unless agreed to by the utility (see annex A).

**4.1.2.3** An embedded generator that operates in parallel with the utility system shall operate within the voltage trip limits defined in 4.2.2.3.2.

#### **4.1.3 Reference source impedance and short-circuit levels (fault levels)**

**4.1.3.1** The impact of the generator on the network voltage and quality of supply levels is directly linked to the (complex) source impedance and short-circuit level. The minimum short-circuit level to which a generator can be connected should be based on the size of the generator as well as the design criteria.

**4.1.3.2** For general purposes of testing and design for potential worst case conditions, a minimum network strength of the following may be assumed:

$Z_{\text{source}} = 1,05 + j 0,32 \text{ ohm}$ , i.e.  $I_{\text{SC}} = 210 \text{ A}$  and  $S_{\text{SC}} = 146 \text{ kVA}$  (three-phase).

NOTE This does not imply a guarantee that the fault level will be more than this at all times. Fault levels less than this may be sufficient for small loads in certain applications.

**4.1.3.3** The maximum network strength will be assumed to be no more than 33 times the rated active power of the generator. The R/X ratio will be assumed between 0,33 to 3.

NOTE 1 In practice, the generators will connect to the network at a wide range of short-circuit ratios. The assumption of a maximum ratio of 33 will allow safe connection of the SSEG in most practical situations.

NOTE 2 The minimum fault level at which the generator may be connected is at the discretion of the manufacturer, provided that the requirements of this specification is met at the specified fault level.

**4.1.3.4** The relevant utility will advise whether equipment may be connected at other network characteristics, i.e. for weaker parts of the network.

**4.1.3.5** The generator documentation and nameplate shall state the reference impedance (complex impedance) and fault level that was used for design and certification and that it is not intended to connect the generator to a network with a higher network impedance than specified for the certification.

NOTE See Annex C (Network Impedance), for more information.

#### **4.1.4 General QOS requirements**

**4.1.4.1** Embedded generators can expect QOS levels on networks to be in line with NRS 048-2. It is expected that the embedded generator will be able to operate continuously under worst-case conditions.

**4.1.4.2** Notwithstanding this, the embedded generator must protect itself from potential excursions beyond NRS 048-2 and ensure fail-safe conditions. Should the embedded generator be unable to operate according to requirements of this document for such excursions, it shall disconnect and cease generation onto the network.

#### **4.1.5 Flicker and voltage changes**

**4.1.5.1** When connected to a network impedance equal to the reference impedance used during certification, no SSEG may generate flicker levels higher than the following:

- a) short-term flicker severity (Pst) = 0,35; and
- b) long-term flicker severity (Plt) = 0,30.

**4.1.5.2** It is anticipated that the utility will plan the connections in line with acceptable flicker limits, i.e. the ratio of the size of the generator to the network strength at the point of connection.

**4.1.5.3** According to VDE-AR-N 4105, no generator shall be connected to a system where generation rejection (i.e. tripping of SSEG while generating at full capacity, regardless of reason) will lead to a voltage change of 3 % or more at the PCC, thereby minimising the potential to exceed rapid voltage change limits.

NOTE 1 A voltage change of 3 % aligns to a ratio of the network fault level to generator size of 33 (ignoring network impedance angle and load power factor).

NOTE 2 Standard connection conditions for customers typically include a maximum flicker contribution in line with annex D of NRS 048-4. Should these flicker levels be exceeded, the customer will be required to put mitigating measures in place as and when required by the utility.

#### **4.1.6 Voltage unbalance**

**4.1.6.1** Under normal circumstances, for single and dual-phase EG, the unbalanced generation may not exceed 4,6 kVA connected between any two or different phases at an installation. Units larger than 4,6 kVA will be split evenly over the available phase connections so that this can be maintained.

NOTE Depending on the network capacity, the utility may impose more stringent conditions.

**4.1.6.2** Three-phase generators may not contribute more than 0,2 % voltage unbalance when connected to a network with impedance equal to the reference impedance.

NOTE Standard connection conditions for customers typically include a maximum voltage unbalance contribution in line with NRS 048-4, Annex D. Should a three-phase customer exceed these voltage unbalance levels, the customer will be required to put mitigating measures in place as and when required by the utility.

#### **4.1.7 Commutation notches**

The relative depth of commutation notches due to line-commutated inverters shall not exceed 5 % of nominal voltage at the POC for any operational state.

#### **4.1.8 DC injection**

**4.1.8.1** The average d.c. current injected by the embedded generator shall not exceed 0,5 % of the rated a.c. output current over any 1-minute period, into the utility a.c. interface under any operating condition.

**4.1.8.2** According to section 4.2.2.5, the generator(s) must disconnect within 500 ms when the d.c. current exceeds this value.

#### **4.1.9 Normal frequency operating range**

An embedded generator that operates in parallel with the utility system shall operate within the frequency trip limits defined in 4.2.2.3.3.

#### 4.1.10 Harmonics and waveform distortion

**4.1.10.1** Only devices that inject low levels of current and voltage harmonics will be accepted; the higher harmonic levels increase the potential for adverse effects on connected equipment.

**4.1.10.2** Acceptable levels of harmonic voltage and current depend upon distribution system characteristics, type of service, connected loads or apparatus, and established utility practice.

**4.1.10.3** The embedded generator output shall have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system.

**4.1.10.4** The harmonic and inter-harmonic current distortion shall comply with the relevant emission limits in accordance with IEC 61727, reproduced in table 1.

**4.1.10.5** The harmonic and inter-harmonic distortion applies up to 3 kHz (60<sup>th</sup> harmonic).

NOTE The harmonic limits above 2,5 kHz and all inter-harmonic limits refer to limits measured in accordance with IEC 61000-4-7.

**Table 1 — Maximum harmonic current distortion as percentage of rated current**

1	2	3	4	5	6
Harmonic order (h)	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$
Percentage of rated current (Odd harmonics)	4,0	2,0	1,5	0,6	0,3
Percentage of rated current (Even harmonics)	1,0	0,5	0,38	0,15	0,08
Percentage of rated current (Inter-harmonics)	0,1	0,25	0,19	0,08	0,03
Total Demand Distortion = 5%					
NOTE 1 Even harmonics are limited to 25 % of the odd harmonic limits					
NOTE 2 Inter-harmonic are limited to 25 % of the odd harmonic limits and adjusted for the 200 Hz band measurement required by IEC 61000-4-7, except for the lower frequencies where the flicker contribution is more likely.					
NOTE 3 Total Demand Distortion = Total Harmonic Distortion					

#### 4.1.11 Power factor

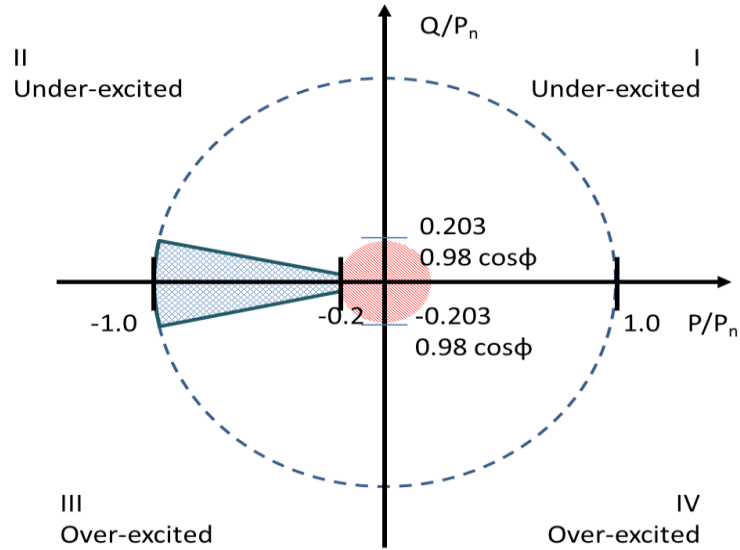
**4.1.11.1** Irrespective of the number of phases to which an embedded generator is connected, it shall comply with the power factor requirements in accordance with 4.1.11.2 to 4.1.11.12 on each phase for system normal conditions when the output power exceeds 20 % of rated active power:

**4.1.11.2** For static power converter embedded generators and synchronous embedded generators of sub-categories A1 and A2, the power factor shall remain above 0,98 as shown in Figure 1. The embedded generator shall operate anywhere in the shaded area of figure 1.

NOTE At the time of publication, this is in contradiction with the RPP Grid Code.

**4.1.11.3** For asynchronous embedded generators of sub-categories A1 and A2, which cannot control the power factor over any range, the power factor shall reach the shaded area of figure 1 within 60 s. The power factor shall remain above 0,98 as shown in figure 1. The embedded generator shall operate anywhere in the shaded area.

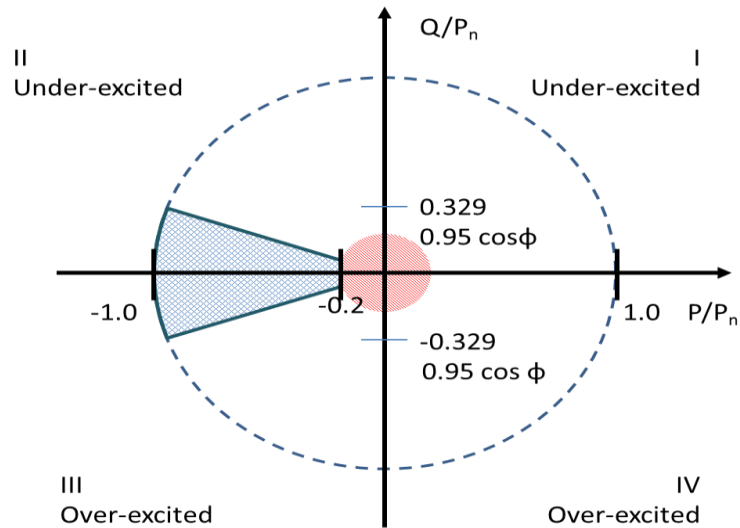
NOTE At the time of publication, this is in contradiction with the RPP Grid Code.



**Figure 1 — Power factor operating requirements for SSEG categorized A1 and A2 (using the load-reference arrows system)**

4.1.11.4 For static power converter embedded generators and synchronous embedded generators of sub-category A3, the power factor shall remain above 0,95 as shown in Figure 2. The embedded generator shall operate anywhere in the shaded area of Figure 2.

4.1.11.5 For asynchronous embedded generators of sub-category A3, which cannot control the power factor over any range, the power factor shall reach the shaded area of Figure 2 within 60 s. The power factor shall remain above 0,95 as shown in Figure 2. The embedded generator shall operate anywhere in the shaded area.



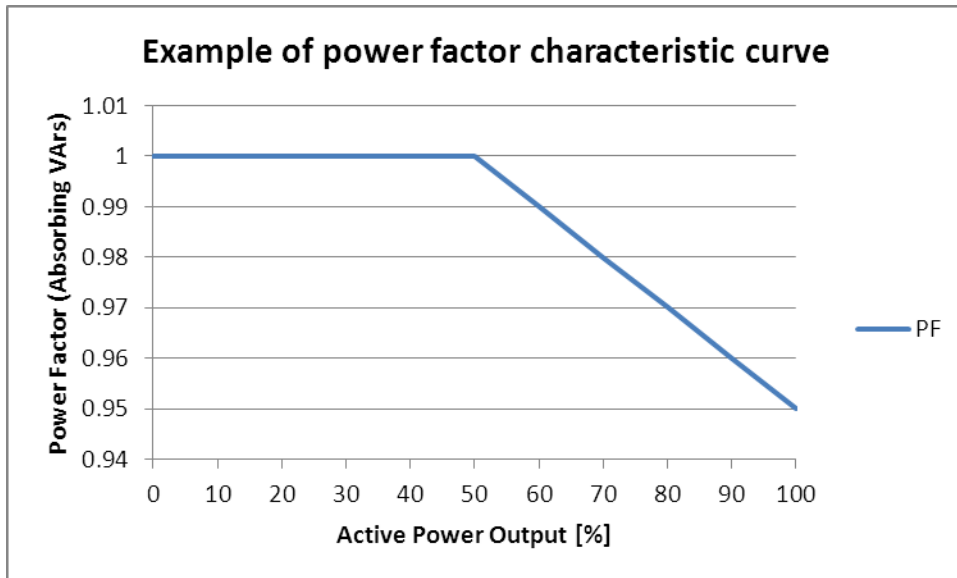
**Figure 2 — Power factor operating requirements for SSEG categorized A3 (using the load-reference arrows system)**

4.1.11.6 Where the EG is capable of controlling the power factor at the POC, the EG should improve the power factor at the POC towards unity.

4.1.11.7 Unless otherwise agreed with the utility, the standard power factor setting shall be unity for the full power output range.

**4.1.11.8** The maximum tolerance on the reactive power setting is 5 % of the rated active power.

**4.1.11.9** For embedded generators of sub-category A3, the power factor shall be settable to operate according to a characteristic curve provided by the utility, if required by the utility, within the range 0,95 leading and 0,95 lagging; An example of a standard characteristic curve is shown in figure 3.



**Figure 3 — Example of power factor characteristics curve (under-excited)**

**4.1.11.10** These limits apply, unless otherwise agreed upon with the utility (see annex A).

**4.1.11.11** Equipment for reactive power compensation shall either:

- a) be connected or disconnected with the embedded generator, or
- b) operated via automatic control equipment for disconnection when not required.

**4.1.11.12** The requirement for and type of detuning for reactive power compensation devices will be agreed upon by the owner of the generator and utility.

NOTE Detuning is highly recommended for all reactive power compensation devices to prevent (a) potential current overloading of capacitors due to existing voltage harmonics, (b) potential voltage transient amplification at the POC due to upstream switching conditions, and (c) potential resonance with the network impedance that may lead to excessive harmonic amplification.

## 4.1.12 Synchronization

**4.1.12.1** All embedded generators shall synchronize with the utility network before the parallel connection is made. This applies to all embedded generators where a voltage exists at the generator terminals before connection with the utility network.

**4.1.12.2** Automatic synchronization equipment shall be the only method of synchronization.

**4.1.12.3** For a synchronous generator, the limits for the synchronizing parameters for each phase are:

- a) frequency difference: 0,3 Hz,
- b) voltage difference: 5 % of nominal voltage per phase, and
- c) phase angle difference: 20 ° (degrees).

**4.1.12.4** Mains excited generators do not need to synchronise when the generator is started as a motor before generation starts.

**4.1.12.5** Mains excited generators may require soft-starting when the start-up voltage change is anticipated to be more than 3 %.

**4.1.12.6** The start-up current for static power converters shall not exceed the full-power rated current of the generator.

**4.1.12.7** Also refer to 4.2.4 for re-synchronising conditions.

**4.1.12.8** The embedded generator shall synchronize with the utility network only when the voltage and frequency has been stable within the ranges provided in 4.2.2.3 for at least 60 seconds.

NOTE Some utilities may require this to be longer than 60 seconds.

### **4.1.13 Electromagnetic compatibility (EMC)**

**4.1.13.1** Electromagnetic compatibility (EMC) refers to the ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment. EMC comprises two components, namely a radiated and conducted component. Significant attention is given to radiated EMC due to the potential impact over larger distances. However, with advances in smart grids and business management systems, the potential impacts from conducted EMI must be considered. The conditions in 4.1.13.2 and 4.1.13.6 below apply to conducted unintentional signals, while clause 4.1.13.7 applies to radiated unintentional emissions from generating equipment.

**4.1.13.2** All unintentional conducted emissions from generating equipment, in the frequency band 30 kHz to 150 kHz, shall be 9 dB $\mu$ V lower than the compatibility levels specified in clause 4.12.3 of IEC 61000-2-2:2002+AMD1:2017 +AMD2:2018 CSV when measured in unsymmetrical voltage mode (i.e. between any phase or neutral and the earth) using a quasi-peak detector. An illustration of the limits is provided in Figure 4, below.

**4.1.13.3** The test method and set up for verifying compliance with 4.1.13.1, herein, shall be according to clause 7 of *CISPR 16-2-1*. The test receiver used for verification shall comply with clauses 4 and 5 of *CISPR 16-1-1:2019*, and the AMN or LISN used for verification shall comply with clause 4 of *CISPR 16-1-2*.

NOTE When measuring conducted emissions at high currents, for example at  $\geq 25$  A, during testing, the AMN or LISN can be connected as a voltage probe. See clause A.5 in Annexure A of *CISPR 16-1-1*.

**4.1.13.4** All unintentional conducted emissions from generating equipment, in the frequency band above 150 kHz to 30 MHz, shall comply with SANS 211 (CISPR11), in particular limits for Class A group 1 (< 20 kVA).

**4.1.13.5** The conducted emission requirement applies to all ports or connections to the utility supply, whether the connection is intended for monitoring, communication, power transfer or any other reason for connecting to the utility supply.

**4.1.13.6** In the event of susceptibility to electromagnetic interference, the unit shall be fail-safe, i.e. any deviation from intended performance must comply with all relevant specifications, both in terms of safety (i.e. disconnection) and impact on the network.

**4.1.13.7** Notwithstanding this, should any interference be experienced to existing or new ripple-control, building management system equipment and/or other PLC-based communication, the owner of the embedded generator should take the necessary remedial action to prevent further interference as will be agreed with the utility or the other affected party.

**4.1.13.8** All radiated emissions from generating equipment shall comply with ICASA requirements.

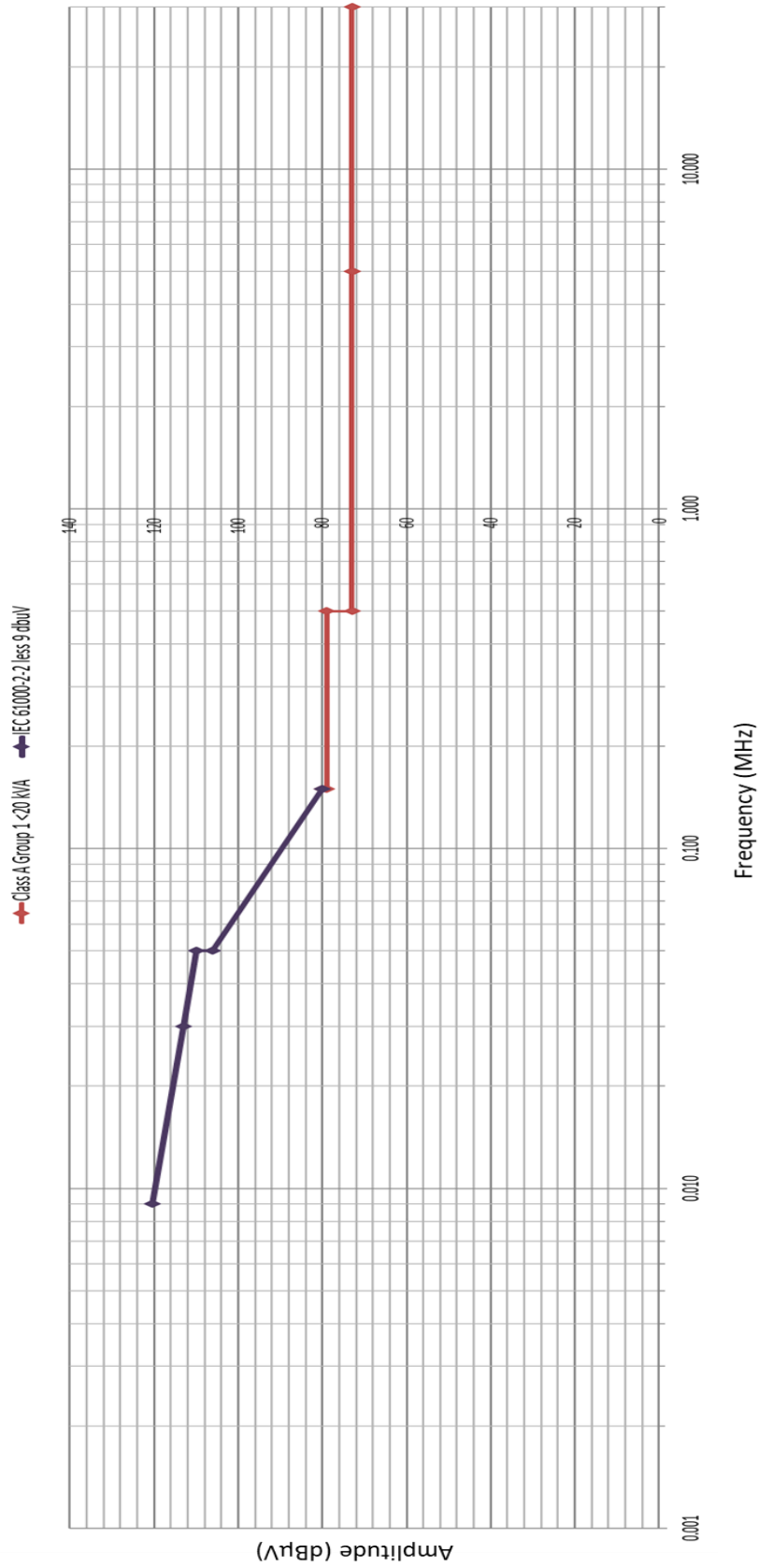


Figure 4 — NRS 097-2-1 emission limits

#### 4.1.14 Mains signalling (e.g. PLC and ripple control)

**4.1.14.1** Mains signalling refers to intentional signals induced into the utility supply network, where the intention is to facilitate data transfer from one component to another.

**4.1.14.2** All intentional emissions (communication signals) from generating equipment shall comply with limits for intentional emissions in SANS 50065-1, limited to an acceptable band as prescribed by SANS 50065-1.

**4.1.14.3** Notwithstanding this, should any interference be experienced to existing or new ripple-control, building management system equipment and/or other PLC-based communication, the owner of the embedded generator shall take the necessary remedial action to prevent further interference as will be agreed with the utility or the other affected party.

### 4.2 Safety protection and control

#### 4.2.1 General

The safe operation of the embedded generator in conjunction with the utility network shall be ensured at all times. Safe operation includes people and equipment safety, i.e.:

- a) People safety: and
  - i) owner (including personnel and / or inhabitants of the property) of the embedded generator;
  - ii) general public safety;
  - iii) utility personnel; and
  - iv) general emergency response personnel, e.g. fire brigade should a fire arise at the embedded generator.
- b) Equipment safety:
  - i) utility equipment;
  - ii) other customers' equipment connected to the same network(s); and
  - iii) generator own equipment.

Some of the safety aspects mentioned above may be covered in other specifications and standards and the embedded generator should ensure that safe operation is maintained at all times taking cognisance of all of the above aspects.

Furthermore, the embedded generator owner is responsible for precautions against damage to its own equipment due to utility originating events, e.g. switching events, voltage and frequency variations, automatic reclosing onto the network etc. However, this protection may not conflict with the requirements of this specification.

#### 4.2.2 Safety disconnect from utility network

##### 4.2.2.1 General

**4.2.2.1.1** All SSEG shall comply with the safety requirements in accordance with SANS/IEC 62109-1 and IEC 62109-2.

NOTE In principle, IEC 62109 documents only apply to PV inverters. However, other SSEG shall prove compliance to these safety requirements to the satisfaction of the utility.

**4.2.2.1.2** The embedded generator shall automatically and safely disconnect from the grid in the event of an abnormal condition. Abnormal conditions include:

- a) network voltage or frequency out-of-bounds conditions,
- b) loss-of-grid conditions,
- c) d.c. current injection threshold exceeded (per phase),
- d) and residual d.c. current (phase and neutral currents summated).



#### **4.2.2.2 Disconnection device (previously disconnection switching unit)**

**4.2.2.2.1** The embedded generator shall be equipped with a disconnection device, which separates the embedded generator from the grid due to abnormal conditions. The disconnection unit may be integrated into one of the components of the embedded generator (for example the PV utility-interconnected inverter) or may be an independent device installed between the embedded generator and the utility interface.

**4.2.2.2.2** The disconnection switching unit shall be able to operate under all operating conditions of the utility network.

NOTE It is the responsibility of the embedded generator owner to enquire about the operating conditions of the utility network, e.g. fault levels for the foreseeable future.

**4.2.2.2.3** A failure within the disconnection device shall lead to disconnection of the generator from the utility supply and indication of the failure condition.

**4.2.2.2.4** A single failure within the disconnection switching unit shall not lead to failure to disconnect. Failures with one common cause shall be taken into account and addressed through adequate redundancy.

**4.2.2.2.5** The disconnection device shall disconnect the generator from the network by means of two series connected robust automated load disconnect switches.

**4.2.2.2.6** Both switches shall be electromechanical switches.

**4.2.2.2.7** Each electromechanical switch shall disconnect the embedded generator on the neutral and the live wire(s).

NOTE The switching unit need not disconnect its sensing circuits.

**4.2.2.2.8** All rotating generating units, e.g. synchronous or asynchronous generating units shall have adequate redundancy in accordance with 4.2.2.2.5.

**4.2.2.2.9** A static power converter without simple separation shall make use of two series-connected electromechanical disconnection switches.

**4.2.4.2.10** The current breaking capacity of each disconnecting switch shall be appropriately sized for the application. In cases where the disconnecting device is an electromechanical switching device such as a contactor, this requires suitable coordination with the upstream short circuit protection device (circuit breaker).

**4.2.2.2.11** Any programmable parameters of the disconnection switching unit shall be protected from interference by third-parties, i.e. password protected or access physically sealed.

**4.2.2.2.12** In order to allow customers to supply their own load in isolated operation (islanded) where this is feasible and required, the disconnection device may be incorporated upstream of part of or all of a customers' loads, provided that none of the network disconnection requirements in this document are violated.

**4.2.2.2.13** All EG installations larger than 30 kVA shall have a central disconnection device.

NOTE 1 This requirement may be amended by the utility, i.e. the utility may require a central disconnection switch unit for any size and type of generator.

NOTE 2 This requirement may be amended by the utility. The central disconnection switch unit will typically be waived only when a lockable disconnection switch, accessible to the utility, is installed.

NOTE 3 This is an interim requirement based on requirements of VDE AR 4105 and will be revisited as more information becomes available.

**4.2.2.2.14** The network and system grid protection voltage and frequency relay for the central disconnection device will be type-tested and certified on its own (stand-alone tested). All clauses of 4.2.2, except 4.2.2.4 (anti-islanding) apply.

**4.2.2.3 Overvoltage, undervoltage and frequency**

**4.2.2.3.1 General**

The values in 4.2.2.3 relate to SSEG in sub-categories A1 and A2. These are kept from a historical perspective. The Grid Code requirements will override values and requirements in this category.

Sub-category A3 generators shall disconnect from the network according to the RPP Grid Code for all abnormal conditions as well as stay connected in accordance with the voltage ride-through requirements of the RPP Grid Code.

Abnormal conditions can arise on the utility system and requires a response from the connected embedded generator. This response is to ensure the safety of utility maintenance personnel and the general public, and also to avoid damage to connected equipment. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this clause and the RPP Grid Code (section 5.2 of version 3.0). The embedded generator shall disconnect in accordance with the requirements of 4.2.2.3 if these conditions occur.

The accuracy for voltage trip values shall be within 0 % to +1 % of the nominal voltage from the upper boundary trip setting, and within -1% to 0% of the nominal voltage from the lower boundary trip setting.

The accuracy for frequency trip values shall be within 0 to +0,1 % of the fundamental frequency from the upper boundary trip setting, and within -0,1 % to 0 % of the fundamental frequency from the lower boundary the trip setting.

**4.2.2.3.2 Overvoltage and undervoltage**

The embedded generator in sub-category A1 and A2 shall cease to energize the utility distribution system should the network voltage deviate outside the conditions specified in table 2. The following conditions shall be met, with voltages in r.m.s. and measured at the POC.

NOTE 1 All discussions regarding system voltage refer to the nominal voltage.

NOTE 2 At the time of publication, these settings are in contradiction to the RPP Grid Code. These may only be applied with exemption to the relevant clause or after the RPP Grid Code has been suitably amended.

NOTE 3 Measurements at the generator terminals will generally be sufficient for the overvoltage settings. If the expected voltage drop across the cable connecting the EG to the POC is too high, undervoltage settings might have to be adjusted.

**Table 2 — Response to abnormal voltages for SSEG in sub-categories A1 and A2**

1	2
<b>Voltage range (at point of connection)</b>	<b>Maximum trip time S</b>
$V < 50 \%$	0,2 s
$50 \% \leq V < 85 \%$	10 s
$85 \% \leq V \leq 110 \%$	Continuous operation
$110 \% < V < 115 \%$	40 s
$115\% \leq V < 120\%$	2 s
$120 \% \leq V$	0,16 s
NOTE If multi-voltage control settings are not possible, the more stringent trip time should be implemented, e.g. 2 s between 110% and 120% of voltage.	

The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive nuisance tripping. The generator does not have to cease to energize if the voltage returns to the normal utility continuous operating condition within the specified trip time.

NOTE Induction/synchronous generators need to be mindful of synchronisation issues and may have to apply faster trip times.

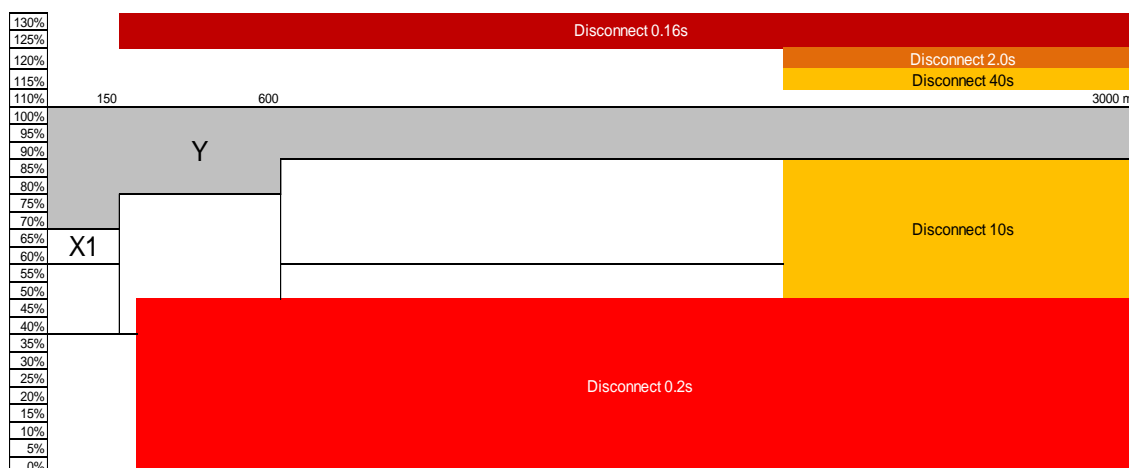
A customer with a multiphase connection shall monitor all phases for out-of-bounds voltage conditions. The EG shall be disconnected if an out-of-bounds voltage condition is detected on any of the phases.

In line with NRS 048-2, it is recommended that A1 and A2 SSEG be able to ride through at least Y and X1 type dips, i.e. not disconnect for these events. The purpose is to avoid excessive nuisance tripping.

Category A3 SSEG shall be able to ride through low and/or high voltage events in accordance with the RPP Grid Code.

The generator shall maintain the pre-dip current during any dip event for which it remains connected.

The ride-through and trip times are shown graphically in figure 5.



**Figure 5 — Graphical representation of voltage-ride-through and voltage disconnect requirements for A1 and A2 EG**

#### 4.2.2.3.3 Over-frequency and under-frequency

This requirement is in line with the RPP Grid Code (version 3.0) and applies to all EG in category A.

NOTE The RPP Grid Code should be consulted for developments in the requirements for response to over-frequency and under-frequency events.

The embedded generation system shall cease to energize the utility network when the utility frequency deviates outside the specified conditions. Both over- and under-frequency conditions indicate system abnormal conditions and all generators are expected to assist in stabilising the system during such periods.

When the utility frequency is less than 47 Hz, the embedded generator shall disconnect from the utility network within 0,2 s.

While the utility frequency is in the range of 47 Hz and 50,5 Hz, the system shall operate normally.

In order to prevent hysteresis switching (on-off toggling) during over-frequency conditions, the output power shall be reduced as follows:

When the utility frequency exceeds 50,5 Hz, the active power available at the time shall be stored as the maximum power value  $P_M$ ; this value  $P_M$  shall not be exceeded until the frequency has stabilised below 50,5 Hz for at least 4 seconds.

The EG system shall control the output power as a function of  $P_M$  at a gradient of 50 % per Hertz as illustrated in figure 5. The power generation shall follow the curve shown in figure 5 up and down while the system frequency is in the range 50,5 Hz to 52 Hz.

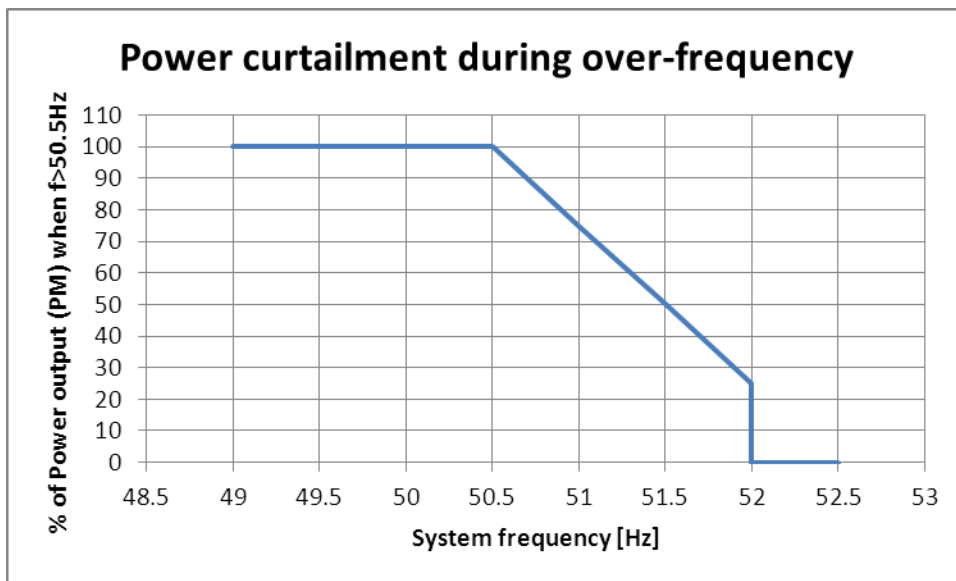
When the utility frequency is more than 52 Hz for longer than 4 seconds, the embedded generator shall cease to energise the utility line within 0,5 s.

**4.2.2.3.3.1 Relaxation for non-controllable generators**

Non-controllable generators may disconnect randomly within the frequency range 50,5 Hz to 52 Hz. The disconnect frequency for non-controllable generators will each be set at a random value by the manufacturer, with the option of changing this to a utility provided setting. The random disconnect frequency shall be selected so that all generators from any specific manufacturer will disconnect uniformly over the range with 0,1 Hz increments.

When the utility frequency is more than the non-controllable generator over-frequency setpoint for longer than 4 seconds, the non-controllable generator shall cease to energise the utility line within 0,5 s.

NOTE At the time of publication, this is in contradiction with the RPP Grid Code.



**Figure 6 — Power curtailment during over-frequency**

**4.2.2.4 Prevention of islanding**

**4.2.2.4.1** A utility distribution network can become de-energized for several reasons: for example, a substation breaker that opens due to a fault condition or the distribution network might be switched off for maintenance purposes. Should the load and (embedded) generation within an isolated network be closely matched, then the voltage and frequency limits may not be triggered. If the embedded generator control system only made use of passive voltage and frequency out-of-bounds detection, this would result in an unintentional island that could continue beyond the allowed time limits.

**4.2.2.4.2** In order to detect an islanding condition, the embedded generator shall make use of at least one active islanding detection method. An active islanding detection method intentionally varies an output

parameter and monitors the response or it attempts to cause an abnormal condition at the utility interface to trigger an out-of-bounds condition. If the utility supply is available, the attempt to vary an output parameter or cause an abnormal condition will fail and no response will be detected. However, if the utility supply network is de-energized, there will be a response to the change which can be detected. This signals an island condition to the embedded generator upon detection of which the embedded generator shall cease to energize the utility network within a specific time period.

**4.2.2.4.3** Active island detection shall be used in all cases where the EG interfaces with the utility network.

**4.2.2.4.4** An islanding condition shall cause the embedded generator to cease to energize the utility network within 2 s, irrespective of connected loads or other embedded generators. The embedded generator employing active islanding detection shall comply with the requirements of IEC 62116 (ed. 1).

NOTE Prevention of islanding measures is only considered on the embedded generator side, i.e. no utility installed anti-islanding measures are considered.

**4.2.2.4.5** All rotating generators shall use a minimum of two islanding detection methods (e.g. rate-of-change-of-frequency and voltage vector shift detection due to the dead bands (slow detection) of islands in both methods).

NOTE It is possible for a condition to exist, where a mains-excited generator becomes self-excited due to capacitance of the network (either cable capacitance or power factor correction). Under such conditions, the mains-excited generator will not disconnect from an island, hence effective islanding detection is required for all rotating generators.

**4.2.2.4.6** Passive methods of islanding detection shall not be the sole method to detect an island condition. When used, passive methods of islanding detection shall be done by three-phase voltage detection and shall be verified by an AC voltage source.

**4.2.2.4.7** The embedded generator shall physically disconnect from the utility network in accordance with the requirements in 4.2.2.2.

#### **4.2.2.5 DC current injection**

The embedded generator shall not inject d.c. current greater than 0,5 % of the rated a.c. output current into the utility interface under any operating condition, measured over a 1-minute interval. The EG shall cease to energize the utility network within 500 ms if this threshold is exceeded.

### **4.2.3 Emergency personnel safety**

No requirements for emergency personnel safety (e.g. fire brigade) existed at the time of publication. It is expected that such issues will be dealt with in other documents, e.g. OHS Act, SANS 10142-1.

### **4.2.4 Response to utility recovery**

**4.2.4.1** The embedded generator shall ensure synchronisation before re-energizing at all times in accordance with 4.1.12.

**4.2.4.2** After a voltage or frequency out-of-range condition that has caused the embedded generator to cease energizing the utility network, the generator shall not re-energize the utility network until the utility service voltage and frequency have remained within the specified ranges for a continuous and uninterrupted period of 60 s. The reconnection shall commence as follows:

**4.2.4.2.1** Non-controllable generators may connect randomly within the 1 minute to 10 minute period after voltage and frequency recovery (period includes the 60 s to confirm recovery). The delay for non-controllable generators will each be set at a random value by the manufacturer, with the option of changing this to a utility provided setting. The random value shall be selected so that no more than 2 % of generators from any specific manufacturer will reconnect within 10s of each other.

**4.2.4.2.2** Controllable generators may reconnect immediately after the 60 s delay confirming recovery of the system voltage and frequency at a maximum rate of 10 % of rated power per minute, i.e. full power output will only be reached after 10 minutes.

This ramp rate may be modified at the request of the utility or in consultation with the utility.

## **4.2.5 Isolation**

**4.2.5.1** In line with SANS 10142-1 (as amended), each energy source should have its own, appropriately rated, isolation device.

**4.2.5.2** It is expected that isolation requirements will be dealt with in more detail in future in e.g. SANS 10142-1/3. Such requirements shall supersede 4.2.5.

**4.2.5.3** The embedded generator shall provide a means of isolating from the utility interface in order to allow for safe maintenance of the EG. The disconnection device shall be a double pole for a single-phase EG, a three-pole for a three-phase delta-connected EG, and a four-pole for a three-phase star-connected EG. The grid supply side shall be wired as the source.

**4.2.5.4** The breaking capacity of the isolation circuit-breaker closest to the point of utility connection shall be rated appropriately for the installation point in accordance with SANS 60947-2.

This disconnection device does not need to be accessible to the utility.

**4.2.5.5** For dedicated supplies, a means shall be provided of isolating from the point of supply in order to allow for safe maintenance of the utility network. The disconnection device shall be a double pole for a single-phase EG, a three-pole for a three-phase delta-connected EG, and a four-pole for a three-phase star-connected EG.

This disconnection device shall be lockable and accessible to the utility.

NOTE 1 A device inside a lockable box is deemed a lockable device.

NOTE 2 This disconnection device may become the new point of control as defined by SANS10142-1.

**4.2.5.6** The requirement for the utility accessible disconnection device may only be waived by the utility where the risk to the network is deemed acceptable to the utility. Such permission shall be provided in writing.

NOTE Full verification form to be signed off and accepted by the utility.

## **4.2.6 Earthing**

**4.2.6.1** The electrical installation shall be earthed in accordance with SANS 10142-1 (as applicable). The earthing requirements for different embedded generation configurations in conjunction with the customer network are described in annex B for the most common earthing systems.

NOTE SANS 10142-1 applies to EG feeding a UPS and no connection to the utility supply (see table B5).

**4.2.6.2** Installations with utility-interconnected inverters without simple separation shall make use of earth leakage protection which are able to respond to d.c. fault currents including smooth d.c. fault currents (i.e. without zero crossings) according to IEC 62109-2 unless the inverter can exclude the occurrence of d.c. earth fault currents on any phase, neutral or earth connection through its circuit design<sup>1)</sup>. This function may be internal or external to the inverter.

NOTE IEC 62109-2, Edition 2011, section 4.8.3.5 gives selection criteria for RCD sensitivities.

**4.2.6.3** Where an electrical installation includes a PV power supply system without at least simple separation between the AC side and the DC side, an integrated RCD function shall be present to provide

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<sup>1)</sup> The appropriate earth leakage unit should be selected to accommodate the higher leakage current of inverters without transformers to avoid nuisance tripping.

fault protection by automatic disconnection of supply shall be type B according to IEC/TR 60755, amendment 2. Where the PV inverter by construction is not able to feed DC fault currents into the electrical installation, an RCD of type B according to IEC/TR 60755 amendment 2 is not required.

NOTE 1 Consideration must also be given to ensure that any d.c. currents do not impair the effectiveness of any other RCD'S installed throughout the a.c. system.

NOTE 2 The earth leakage unit may also fulfil the requirement of the all-pole disconnection device as stated in 4.2.6.

NOTE 3 The function of this RCD is not to provide protection against circulating d.c. currents in the inverter and a.c. supply, i.e. does not override 4.1.8.

#### **4.2.7 Short-circuit protection**

**4.2.7.1** The embedded generator shall have suitably rated short-circuit protection at the connection to the AC mains in accordance with SANS 10142-1 and 3.

**4.2.7.2** The short-circuit characteristics for the SSEG shall be provided to the utility.

#### **4.2.8 Maximum short-circuit contribution**

Embedded generators have the potential to increase the fault level of the network to which it is connected. In order to limit the fault level changes in low voltage networks and allow coordination of fault levels with the utility, no generator will exceed the following fault level contribution:

- a) for synchronous generators: 8 times the rated current;
- b) for asynchronous generators: 6 times the rated current; and
- c) for generators with inverters: 1 times the rated current.

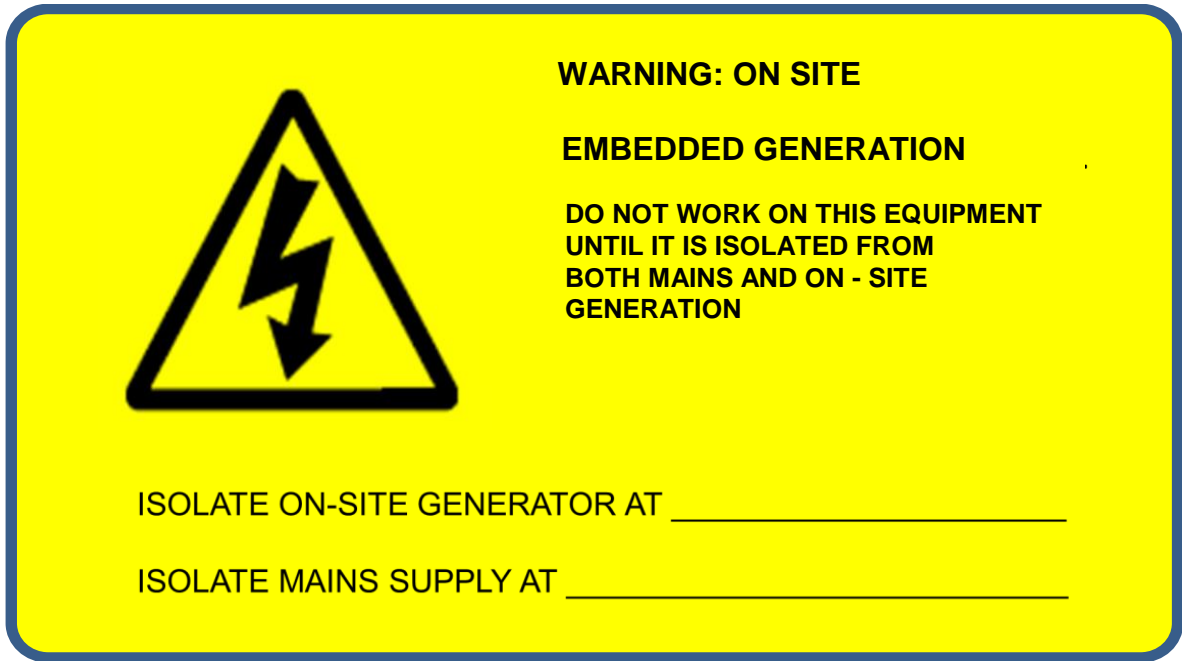
NOTE At the time of installation, the short-circuit capacity of all existing equipment should be confirmed and upgraded where necessary. Suitable fault current limiting devices may be required to ensure a safe installation. The potential impact on neighbouring installations should also be considered to ensure that those installations remain safe.

#### **4.2.9 Labelling**

**4.2.9.1** A label on the distribution board of the premises where the embedded generator is connected shown in figure 7, shall state: "WARNING: ON-SITE EMBEDDED GENERATION . DO NOT WORK ON THIS EQUIPMENT UNTIL IT IS ISOLATED FROM BOTH MAINS AND ON-SITE GENERATION SUPPLIES." or similar warning. Disconnection points for all supplies shall be indicated.

**4.2.9.2** The label shall be permanent with lettering of height at least 8 mm.

**4.2.9.3** The label shall comply to requirements of SABS 1186-1.



**Figure 7 — Example of labelling (more isolation points to be added as required)**

**4.2.9.4** The absence of emergency shutdown capabilities will be indicated on signage in accordance with 4.2.2.





**Figure 8 — Example of labelling for metering points (Colouring and other requirements to be confirmed with the utility).**

#### **4.2.10 Robustness requirements**

According to 4.2.2.1 all SSEG shall comply with safety requirements in accordance to SANS/IEC 62109-1 and IEC 62109-2.

NOTE This section will be expanded in future revisions.

### **4.3 Metering**

#### **4.3.1 General**

**4.3.1.1** All meters utilized by the utility shall be the property of the utility even when the meters are located on the premises of the customer. Meters that are embedded in the customer's network shall be accessible to the utility on request.

**4.3.1.2** Three metering configurations are known in the case of premises where embedded generators are operated, dependent on the tariff structure required or implemented by the supplier. The details are given in 4.3.2 and 4.3.3.

**4.3.1.3** The utility will advise what metering is required based on the application and location of the embedded generator.

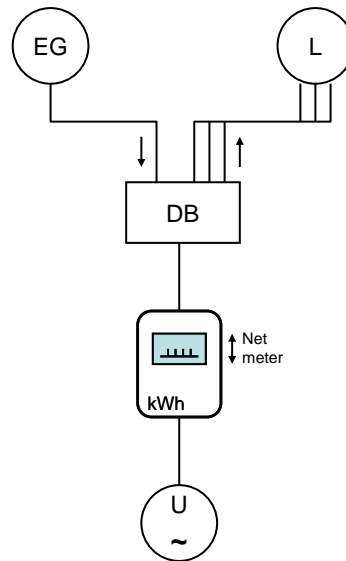
**4.3.1.4** Metering will comply to SANS 474/NRS 057 and SANS 473/NRS 071.

**4.3.1.5** Where applicable (manual reading), suitable signage will be attached at the meter, indicating that import and export registers need to be read. Refer to Figure 8 and 4.2.9.

#### **4.3.2 Single-quadrant meter installation**

**4.3.2.1** The single-meter arrangement is given in figure 9.

**4.3.2.2** The EG feeds into the customer network (L), offsetting the customer's own consumption. If the customer is a net electricity importer from the utility (U), the cumulative consumption meter reading will increase. If the customer is a net exporter, the cumulative consumption meter reading decreases.



#### Legend

DB	distribution board
EG	embedded generation
L	customer network
U	utility network

NOTE This type of installation requires an electronic meter where differentiated import and export rates apply.

**Figure 9 — Single meter installation**

**4.3.2.3** As a result of using a single meter, the overall consumption and generation of the customer is not recorded. The net import and export of energy is metered and balanced over the metering period.

**4.3.2.4** A net meter records and balances energy in a single register. An alternative to the net meter is a bi-directional meter which records energy import and export in separate registers. The registers need to be balanced off against each other to provide the necessary information to the billing system. Separate register meters may be preferred by utilities for reasons of revenue protection.

### 4.3.3 Multiple meter installation

NOTE The feed-in tariff may be worded differently in policy documents, however, the principle is discussed in this section.

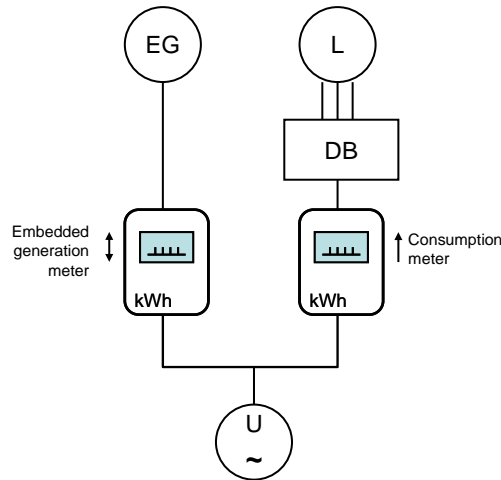
**4.3.3.1** Feed-in tariff metering records all the energy generated from the embedded generator and reimburses the EG customer at the set FIT. The consumption of the EG customer is recorded in full and billed in the conventional manner. A customer with embedded generation and consumption therefore requires two meters or a bi-directional active energy meter that records energy flow in both directions.

**4.3.3.2** The metering configuration for FIT metering is given in figure 10 and is referred to as “separate metering”. An existing consumption meter, whether prepayment or conventional, can remain in place. The embedded generation meter shall be a bi-directional active energy meter that records energy flow in both directions.

**4.3.3.3** This metering configuration records overall consumption (L) and overall generation (EG) which is exported to the utility network (U).

**4.3.3.4** The separate metering configuration in figure 10 is the most basic FIT metering configuration.

NOTE The relevant regulations applicable in municipalities may not allow this metering configuration in which case the EG can be connected through the separate embedded generation metering configuration shown in figure 10.



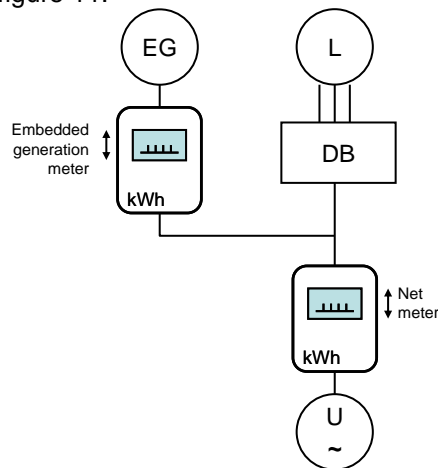
Legend

- DB distribution board
- EG overall generation
- L overall consumption
- U utility network

NOTE The EG may have auxiliary supply (electricity usage)

**Figure 10 — Separate metering**

4.3.3.5 In the case where the output of the EG cannot physically be taken to the main distribution board of the customer’s premises, an EG meter may be embedded in the customer’s network. The appropriate metering configuration is given in figure 11.



Legend

- DB distribution board
- EG embedded generation
- L consumption
- U utility network

**Figure 11 — Separate embedded metering**

**4.3.3.6** The overall generation of the EG is recorded in the bi-directional embedded generation meter while the overall consumption is balanced off between the net meter and the EG meter<sup>2)</sup>. The net meter shall be a bi-directional meter.

#### **4.3.4 Types of meter**

**4.3.4.1** Energy meters used in conjunction with embedded generation shall record active energy. The meters shall be bi-directional type meters. The meters can either be of the single or the separate register type.

**4.3.4.2** The current specification for pre-payment meters does not cater for embedded generation.

**4.3.4.3** In the event that installations with embedded generators are required to record reactive energy in conjunction with active energy, four-quadrant electronic meters shall be utilized.

**4.3.4.4** Meters with the capability of metering quality of supply parameters shall activate the monitoring facility on the meter.

NOTE The modalities of the billing and revenue procedures for EG customers will be addressed in the future NRS 097-2-4 specification.

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2) The overall electricity consumption over a period is equivalent to the sum of the net meter differential reading and the EG meter differential reading.

## **Annex A – Notes to purchase**

(informative)

NOTE The customer is advised to contact the utility to discuss potential further connection requirements.

**A.1** The following requirement shall be specified in tender invitations and in each order or contract:

- a) whether all power quality parameters shall be measured at the POC (see 4.1.1.3).

**A.2** The following requirements shall be agreed upon between the customer and the utility:

- a) whether the EG shall be type approved (see 4.1.1.5);
- b) whether the EG may control the voltage (see 4.1.2.2); and
- c) the power factor limits (see 4.1.11).

## **Annex B – Earthing system**

(informative)

NOTE SANS 10142-1 does not apply to embedded generators (i.e. connected in parallel to the utility network). Annex B is provided as minimum requirements for earthing systems until the update of SANS 10142-1.

### **B.1 Application of SANS 10142-1**

#### **B.1.1 General**

SANS 10142-1 applies to low-voltage wiring, earthing, bonding and safety. The requirements in B.1.2 to B.1.5 relating to earthing and to neutral and earth path connections apply.

#### **B.1.2 Neutral conductor**

The neutral conductor shall not be connected direct to earth or to the earth continuity conductor on the load side of the point of control (see 6.1.6 in SANS 10142-1:2012).

#### **B.1.3 Customer's earth terminal**

Each installation shall have a consumer's earth terminal (see 3.18 of SANS 10142-1:2012) at or near the point where the supply cables enter the building or structure. All conductive parts that are to be earthed (see 6.12.3 in SANS 10142-1:2012) shall be connected to the main earthing terminal (see 3.29.4 in SANS 10142-1:2012), which shall be connected to the consumer's earth terminal. The consumer's earth terminal shall be earthed by connecting it to the supply earth terminal (see 3.78 in SANS 10142-1:2012) or the protective conductor (see 3.15.8 in SANS 10142-1:2012) and, if installed, the earth electrode. The effectiveness of the supply protective conductor shall be determined in accordance with 8.7.5 in SANS 10142-1:2012 (see 6.11.1 as amended by amendment No. 6 in SANS 10142-1:2012).

#### **B.1.4 Earthing of combined sources**

When an installation that has a common neutral is supplied from a combination of transformers and generators located near one another, the neutral terminal of these shall be connected to a single neutral bar. This neutral bar shall be the only point at which the neutral of the installation is earthed except in the case in 7.12.3.1.3 in SANS 10142-1:2012 (see 6.12.4 as amended by amendment No. 6 in SANS 10142-1:2012).

#### **B.1.5 Neutral bar earthing**

**B.1.5.1** Protection in accordance with the requirements in 6.7 in SANS 10142-1:2012 shall be provided for the electrical installation in such a manner as to ensure correct operation of the protection devices, irrespective of the supply or combination of sources of supply. Operation of the protection devices shall not rely upon the connection to the earthing point of the main supply.

**B.1.5.2** Where there is no existing earth electrode in the electrical installation, a suitable earth electrode may be installed in accordance with SANS 10199. When installed, the electrode shall be bonded to the consumer's earth terminal and to the earthing point of the generating set with a conductor of at least half the cross-section of that of the phase conductor, but not less than 6 mm copper, or equivalent. This also applies to a single-phase supply.

NOTE 1 In the case of the TN system of electricity supply, an earth electrode is normally not required in an electrical installation (see 7.12.3.1.1 as amended by amendment No. 6 in SANS 10142-1:2012).

**Annex B**

(continued)

NOTE 2 IEC 60364-1 distinguishes three families of earthing arrangement, using the two-letter codes TN, TT, and IT. The first letter indicates the connection between earth and the power-supply equipment (generator or transformer). The second letter indicates the connection between earth and the electrical device being supplied. In the case of TN systems, T indicates a direct connection of a point with earth (Latin: terra) and N indicates direct connection to neutral at the origin of the installation, which is connected to the earth.

**B.1.5.3** When an installation is supplied from a combination of transformers and generators located near one another, including alternative supplies, the neutral terminal of these shall be connected to a single earthed neutral bar. This neutral bar shall be the only point at which the neutral of the installation is earthed. Any earth leakage unit shall be positioned to avoid incorrect operation due to the existence of the parallel neutral or earth path (see 7.12.3.1.2 as amended by amendment No. 6 in SANS 10142-1:2012).

**B.1.5.4** Where alternative supplies are installed remotely from the installation and it is not possible to make use of a single neutral bar, which is earthed, the neutral of each unit shall be earthed at the unit and these points shall be bonded to the consumer's earth terminal (see 6.12.4 of SANS 10142-1:2012). The supply that supplies the installation or part of the installation shall be switched by means of a switch that breaks all live conductors operating substantially together (see annex S of SANS 10142-1:2012), to disconnect the earthed neutral point from the installation neutral when the alternative supply is not connected (see also 6.1.6 of SANS 10142-1:2012 and 7.12.3.1.3 (as amended by amendment No. 6 in SANS 10142-1:2012)).

**B.1.5.5** Where only part of an installation is switched to the alternative supply in the same distribution board, the neutral bar shall be split (see figure S.2 in annex S of SANS 10142-1:2012) and 7.12.3.1.3 (as amended by amendment No. 6 in SANS 10142-1: 2009).

**B.2 Embedded generator and UPS configurations**

**B.2.1** Various configurations of embedded generator and UPS systems were examined, and cross-referenced with the main electrical supply earthing configurations (i.e. TN-S, TN-C-S). Table B.1 shows the permutations explored.

NOTE The TT configuration is generally not used in South Africa, but could sometimes be found in certain rural electrification network spurs.

**B.2.2** Tables B.2 to B.5 illustrate the typical system application types and connections.

**Annex B**  
(continued)

**Table B.1 — Generic embedded generation/UPS type versus electricity supply configuration**

1	2	3	4	5	6
Figure reference	Application type	Alternative supply characteristic	Main electricity supply system configuration examined		
		Internal N-PE bridge connection	TN-S	TN-C-S	TT
Table B.2	Alternative generator, e.g. stand-by diesel or stand-alone generator	Unbridged N-PE	Y	Y	Y
		N-PE bridged	Y	Y	Y
Table B.3	Embedded generator, e.g. utility interconnected PV system		Y	Y	Y
Table B.4	UPS system with a.c. coupled embedded generator	Unbridged N-PE	Y	Y	Y
		N-PE bridged	Y	Y	Y
Table B.5	UPS system	Unbridged N-PE	Y	Y	Y
		N-PE bridged	Y	Y	Y
	UPS system with d.c. coupled embedded generator (e.g. PV or wind)	Unbridged N-PE	Y	Y	Y
		N-PE bridged	Y	Y	Y
NOTE For information only.					



**Annex B**  
(continued)

**Table B.2 — Diesel generator in alternative supply configuration**

1 Supply earthing system	2 Wiring diagram	3 Earthing comments
<p><b>TN-S</b></p> <ul style="list-style-type: none"> <li>• Five-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• Alternative supply earth electrode required</li> <li>• Bridge N-PE required on alternative supply.</li> <li>• Four-pole change-over switch required.</li> </ul>
<p><b>TN-C-S</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• Bridge N-PE required on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• Alternative supply earth electrode required</li> </ul> <p><b>Options</b></p> <ul style="list-style-type: none"> <li>• If bridged N-PE on alternative supply, then four-pole change-over switch required.</li> <li>• If open N-PE on alternative supply, then three-pole change-over switch required.</li> </ul>
<p><b>TT</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• Bridge N-PE required on alternative supply.</li> <li>• Four-pole change-over switch required.</li> </ul>
<p><b>Key:</b> CB circuit-breaker      DB distribution board      E/L earth leakage          GEN alternative generator      UPS battery alternative supply</p>		

**Annex B**  
(continued)

**Table B.3 — Embedded generator without alternative supply**

1 Supply earthing system	2 Wiring diagram	3 Earthing comments
<p><b>TN-S</b></p> <ul style="list-style-type: none"> <li>• Five-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> <li>• Main supply = Point of Control</li> <li>• Main DB</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• RCD (Type B) required for transformerless inverters.</li> </ul> <p><b>Options</b></p> <ul style="list-style-type: none"> <li>• EG earth electrode desired</li> </ul>
<p><b>TN-C-S</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• Bridge N-PE required on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• EG on E/L device</li> </ul> <p><b>Options</b></p> <ul style="list-style-type: none"> <li>• EG earth electrode desired</li> </ul>
<p><b>TT</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• EG on E/L device</li> </ul>
<p><b>Key:</b> CB circuit-breaker      DB distribution board      E/L earth leakage          GEN alternative generator      EG embedded generator      UPS battery alternative supply</p>		

**Annex B**  
(continued)

**Table B.4 — Alternative supply with a.c. coupled embedded generator**

1 Supply earthing system	2 Wiring diagram	3 Earthing comments
<p><b>TN-S</b></p> <ul style="list-style-type: none"> <li>• Five-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• EG on E/L device</li> <li>• Alternative supply earth electrode required</li> <li>• Bridge N-PE required on alternative supply.</li> <li>• Change-over switch 1 required to be four-pole</li> <li>• Change-over switch 2 required to be four-pole.</li> </ul>
<p><b>TN-C-S</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• Bridge N-PE required on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• EG on E/L device</li> <li>• Alternative supply earth electrode required</li> </ul> <p><b>Options</b></p> <ul style="list-style-type: none"> <li>• If bridged N-PE on alternative supply, then change-over switch 1 required to be four-pole.</li> <li>• If open N-PE on alternative supply, then change-over switch 1 required to be three-pole.</li> <li>• Change-over switch 2 required to be four-pole.</li> </ul>
<p><b>TT</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• EG on E/L device</li> <li>• Bridge N-PE required on alternative supply.</li> <li>• Change-over switch 1 required to be four-pole</li> <li>• Change-over switch 2 required to be four-pole.</li> </ul>
<p><b>Key:</b> CB circuit-breaker      DB distribution board      E/L earth leakage          GEN alternative generator      EG embedded generator      UPS battery alternative supply</p>		

**Annex B**  
(continued)

**Table B.5 — Alternative supply with or without d.c. coupled embedded generator**

1 Supply earthing system	2 Wiring diagram	3 Earthing comments
<p><b>TN-S</b></p> <ul style="list-style-type: none"> <li>• Five-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• If bridged N-PE on alternative supply, then four-pole change-over switch required.</li> <li>• If open N-PE on alternative supply, then three-pole change-over switch required</li> </ul>
<p><b>TN-C-S</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode not required.</li> <li>• Bridge N-PE required on consumer's earth terminal</li> </ul>		<p><b>Options</b></p> <ul style="list-style-type: none"> <li>• If bridged N-PE on alternative supply, then four-pole change-over switch required.</li> <li>• If open N-PE on alternative supply, then three-pole change-over switch required.</li> </ul>
<p><b>TT</b></p> <ul style="list-style-type: none"> <li>• Four-wire supply.</li> <li>• Consumer's earth electrode required.</li> <li>• No N-PE bridge on consumer's earth terminal</li> </ul>		<p><b>Requirements</b></p> <ul style="list-style-type: none"> <li>• Bridged N-PE required on alternative supply.</li> <li>• Four-pole change-over switch required.</li> </ul>
<p><b>Key:</b> CB circuit-breaker      DB distribution board      GFDI ground fault detector interrupter          GEN alternative generator      EG embedded generator      UPS battery alternative supply</p>		

## **Annex B**

(continued)

### **B.3 Rules of thumb established for embedded generation and alternative systems**

#### **B.3.1 General**

Earthing and wiring guidelines were developed as a result of the above rigorous analysis. See tables B.2 to B.5.

#### **B.3.2 Earth electrode**

**B.3.2.1** All alternative systems shall have an own earth electrode connected to the consumer's earth terminal and shall comply with 7.12.3.1.1 in SANS 10142-1:2012.

**B.3.2.2** Embedded generators need not have their own earth electrode in accordance with SANS 10142-1, but an own earth electrode is preferred.

#### **B.3.3 N-PE bridge on consumer's earth terminal**

**B.3.3.1** The TN-C-S system shall be bridged between N and PE on the consumer's earth terminal in the installation on the supply side of the point of control.

**B.3.3.2** TN-S and TT systems shall be un-bridged (as normal practice).

NOTE This is to comply with standard installation requirements for safety.

#### **B.3.4 N-PE bridge on alternative supply**

**B.3.4.1** TN-S and TT systems shall be bridged.

**B.3.4.2** The TN-C-S may be either bridged or un-bridged. This, however, impacts on change-over switch requirements.

#### **B.3.5 Change-over switch No. 1 (between main supply and alternative supply)**

**B.3.5.1** In the case of alternative systems WITHOUT an internal N-PE bridge (i.e. where N and PE are isolated), the following is required:

- a) for a three-phase system: a three-pole change-over switch with common neutral bar; and
- b) for a single-phase system: a single-pole change-over switch with common neutral bar.

**B.3.5.2** In the case of alternative systems WITH an internal N-PE bridge, the following is required:

- a) for a three-phase system: a four-pole change-over switch including neutral, or a three-pole with overlapping neutral; and
- b) for a single-phase system: a two-pole change-over switch including neutral, or a single pole with overlapping neutral.

**B.3.5.3** Manual change-over switches shall be three position switches, i.e. break-before-make.

**Annex B**  
(concluded)

**B.3.6 Change-over switch No. 2** (between a.c. coupled embedded generator and alternative supply)

**B.3.6.1** In the case of a three-phase system, there shall be a four-pole change-over switch including neutral, or a three-pole with overlapping neutral.

**B.3.6.2** In the case of a single-phase system, there shall be a two-pole change-over switch including neutral, or a single pole with overlapping neutral.

## Annex C – Network impedance (normative)

**C.1.1.1** The impact of the generator on the network voltage and quality of supply levels is directly linked to the (complex) source impedance and short-circuit level. No representative information is available on the ranges for these quantities in South Africa; international results are used to inform the typical fault level that may be assumed. The reference impedance proposed in IEC 60725 is  $0,4 + j0,25 \Omega$ , resulting in a fault level of 488 A. However, given the typical long feeder installations in South Africa, it may be assumed that the fault levels would be significantly lower.

**C.1.1.2** Values available from other countries as measured in 1980 (PQE02) are provided in table C1.

**Table C1 – Available data for LV network impedance (percentages of consumers with impedance less than stated value) in ohms at 50 Hz**

1	2	3	4	5
Country	Percentage of consumers with less than stated impedance			
	98%	95%	90%	85%
Australia	-	$0,43+j0,33$	-	-
Belgium	-	$0,63+j0,33$	$0,32+j0,17$	$0,28+j0,15$
France	-	$0,55+j0,34$	$0,45+j0,25$	$0,34+j0,21$
Germany	-	$0,45+j0,25$	$0,36+j0,21$	$0,31+j0,17$
Ireland	$1,47+j0,64$	$1,26+j0,60$	$1,03+j0,55$	$0,94+j0,43$
Italy	-	$0,59+j0,32$	$0,48+j0,26$	$0,44+j0,24$
The Netherlands	-	$0,70+j0,25$	$0,41+j0,21$	$0,32+j0,17$
Switzerland	-	$0,60+j0,36$	$0,42+j0,25$	$0,30+j0,18$
United Kingdom	$0,46+j0,45$	-	$0,25+j0,23$	-
USSR	-	$0,63+j0,30$	$0,50+j0,26$	-

**C.1.1.3** Data recorded by France in 1987, indicates a network impedance for 85% of its customers supplied via overhead lines as  $1,12+j0,36 \Omega$  or better.

**C.1.1.4** A summary of data from Spain is presented in table C2.

**Table C2 – Summary of Spanish LV network impedance values (percentages of consumers with impedance less than stated value) in ohms at 50 Hz**

1	2	3	4	5
Impedance at LV	98 %	95 %	90 %	85 %
Spanish network Category A	$1,58 + j 0,45$	$0,86 + j 0,31$	$0,58 + j 0,23$	$0,44 + j 0,2$
I_SC [A]	140	252	369	476
Spanish network Category B	$2,12 + j 0,61$	$1,59 + j 0,40$	$1,22 + j 0,23$	$1,03 + j 0,19$
I_SC [A]	104	140	185	220
Combined A+B	$1,75 + j 0,46$	$1,05 + j 0,32$	$0,67 + j 0,23$	$0,51 + j 0,2$
I_SC [A]	127	210	325	420

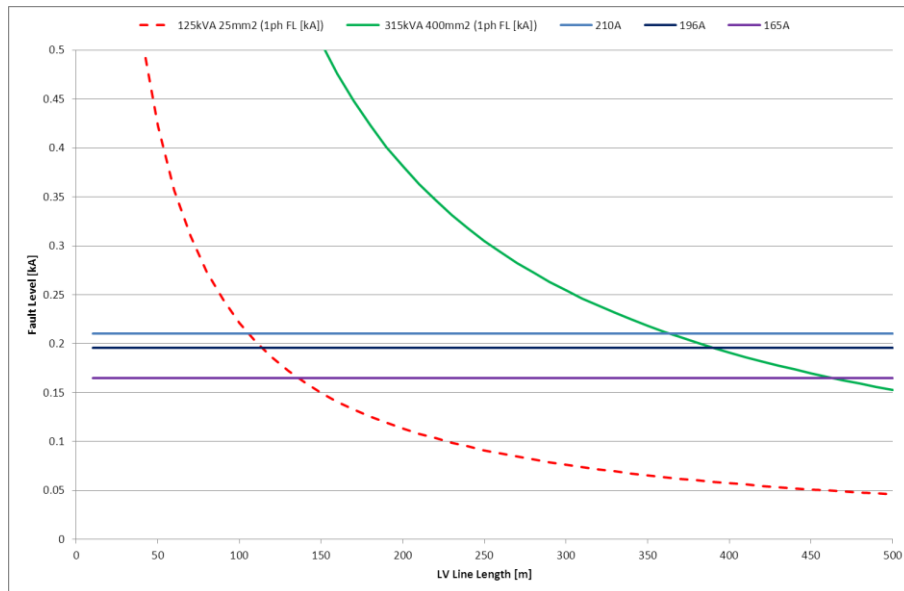
**Annex C**  
(concluded)

**C.1.1.5** Based on engineering judgement by the author using the anticipated landscape, and rural versus urban development, of the available data, Spain, Italy and France would seem to have the most comparative LV network design to South Africa. Whilst the X/R ratio of these impedances varies, the most representative values for overhead networks (majority of networks in South Africa) are:

Spain:  $1,05 + j0,32 \Omega$  95<sup>th</sup> percentile (RSA preferred – see 4.1.3.2)  
 France:  $1,12 + j0,36 \Omega$  85<sup>th</sup> percentile  
 Italy:  $0,59 + j0,32 \Omega$  95<sup>th</sup> percentile

Possible fault levels on LV networks are shown in **Error! Reference source not found.**, using the 5<sup>th</sup> percentile of MV fault levels and two options for the LV feeder transformer and conductor (125 kVA transformer feeding 25 mm<sup>2</sup> conductor versus 315 kVA transformer feeding 400 mm<sup>2</sup> conductor). It is clear that many customers may still experience lower fault levels than this.

**C.1.1.6** It is proposed that the 95<sup>th</sup> percentile impedance be used as a reference for South Africa until better information is available.





## Annex D – (Annex A of VDE-AR-N 4105) Explanations (normative)

### A.1 “Power generation system” (3.1.8) and “power generation unit” (3.1.9)

Figure A.1 shows the power generation system, the power generation unit and the sum of all power generation systems connected to the same network connection point.

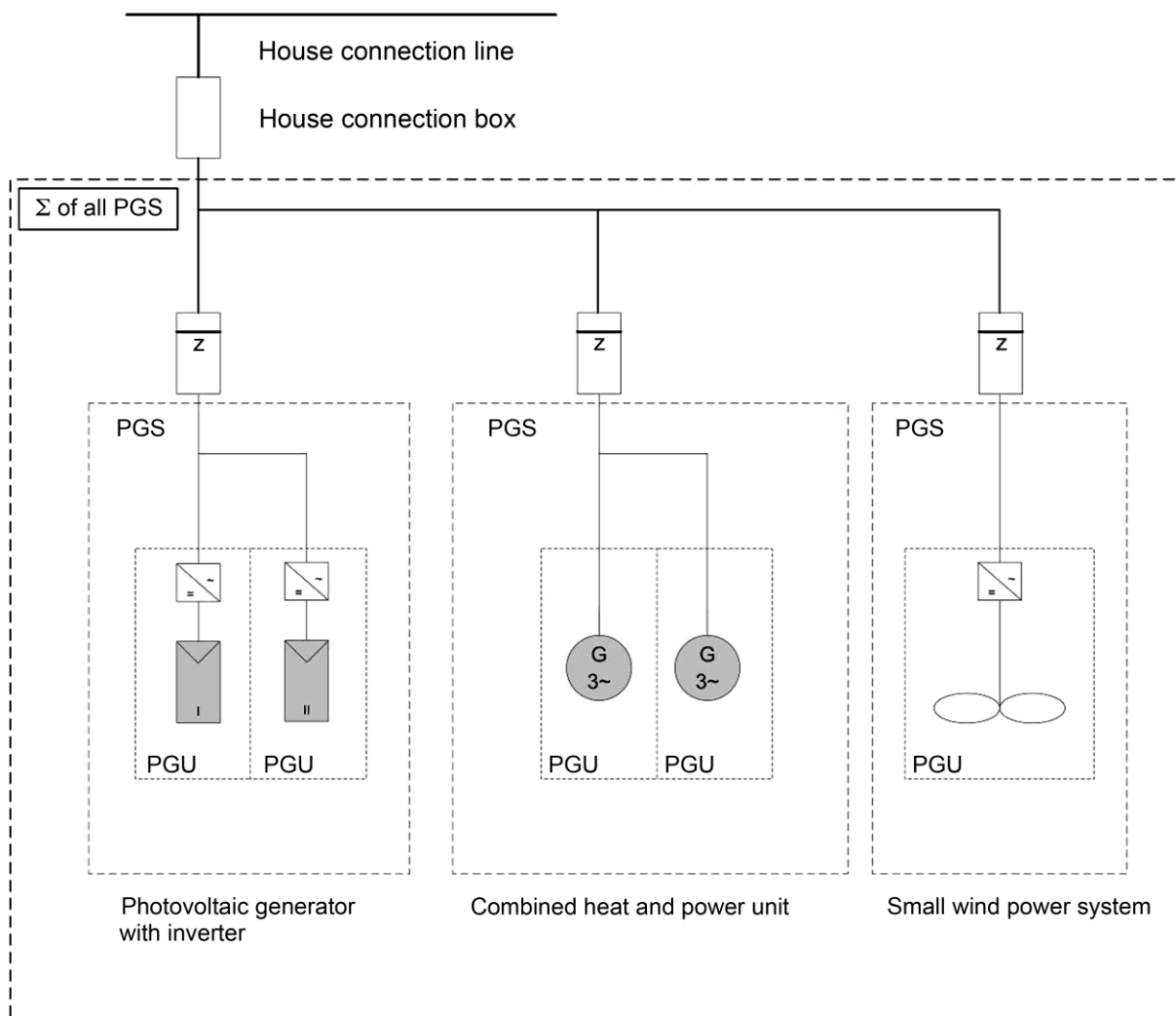


Figure A.1 — Overview on the concepts of power generation unit and power generation system

### A.2 Permissible voltage change (5.3)

The operation of power generation systems changes the operating voltage of the network. The voltage change at the PCC for the extraction of inductive reactive power can be expressed as follows:

$$\Delta u_a = \frac{S_{Amax} \cdot (R_{KV} \cdot \cos|\varphi| - X_{KV} \cdot \sin|\varphi|)}{U^2} \quad (\text{A.1})$$

As shown by equation (A.1), the voltage change may become negative, if the first term in the numerator becomes smaller than the second one, which is possible when  $\cos \varphi$  is sufficiently small, hence, if there is a sufficiently high extraction of inductive reactive power.

## Annex D (continued)

For the extraction of capacitive reactive power:

$$\Delta u_a = \frac{S_{Amax} \cdot (R_{kV} \cdot \cos|\varphi| + X_{kV} \cdot \sin|\varphi|)}{U^2} \quad (A.2)$$

This equation shows that the extraction of capacitive reactive power adds to the voltage increase which is to be taken into consideration for variable reactive power extraction.

Equations (A.1) and (A.2) are practicable approximations. The voltage changes calculated by means of these equations are slightly larger than the more exact results of a complex load-flow analysis.

### A.3 System reactions (5.4)

#### A.3.1 Rapid voltage changes

The factor  $k_{imax}$  is referred to as the maximum switching current factor and indicates the ratio of the highest current occurring during the switching operation gives (e.g. a starting current  $I_a$ ) to the nominal current of the power generation system; for example:

$$k_{imax} = \frac{I_a}{I_{nG}} \quad (A.3)$$

Results obtained from a calculation using this maximum switching current factor represent an upper estimate and are therefore, as a matter of principle, on the safe side. Values for this factor shall be gathered from the certificate of conformity.

If the maximum switching current factor  $k_{imax}$  is not calculated using equation (A.3), then the following reference values may be used:

- $k_{imax} = 1,2$  for synchronous generators with fine synchronisation, inverters;
- $k_{imax} = 4$  for asynchronous generators, which are connected at 95 % to 105 % of their synchronous rotational speed if no further details are available as to the type of current limitation.

With regard to short-term transient phenomena, the condition mentioned below shall be adhered to for very short voltage changes;

- $k_{imax} = 8$  for asynchronous generators, which are started from the network by means of motors if  $I_a$  is unknown.

Rapid voltage changes can be calculated more accurately than with equation (3) if the feed-in and network angles are taken into consideration:

$$\Delta u = k_{imax} \frac{S_{rE}}{S_{kV}} \cdot \cos(\psi + \varphi) \quad (A.4)$$

Where:

- is the network impedance angle  $\psi = \arctan\left(\frac{X_{kV}}{R_{kV}}\right)$
- $\varphi$  is the displacement factor of the power generation system

The displacement factor  $\varphi$  shall be positive for under-excited generator operation and negative for over-excited generator operation.

## Annex D

(continued)

Even if asynchronous machines or smaller synchronous generators without fine-step synchronisation are connected to the network with an approximately synchronous rotational speed, there may be very short voltage changes as a result of internal transient phenomena. Such a voltage change is permitted to be two times the otherwise applicable value, i.e. 6 %, provided that it is no longer than two full oscillations and that the voltage change following it does not exceed 3 % of the voltage measured initially before connection of the asynchronous machine.

Coincidence of switching operations of several generators connected to the same PCC leads to a multiple of the voltage change caused by a single generator and is to be avoided, if the maximum voltage change exceeds 3 % in total. One possible way that is suitable in terms of technology is to stagger the individual switching operations. With that, the intervals between two switching operations are determined by the magnitude of the voltage changes caused by them and they shall be at least 10 minutes for the maximum permissible apparent generator power. In case of a nominal generator power of less than half the permitted value, an interval of one minute is sufficient.

### A.3.2 Flicker

According to 5.4.3, flicker is deemed to be sufficiently limited for power generation systems with rated currents of up to 75 A, if the limit values of DIN EN 61000-3-3 (VDE 0838-3) or DIN EN 61000-3-11 (VDE 0838-11) are complied with.

If the limit values of DIN EN 61000-3-3 (VDE 0838-3) are not complied with at the reference impedance  $Z_{ref}$ , connection may still be permissible, according to DIN EN 61000-3-11 (VDE 0838-11), if the amount of the impedance of the supply network at the connection point shared with the public network is less than the amount of the maximum permissible network impedance  $Z_{max}$  determined in accordance with DIN EN 61000-3-11 (VDE 0838-11). In order to perform this comparison, the network impedance shall be determined at the connection point and compared with the value  $Z_{max}$  gathered from the device documents. The connection owner provides the network operator with the necessary values from the device documents of the manufacturer.

For power generation systems with several power generation units,  $P_{fii}$  shall be calculated separately for each individual power generation unit and, using this value, a resulting value for the flicker interference factor at the PCC shall be obtained using the following equation:

$$R_{t\ res} = \sqrt{\sum_i R_{fii}^2} \quad (A.5)$$

For a power generation system consisting of  $n$  identical power generation units, the resulting value for the flicker interference factor is:

$$R_{t\ res} = \sqrt{n} \cdot R_{tE} \quad (A.6)$$

### A.3.3 Harmonics and inter-harmonics

#### A.3.3.1 General

When calculating the permissible harmonic currents care shall be taken not to apply the rated short-circuit power of the low voltage network but the actual network short-circuit power  $S_{kV}$  at the PCC.

For the superposition of the harmonic currents of certain inverter types, the type specific rules listed in the following apply.

## Annex D (continued)

### A.3.3.2 Line-commutated inverters (six- or 12-pulse)

The inverter-typical harmonic currents (of 5<sup>th</sup> order, 7<sup>th</sup> order, 11<sup>th</sup> order, 13<sup>th</sup> order, etc.) as well as non-typical ones of very low order ( $\nu < 13$ ) are added up arithmetically:

$$I_{\nu} = \sum_{i=1}^n I_{\nu i} \quad (\text{A.7})$$

For the non-typical harmonics of higher order ( $\nu \geq 13$ ), the total harmonic current of an order equals the root of the sum of squares of the harmonic currents of this order:

$$I_{\nu} = \sqrt{\sum_{i=1}^n I_{\nu i}^2} \quad (\text{A.8})$$

### A.3.3.3 Pulse-modulated inverters

For an ordinal number  $\mu$  which is, in principle, non-integral but also includes integral values for values of  $\mu \geq 13$ , the total current equals the root of the sum of squares of the currents of the power generation units:

$$I_{\mu} = \sqrt{\sum_{i=1}^n I_{\mu i}^2} \quad (\text{A.9})$$

If untypical harmonic currents occur with such inverters for integral ordinal numbers of  $\nu < 13$ , these currents shall be added up arithmetically in correspondence to equation (A.7). Harmonic currents above 2<sup>nd</sup> order as well as inter-harmonics may be calculated using equation (A.9), if the pulse frequency of the inverter is at least 1 kHz.

If several power generation units/power generation systems are effective at the same PCC, then the harmonic currents permissible for an individual power generation unit/power generation system are calculated from the apparent power  $S_{A i \max}$  of the power generation unit/power generation system  $i$  and the feed-in power connectable or planned  $S_{AV}$  at this PCC as follows:

- for arithmetical addition of the harmonic currents, using equation (A.7):

$$I_{\nu A i \text{zul}} = I_{\nu \text{zul}} \cdot \frac{S_{A i \max}}{S_{AV}} \quad (\text{A.10})$$

- for square addition of the harmonic currents using equation (A.8) and equation (A.9):

$$I_{\nu A i \text{zul}} = I_{\nu \text{zul}} \cdot \sqrt{\frac{S_{A i \max}}{S_{AV}}} \quad (\text{A.11})$$

Under special circumstances, harmonics of higher frequency (i.e. within a range above 1 250 Hz) may occur, which are attributable to the fact that weakly damped resonances of sub-networks are excited by commutation notches. In such a case, particular measures shall be taken which are described in greater detail in Technische Regeln zur Beurteilung von Netzrückwirkungen (Technical rules for evaluation of network reactions).

## A.4 Connection criteria (5.5)

Table A.1 shows the possible variants of feed-in and protection as determined by the maximum apparent power of the power generation system  $S_{A \max}$ .

## Annex D

(continued)

Table A.1 — Implementation of the connection criteria after 5.5

	2	3	4
	<b>EA ≤ 13,8 kVA</b>	<b>13,8 ≤ EA ≤ 30 kVA</b>	<b>EA &gt; 30 kVA</b>
Feed-in	Single-phase or three-phase current	Three-phase current	Three-phase current
Protection	Integrated NS protection with $U > = 1,1 U_n$ or Central NS protection with $U > = 1,1 U_n$ or Central NS protection with $U > = 1,1 U_n$ and Integrated NS protection with $U > = 1,1 \dots 1,15 U_n$		Central NS protection with $U > = 1,1 U_n$ or Central NS protection with $U > = 1,1 U_n$ and Integrated NS protection with $U > = 1,1 \dots 1,15 U_n$

## A.5 Reactive power (5.7.5)

For power generation units, the reactive power control serves to better integrate the power generation systems into the low-voltage network. It provides an important contribution to the efficient use of available network capacities.

Along with the properties of the power generation system (fluctuating or constant feed-in), it is also required to take into account the respective network conditions in order to achieve optimum usage.

In a network in which the feed-in power is limited by the voltage criterion (typically line taps), the voltage stability can be optimised by under-excited operation of the power generation system (Figure A.2).

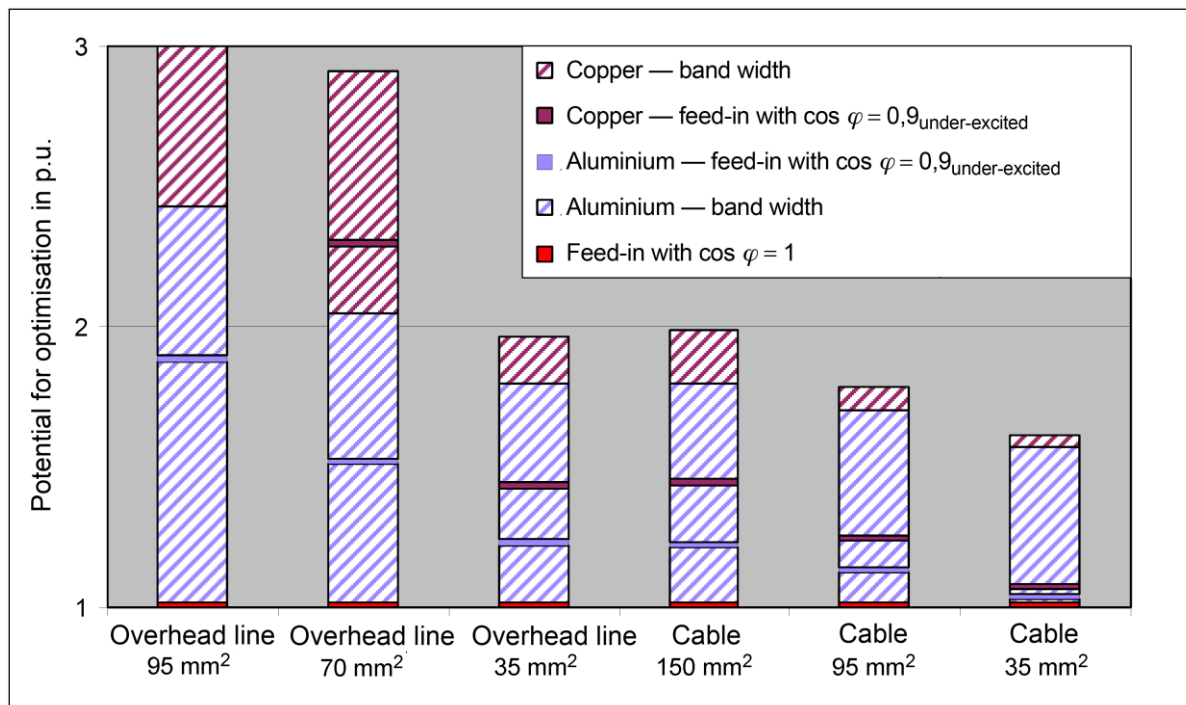


Figure A.2 — Potential for optimisation provided by a suitable reactive power feed-in for typical overhead line or cable types (related to an operation mode where  $\cos \varphi = 1$ )

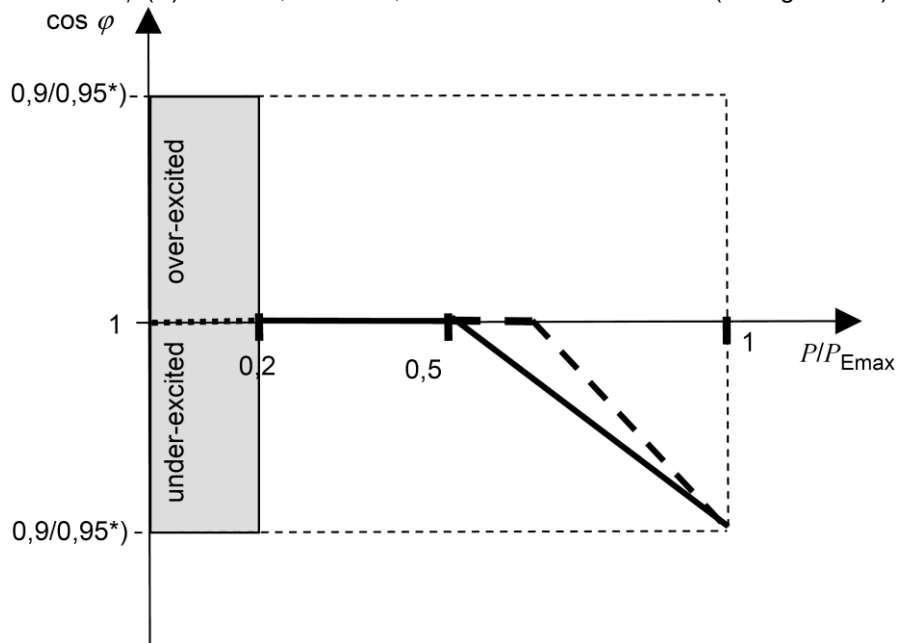
**Annex D**  
(continued)

The bandwidth takes into account an under-excited operation mode between  $\cos \varphi = 0,9$  and  $\cos \varphi = 1$ , typical local network transformers as well as the distance of the power generation system to the local network transformer.

Due to their lower  $R/X$  ratio, the potential for optimisation is generally larger for overhead lines than it is for cables. Even for great distances from the local network transformer, there are considerable effects on the mains voltage when using a suitable reactive power control.

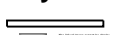
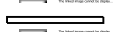
However, it shall be noted that the reactive power control comes along with a greater power loss in the low-voltage network. This power loss can be minimised using a characteristic curve  $\cos \varphi (P)$ . When doing so, the power generation system is operated in an under-excited mode only, if it feeds with nearly rated power. Because of this behaviour, the characteristic curve  $\cos \varphi (P)$  is suitable for power generation systems with fluctuating power feed-in, such as PV systems.

The network operator may provide different characteristic curves for the power generation system's reactive power operation mode depending on the network conditions. In general, the prescribed characteristic curve  $\cos \varphi (P)$  has two, however, not more than four nodes (cf. Figure A.3).



\*) Depending on  $S_{Amax}$ .

**Key**

-  Standard characteristic curve
-  Variant of the characteristic curve

**Figure A.3 — Examples of a characteristic curve  $\cos \varphi (P)$  with three nodes**

Starting with a power of  $0,2 P_{E_{max}}$ , the characteristic curve shall be adhered to.

The reactive power operation mode used to ensure static voltage stability in the networks is a new requirement for power generation systems and requires further consideration in particular for reactive energy clearing and for the use of reactive current compensation systems.

For full feed-in of the power generation system, the network operator will, in general, require an the power generation system to operate in an under-excited mode above  $0,5 P_n$  (also see the standard characteristic curve  $\cos \varphi (P)$  in Figure 4).

## Annex D (continued)

For excess feeding the use of an “intelligent” reactive current compensation system is required which, depending on the overall behaviour of the customer system for extraction or feed-in, regulates the displacement factor  $\cos \varphi$  respectively required for the entire customer system at the network connection point. As long as the required reactive current compensation systems are not commercially available, it is advisable to use a differentiated approach when specifying the displacement factor  $\cos \varphi$  of the power generation system.

In the case of the greater part of the generated power being supplied to the network operator's network and for a feed-in power of more than approx. one third of the maximum extraction power agreed, a displacement factor  $\cos \varphi$  in the range from 0,90<sub>under-excited</sub> to 0,95<sub>under-excited</sub> is normally to be set in accordance with the network operator's provisions. If a reactive current compensation system regulates in relation to  $\cos \varphi$  at the network connection point, then the predefined value shall be set at the reactive current compensation system. The power generation system may be set to  $\cos \varphi = 1$ . If  $\cos \varphi$  is regulated only in correspondence to the extraction customer part of the customer system, then the power generation system shall be set to the value of  $\cos \varphi$  provided by the network operator.

More detailed information on the power ratio can be obtained by network calculations examining the effects that the different load cases of the customer system have on the voltage change at the network connection point.

In cases where the feed-in power is less than one third of the maximum extraction power agreed, a specific default for the displacement factor of the power generation system is normally not required. For minimisation of the losses in the entire system, a displacement factor of  $\cos \varphi = 1$  shall be aimed for.

If a reactive energy clearing is applied that is influenced by the power generation system, then the network operator and the system operator should always coordinate their procedures for a reactive power compensation of the customer system and for the default displacement factor for the power generation system. It may also be sensible to use a reactive energy meter (e.g. load-profile meter) for the power generation system and, for balancing purposes, to take into account the entire supply point for the customer system.

### A.6 General requirements, single-fault tolerance (6.1)

The central NS protection, integrated NS protection, integrated interface switch as well as the trigger circuit consisting of the integrated NS protection and integrated interface switch shall meet the requirements for single-fault tolerance.

Taking into account the basic safety principles, these devices shall be designed, constructed, chosen, assembled and combined at least so that they can withstand the operating conditions to be expected (e.g. reliability with regard to their breaking capacity and switching frequency) as well as the external influences to be expected (e.g. mechanical vibration, external fields, interruptions or disturbances of the energy supply).

A single fault shall not lead to a loss of the safety function. Faults of common cause shall be taken into account if the probability for the occurrence of such a fault is significance. Whenever reasonably practical, the individual fault shall be displayed and lead to the power generation unit or system being disconnected.

NOTE 1 This requirement for the detection of individual faults does not mean that all faults are detected. Accumulation of undetected faults can therefore lead to an unintentional output signal and to a hazardous state.

## Annex D (continued)

NOTE 2 This system allows for:

- a) the safety to always be maintained in the event of a single fault;
- b) some but not all faults to be detected;
- c) the accumulation of undetected faults to possibly lead to the loss of the safety functions.

NOTE 3 Further explanation of the term "single-fault tolerance": For implementation of the single-fault tolerance, all the units required for the protective functions in the devices are executed so that, in the event of a fault occurring (e.g. malfunctioning of a processor or measurement amplifier), this malfunction is detected by another unit and leads to disconnection.

Independent of each other, the series-connected switches shall have a breaking capacity corresponding to the rated current of the power generation system. At least one switch shall be executed as a power relay or contactor and be suitable for overvoltage category 2. For single-phase feed-in systems, the switch shall have one contact of this overvoltage category each for both the neutral conductor and the line conductor. For poly-phase supply systems, it is required to have one contact of this overvoltage category each for all active conductors. The second switch may be formed by the electronic switching components of the inverter bridge or another circuit provided that the electronic switching components can be disconnected by control signals and that it is ensured that a failure is detected and leads to prevention of the operation at the latest at the next reconnection.

For inverters without simple separation between network and PV generator (inverters without transformers), both the switches mentioned in the paragraph above shall be executed as power relays, contactors or mechanical circuit-breakers with the requirements described therein, although a disconnection device is permitted to be connected between PV generator and inverter.

### A.7 Interface switch (6.4)

All-phase switching means switching all active conductors of the power generation system from the feed-in point to the customer system or from the network operator's network (depending on the interface switch mounting place). DIN VDE 0100-200 (VDE 0100-200) defines active conductors as all conductors intended to be live under normal operating conditions and includes the neutral conductor. By agreement, PEN conductors are excluded.

DIN VDE 0100-460 (VDE 0100-460) defines the conductors to be switched. Depending on the network system at the interface switch mounting place, the following requirements arise. In the TT system, the three line conductors and the neutral conductor shall be connected. In the TN-C system and in the TN-C part of the TN-C-S system, the three line conductors shall be connected. In the TN-S system and in the TN-S part of the TN-C-S system, the three line conductors and the neutral conductor shall be connected. This means that, with the exception of the conductors with a PE function, all conductors shall be connected.

If connection of the neutral conductor is required, then a interface switch shall be used which connects the neutral conductor with phase-lead at turn-on and phase-lag at turn-off, however, at least simultaneously.

### A.8 Protective devices for the interface switch (6.5)

#### A.8.1 General

With regard to the proper protection of the power generation system, it shall be considered that the short-circuit current is considerably lower for island mode than for network parallel operation. For power generation systems feeding into the low-voltage network via inverters, it may even be less than the system's rated current. The use of residual current devices (RCD) may be inevitable.



**Annex D**  
(concluded)**A.8.2 Protective functions**

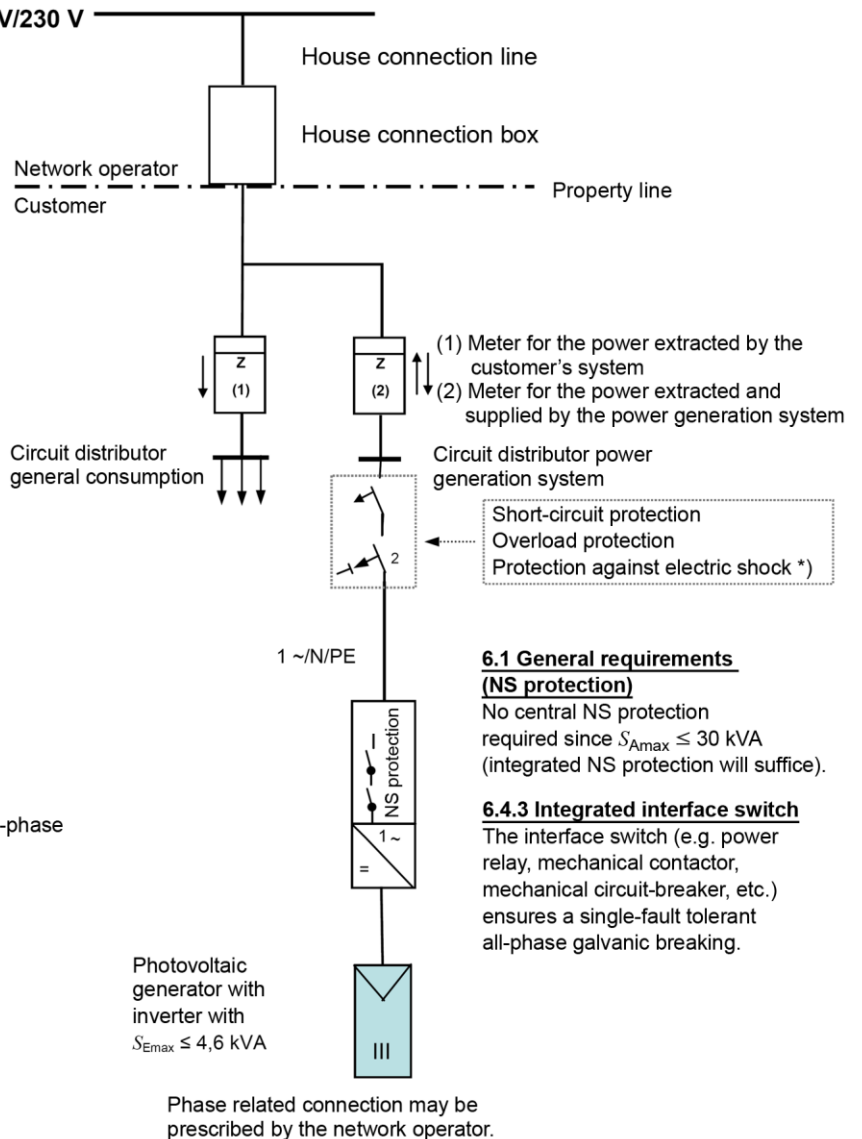
Should operational problems occur for existing systems in the context of the protective functions required by the now obsolete VDEW directive "Eigenerzeugungsanlagen am Niederspannungsnetz" (Power generation systems connected to the low-voltage network) (such as problems with the net impedance measurement hitherto applied), the existing system may be retrofitted following the provisions of this VDE application guide.

**Annex E – (Annex B of VDE-AR-N 4105) Connection examples**  
(normative)

**B.1 Maximum apparent connection power  $S_{Amax} \leq 4,6$  kVA**

**5.5 Connection criteria**

As a rule, power generation systems shall be designed and connected to the network as balanced three-phase generators. Power generation systems may also be single-phase connected to the network, if the sum of all single-phase connected power generation units per network connection does not exceed  $S_{E_{max}} \leq 4,6$  kVA per line conductor. Therefore, it is possible to connect in single phase, distributed to the three line conductors, at maximum  $3 \times 4,6$  kVA =  $\sum S_{E_{max}} \leq 13,8$  kVA. As soon as the limits given above are exceeded at the network connection point, any extension shall be three-phase connected to the three-phase system. For all that, the maximum permissible imbalance of 4,6 kVA at a single network connection point for the sum of all power generation systems applies here as well. This requirement may also be satisfied by communicatively coupling single-phase connected power generation units of the same primary energy carrier or by replacing the single-phase inverters with three-phase inverters.



**6.1 General requirements**

**(NS protection)**

No central NS protection required since  $S_{Amax} \leq 30$  kVA (integrated NS protection will suffice).

**6.4.3 Integrated interface switch**

The interface switch (e.g. power relay, mechanical contactor, mechanical circuit-breaker, etc.) ensures a single-fault tolerant all-phase galvanic breaking.

\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

**Figure B.1 — Connection of a single-phase power generation unit with full feed-in and a maximum apparent connection power  $\leq 4,6$  kVA**

**Annex E**  
(continued)

**B.2 Maximum apparent connection power  $S_{Amax} \leq 13,8$  kVA**

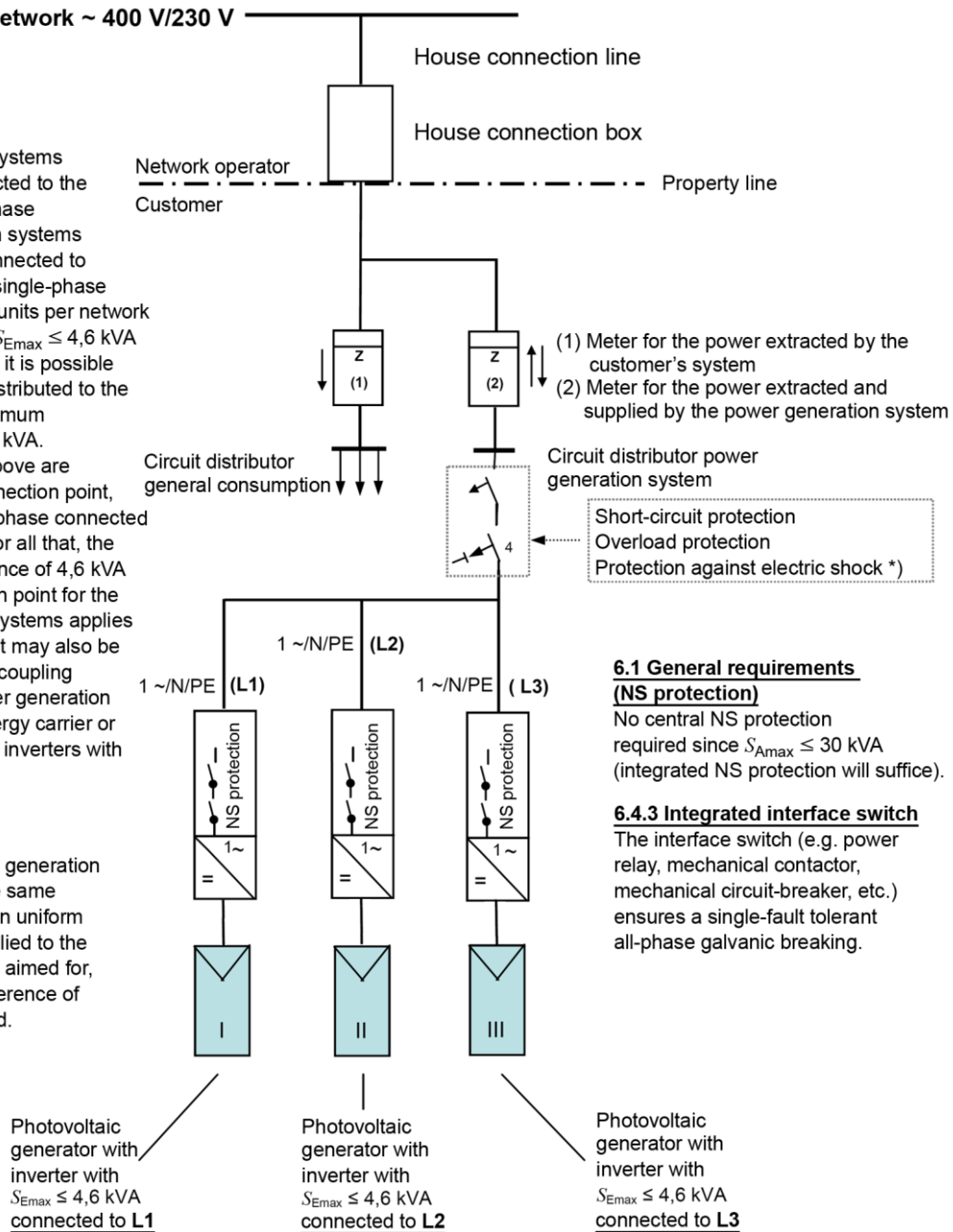
**5.5 Connection criteria**

As a rule, power generation systems shall be designed and connected to the network as balanced three-phase generators. Power generation systems may also be single-phase connected to the network, if the sum of all single-phase connected power generation units per network connection does not exceed  $S_{E_{max}} \leq 4,6$  kVA per line conductor. Therefore, it is possible to connect in single phase, distributed to the three line conductors, at maximum  $3 \times 4,6$  kVA =  $\sum S_{E_{max}} \leq 13,8$  kVA.

As soon as the limits given above are exceeded at the network connection point, any extension shall be three-phase connected to the three-phase system. For all that, the maximum permissible imbalance of 4,6 kVA at a single network connection point for the sum of all power generation systems applies here as well. This requirement may also be satisfied by communicatively coupling single-phase connected power generation units of the same primary energy carrier or by replacing the single-phase inverters with three-phase inverters.

**5.4.5. Voltage unbalance**

If several single-phase power generation systems are connected to the same network connection point, then uniform distribution of the power supplied to the three line conductors shall be aimed for, where a maximum power difference of 4,6 kVA shall not be exceeded.

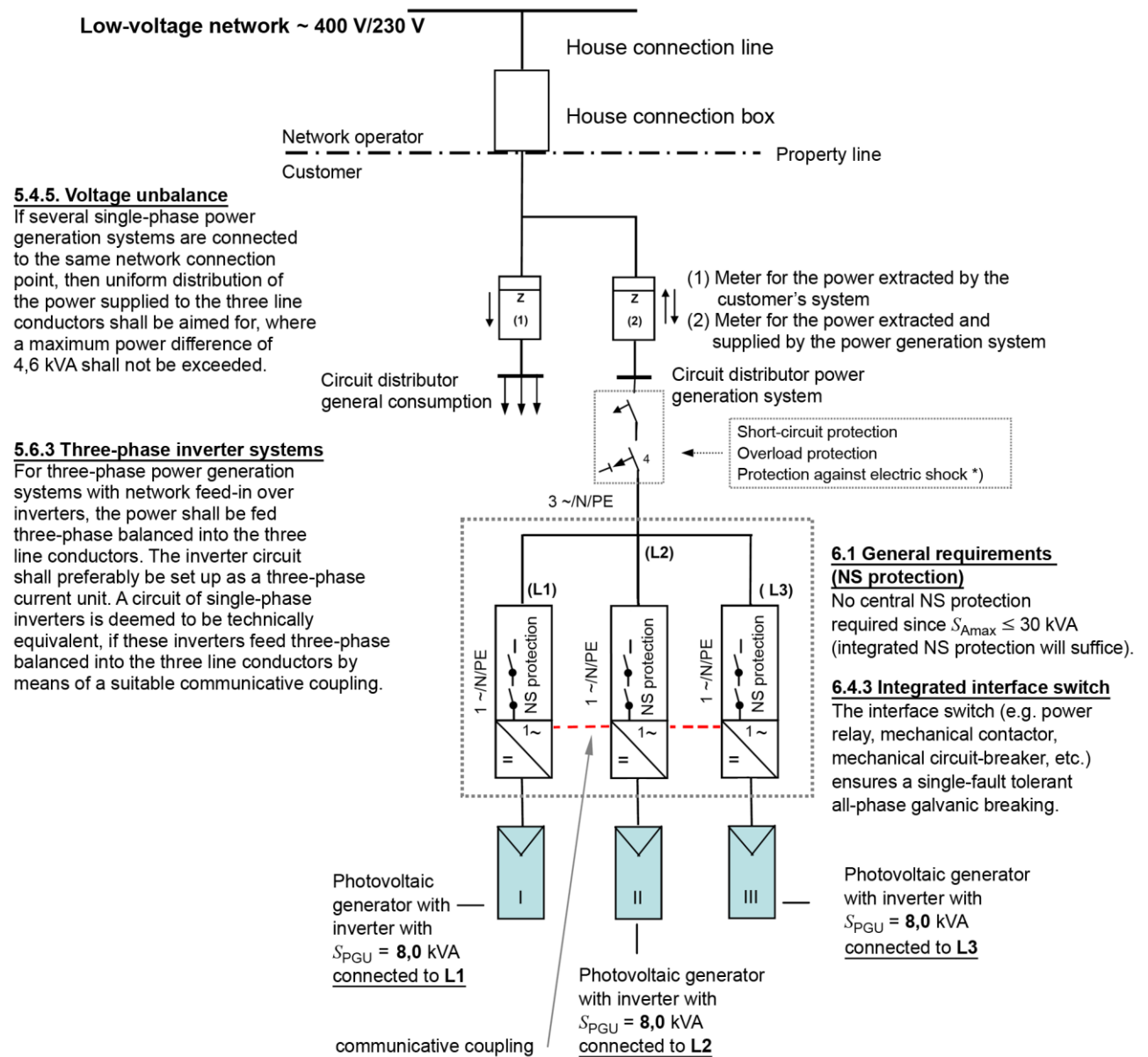


\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

**Figure B.2 — Connection of 3 single-phase power generation units with full feed-in and a maximum apparent connection power  $\leq 4,6$  kVA per line conductor**

**Annex E**  
(continued)

**B.3 Power generation system with communicative coupling of the single-phase inverters and with integrated NS protection**

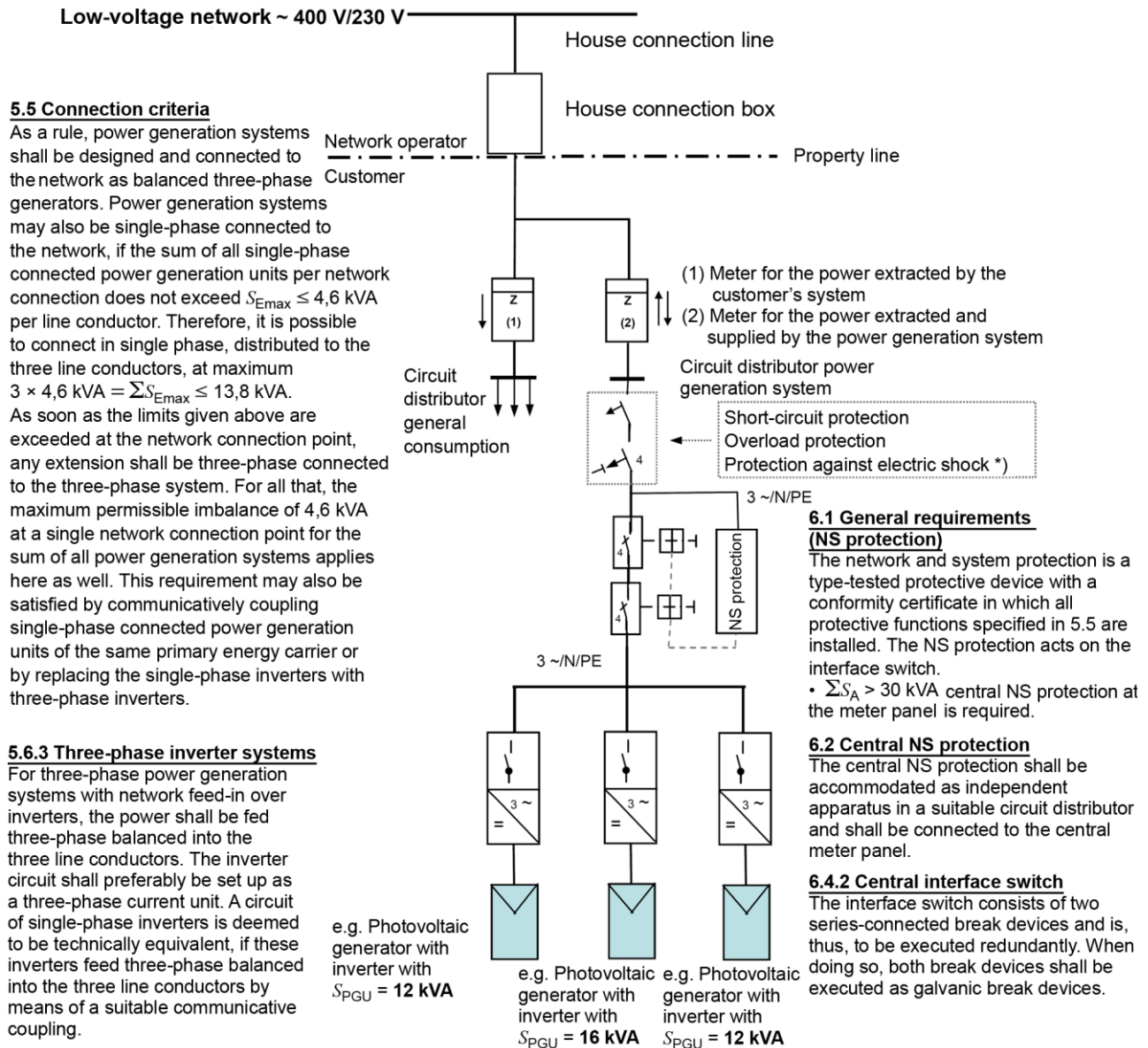


\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

**Figure B.3 — Connection of 3 single-phase power generation units in full feed-in and with communicative coupling**

## Annex E (continued)

### B.4 Maximum apparent connection power of $S_{Amax} > 30$ kVA



\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

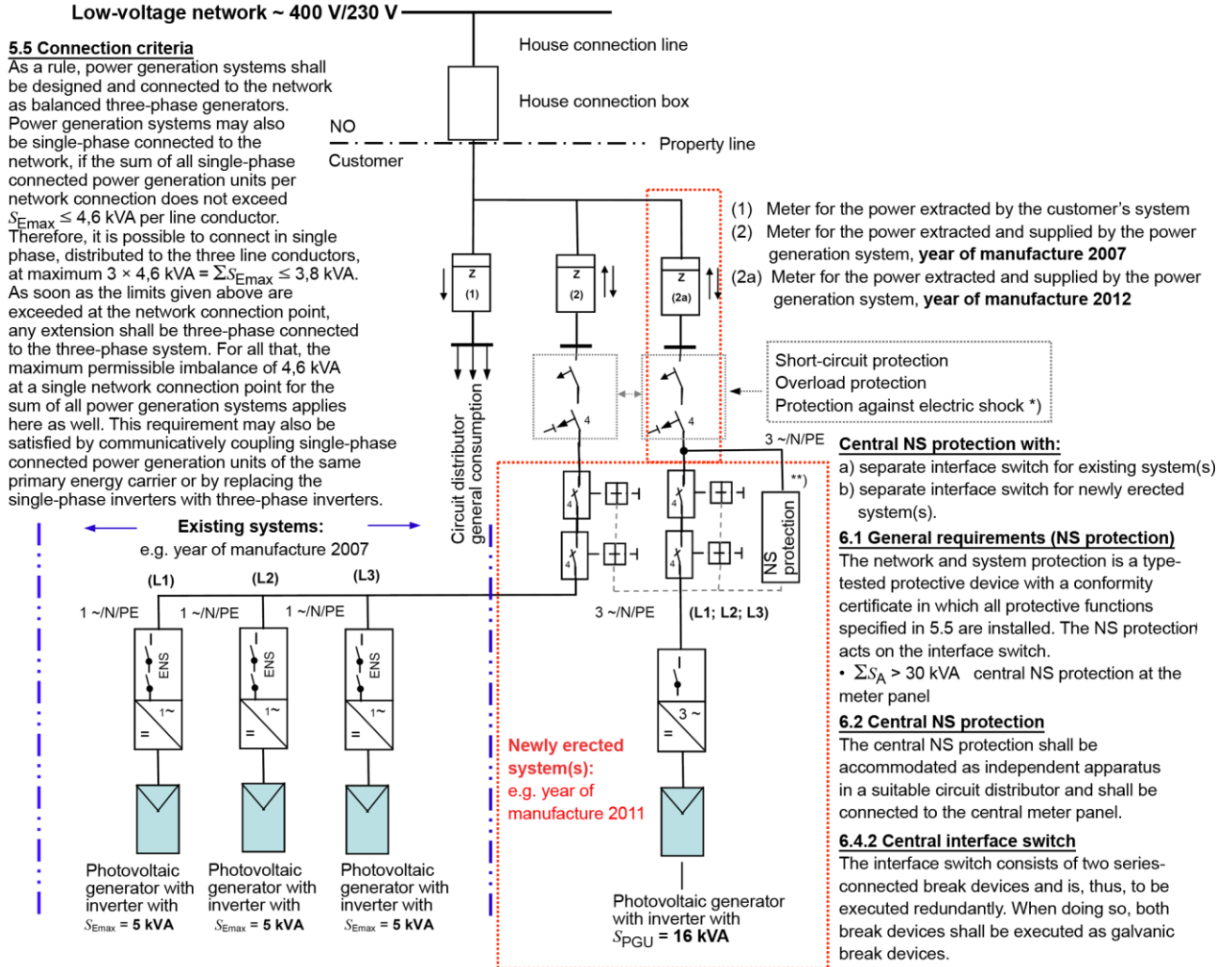
NOTE Co-ordination with the network operator is required with regard to the meter panel execution for system sizes with operating currents  $> 6$  A.

- direct measurement
- half-indirect measurement

**Figure B.4 — Connection of 3 three-phase power generation units with full feed-in**

**Annex E**  
(continued)

**B.5 New power generation unit connected in parallel to an existing system**  
 $S_{Amax} > 30 \text{ kVA}$



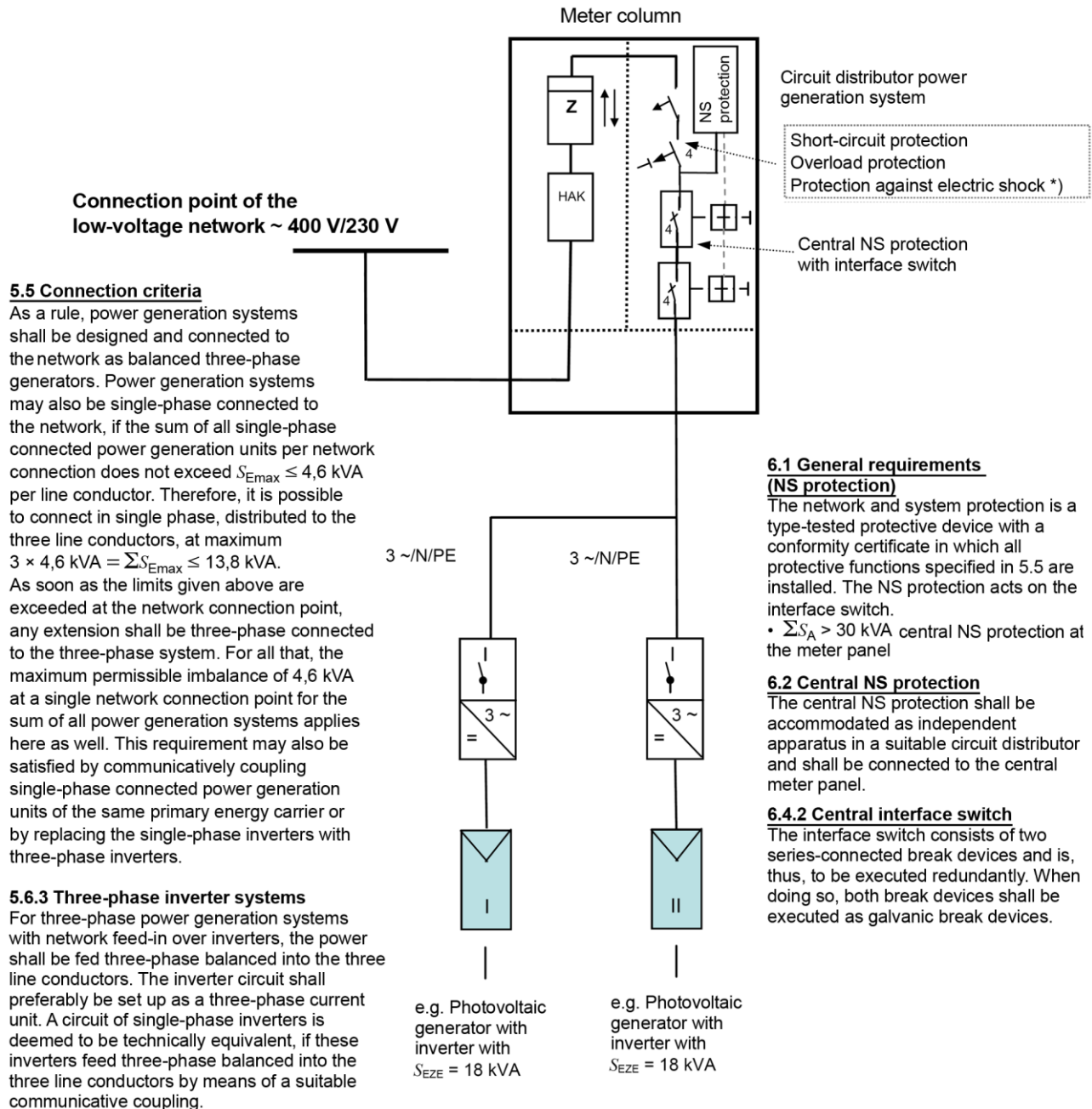
\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

**Figure B.5 — Connection of a new power generation unit connected in parallel to an existing system with full feed-in for a maximum apparent connection power  $S_{Amax} > 30 \text{ kVA}$**



## Annex E (continued)

### B.6 Connection with meter column



\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

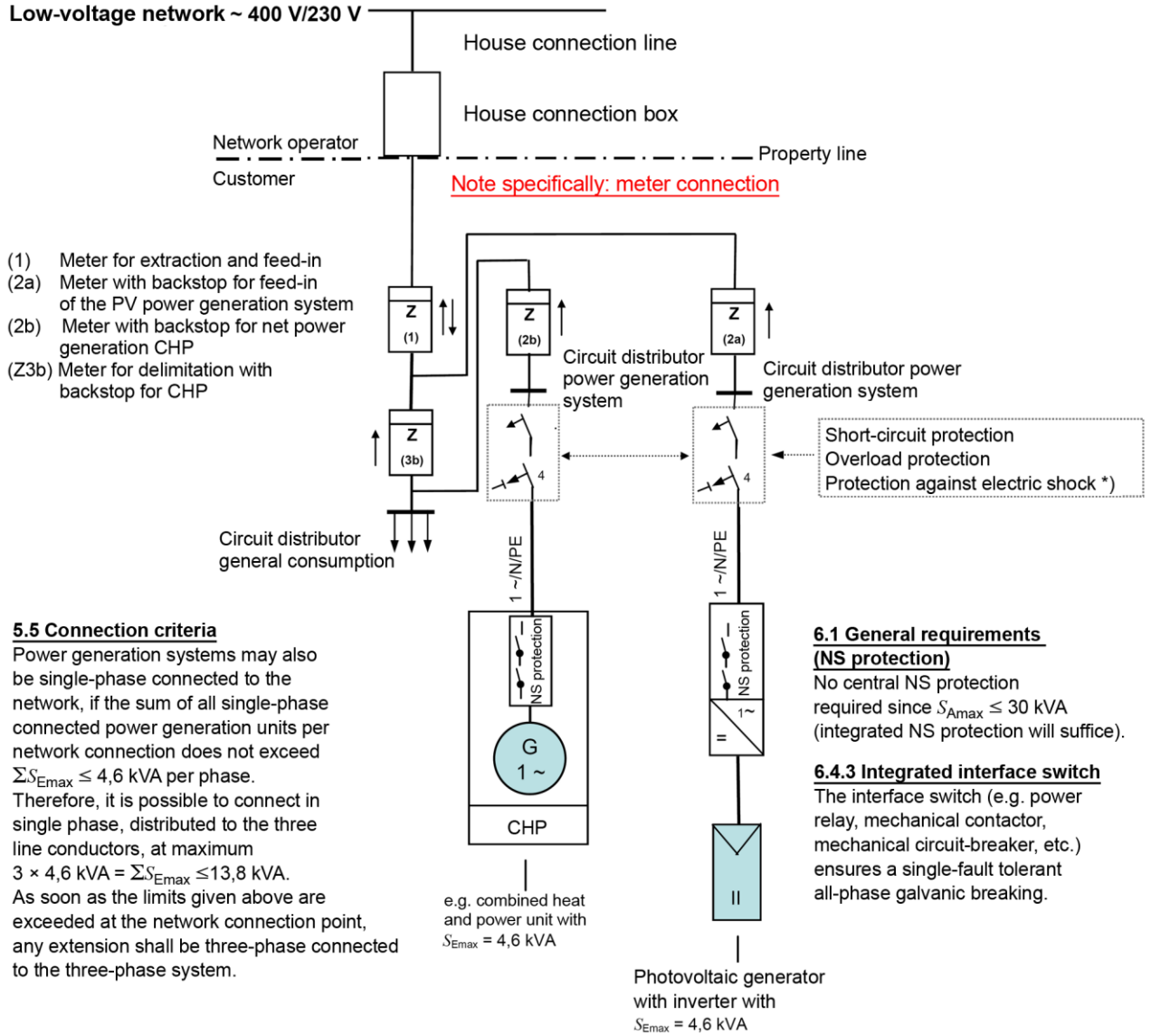
NOTE Co-ordination with the network operator is required with regard to the meter panel execution for system sizes with operating currents  $> 63$  A.

- direct measurement
- half-indirect measurement

**Figure B.6 — Connection of a power generation system with meter column for a maximum apparent connection power  $S_{A\max} > 30$  kVA**

**Annex E**  
(continued)

**B.7 Connection for excess feed-in (self consumption in accordance with EEG, § 33 EEG and KWK-G, § 4 (3))**



**5.5 Connection criteria**

Power generation systems may also be single-phase connected to the network, if the sum of all single-phase connected power generation units per network connection does not exceed  $\sum S_{E_{max}} \leq 4,6 \text{ kVA}$  per phase. Therefore, it is possible to connect in single phase, distributed to the three line conductors, at maximum  $3 \times 4,6 \text{ kVA} = \sum S_{E_{max}} \leq 13,8 \text{ kVA}$ . As soon as the limits given above are exceeded at the network connection point, any extension shall be three-phase connected to the three-phase system.

**6.1 General requirements (NS protection)**

No central NS protection required since  $S_{A_{max}} \leq 30 \text{ kVA}$  (integrated NS protection will suffice).

**6.4.3 Integrated interface switch**

The interface switch (e.g. power relay, mechanical contactor, mechanical circuit-breaker, etc.) ensures a single-fault tolerant all-phase galvanic breaking.

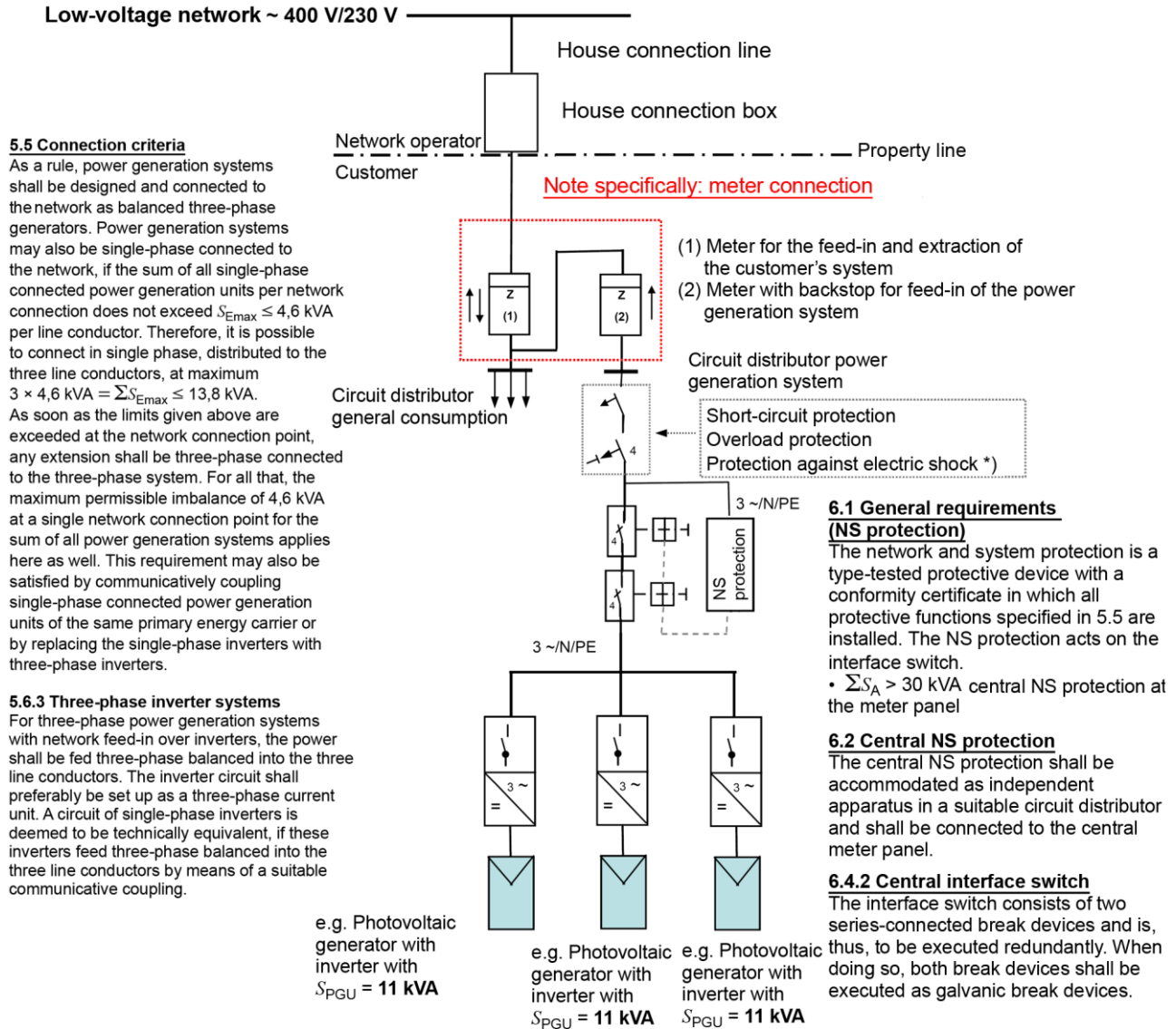
\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

**Figure B.7 — Connection of a power generation system with excess feed-in (taking into account self consumption in accordance with EEG, § 33 and KWK-G, § 4 (3))**



**Annex E**  
(continued)

**B.8 Connection for excess feed-in of > 30 kVA**



\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410) and DIN VDE 0100-712 (VDE 0100-721), respectively.

NOTE Co-ordination with the network operator is required with regard to the meter panel execution for system sizes with operating currents > 63 A.

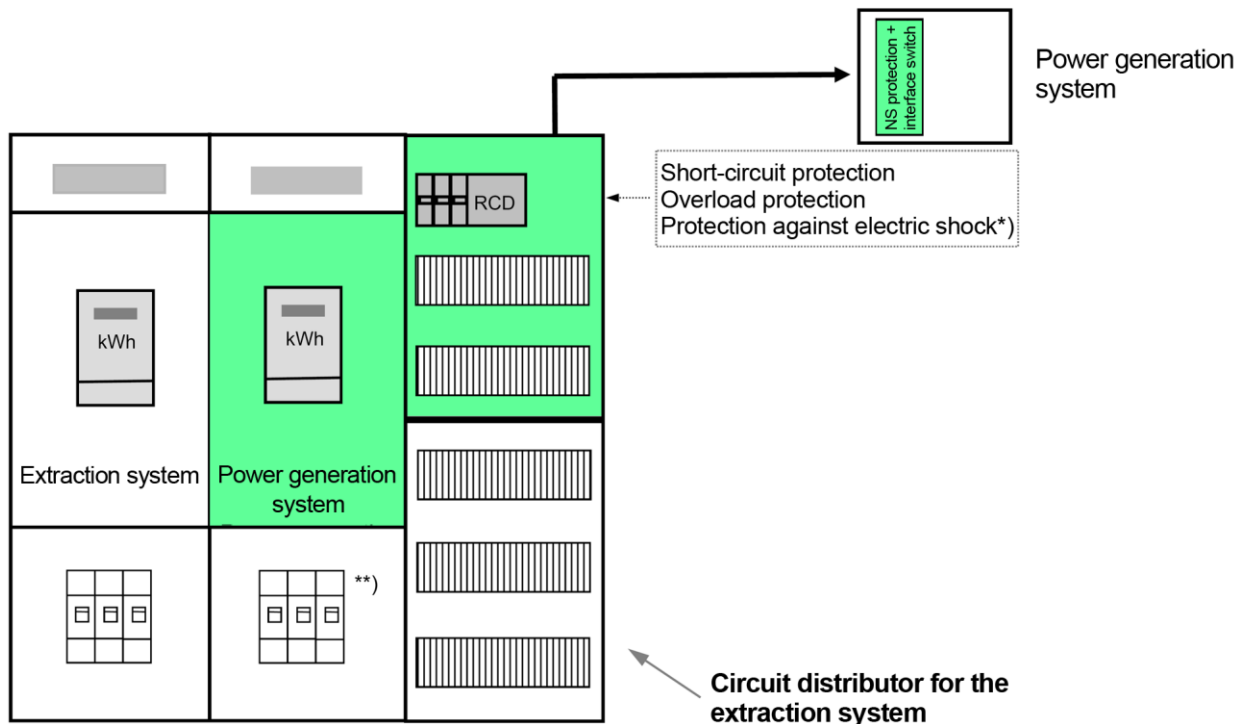
- a) direct measurement
- b) half-indirect measurement

**Figure B.8 — Connection of a power generation system with excess feed-in for a maximum connection power  $S_{A_{max}} > 30$  kVA**

**Annex F – (Annex C of VDE-AR-N 4105) Example of meter panel configurations**  
(normative)

**C.1 Meter panel for connection of a power generation system with a maximum apparent connection power  $S_{Amax} \leq 30$  kVA (full feed-in)**

Circuit distributor next to the meter panel (single-family house)



\*) RCD required in the TT system or in accordance with, e.g., DIN VDE 0100-410 (VDE 0100-410), respectively.

\*\*) Selective overcurrent protective device in accordance with TAB 2007, 7.4 required for full feed-in only.

**Figure C.1 — TAB meter panel: general system and power generation system  $\leq 30$  kVA**

NOTE 1 For NS protection (also see 6.1):

For a maximum apparent connection power  $S_{Amax} \leq 30$  kVA, the NS protection may be integrated in the system control of the power generation units (integrated NS protection).

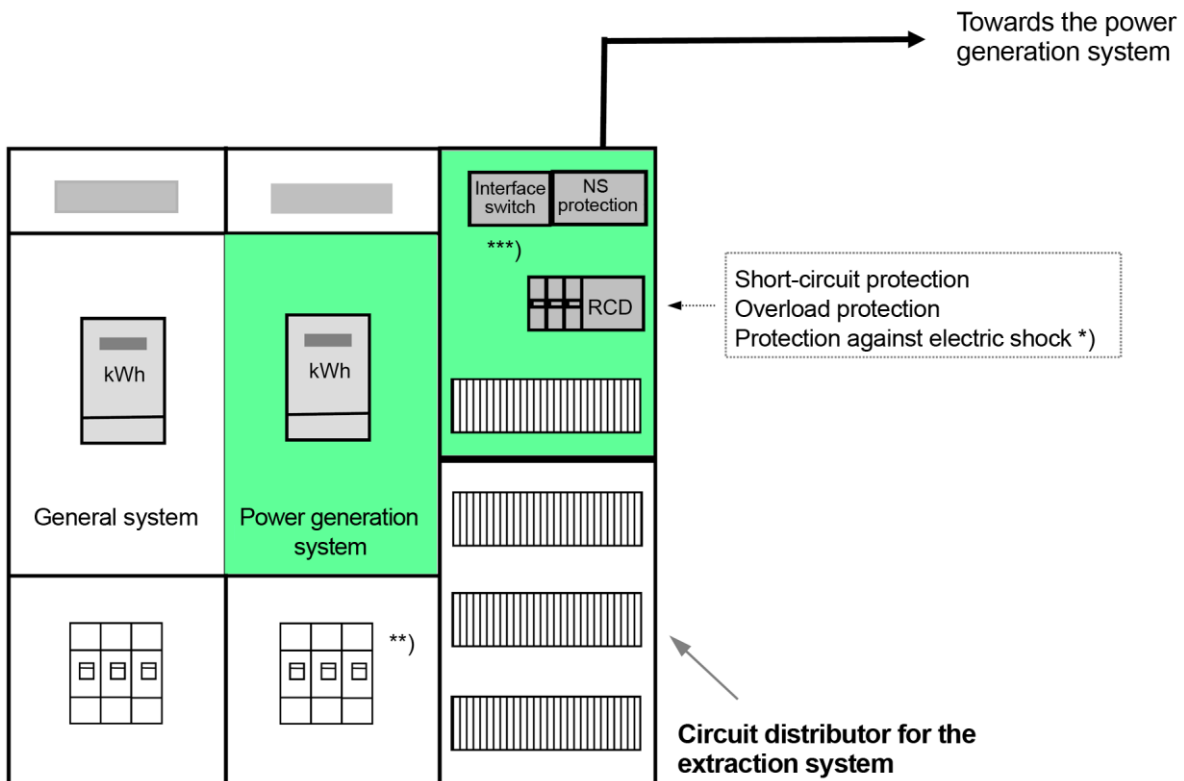
NOTE 2 For the interface switch (also see 6.4.2):

For power generation systems with inverters, the interface switch may be provided on the inverter’s network side. A short circuit in the inverter shall not affect the interface switch in its breaking function.

## Annex F (continued)

### C.2 Meter panel for the connection of a power generation system with a maximum apparent connection power $S_{Amax} > 30$ kVA and with central NS protection

#### Circuit distributor next to the meter panel (single-family house)



\*) RCD required in the TT system or in accordance with DIN VDE 0100-410 (VDE 0100-410), respectively.

\*\*) Selective overcurrent protective device in accordance with TAB 2007, 7.4 required for full feed-in only.

\*\*\*) The ball switch may also be inserted decentralised at or in the power generation system.

**Figure C.2 — TAB meter cabinet: general system and power generation system > 30 kVA**

NOTE 1 For NS protection (also see 6.1):

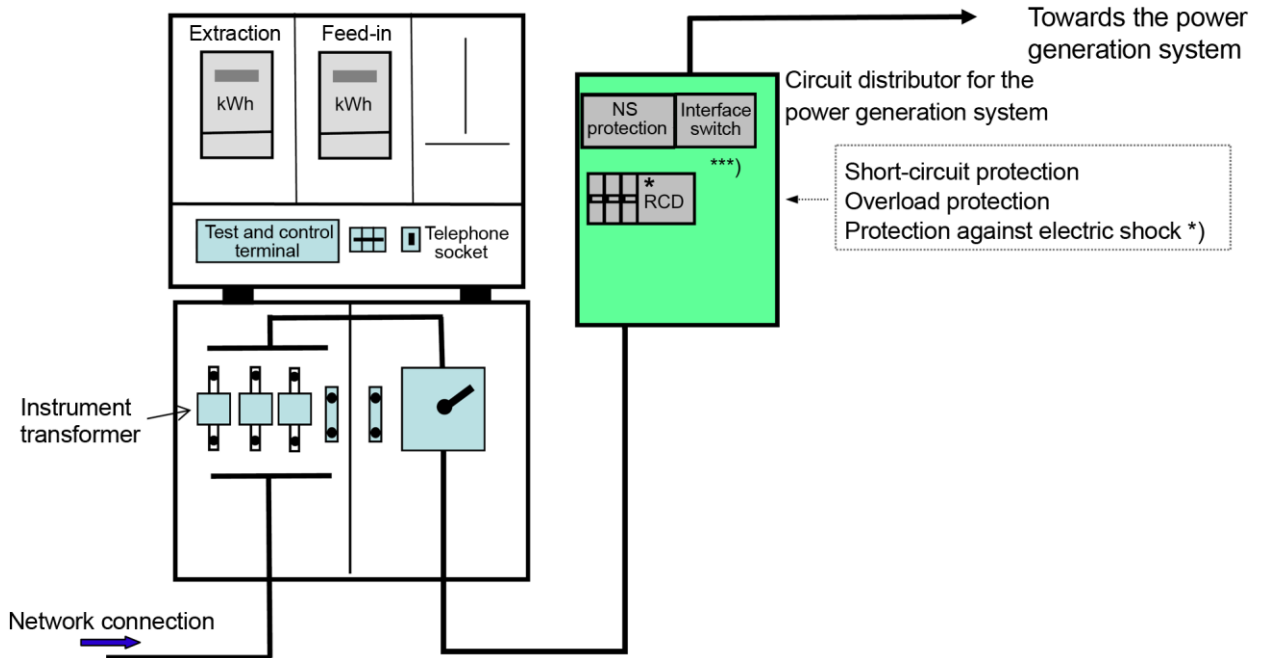
The NS protection is to be implemented as central NS protection at the meter panel.

NOTE 2 For the interface switch (also see 6.4.2):

The two break devices of the interface switch are to be installed in the circuit distributor of the power generation system adjacent to the meter panel.

**Annex F**  
(continued)

**C.3 Meter panel for the connection of a power generation system that includes transformer measurement**



- \*) RCD required in the TT system or in accordance with DIN VDE 0100-410 (VDE 0100-410), respectively.
- \*\*\*) The ball switch may also be inserted decentralised at or in the power generation system.

**Figure C.3 — Meter panel for the connection of a power generation system that includes transformer measurement**

NOTE 1 For NS protection (also see 6.1):

The NS protection is to be implemented as central NS protection at the meter panel.

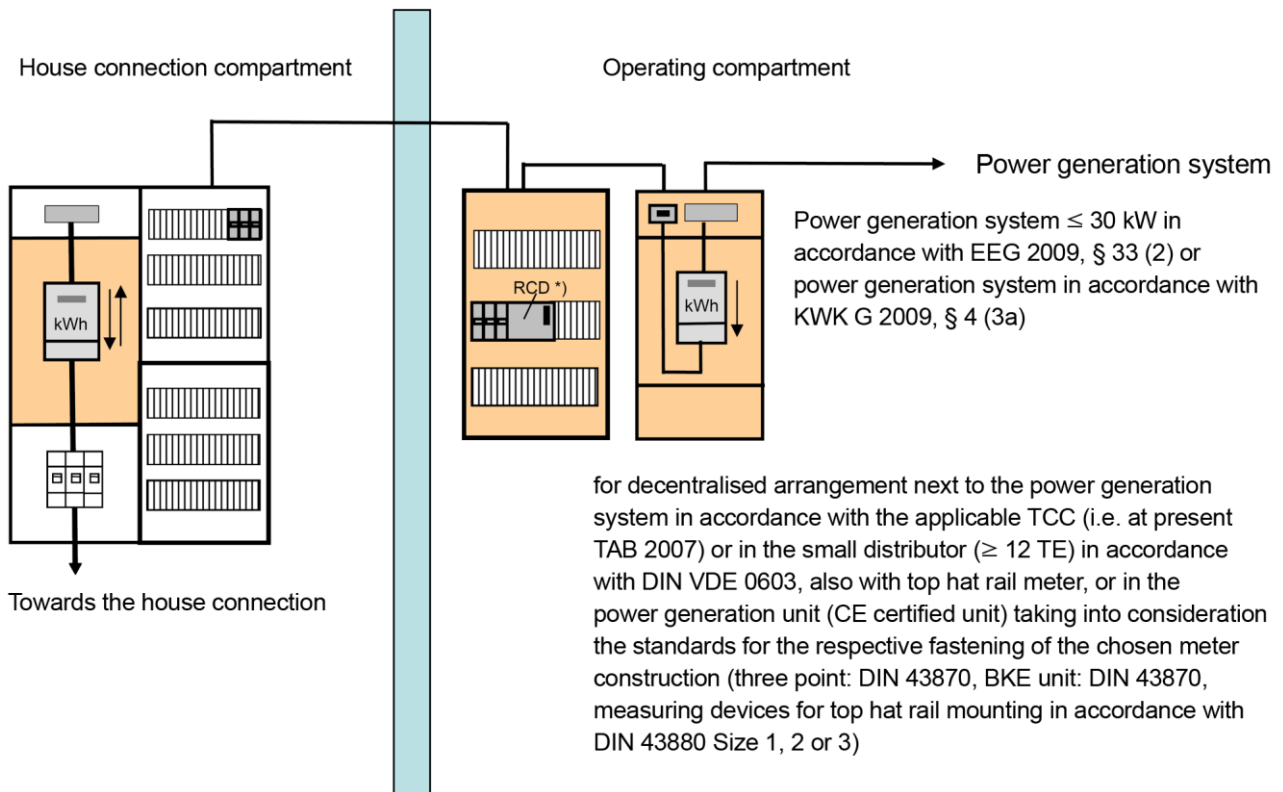
NOTE 2 For the interface switch (also see 6.4.2):

The two break devices of the interface switch are to be installed in the circuit distributor of the power generation system adjacent to the meter panel.

## Annex F (continued)

### C.4 Meter panel (that may also be arranged in a decentralised manner) for the connection of a power generation system for self consumption or excess feed-in in accordance with EEG, § 33 and KWK-G, § 4

#### C.4.1 General



\*) RCD required in the TT system or in accordance with DIN VDE 0100-410 (VDE 0100-410), respectively.

**Figure C.4 — Meter panel (that may also be arranged in a decentralised manner) for the connection of a power generation system for self consumption or excess feed-in**

NOTE 1 For NS protection (also see 6.1):

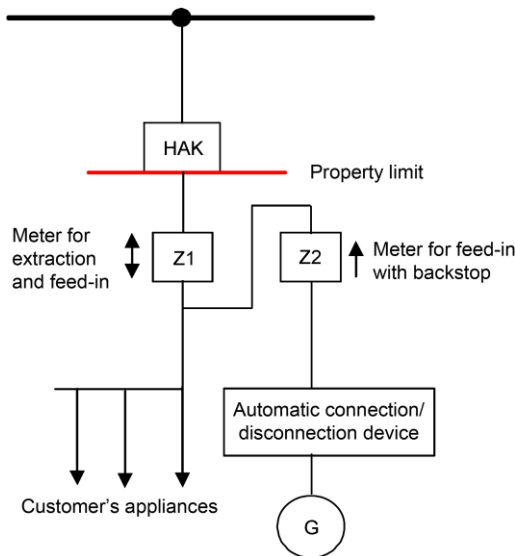
The NS protection may be integrated in the system control of the power generation units (integrated NS protection) for a maximum apparent connection power  $S_{Amax} \leq 30$  kVA.

NOTE 2 For the interface switch (also see 6.4.2):

For power generation systems with inverters, the interface switch may be provided on the inverter's network side. A short circuit in the inverter shall not affect the interface switch in its breaking function.

**Annex F**  
(continued)

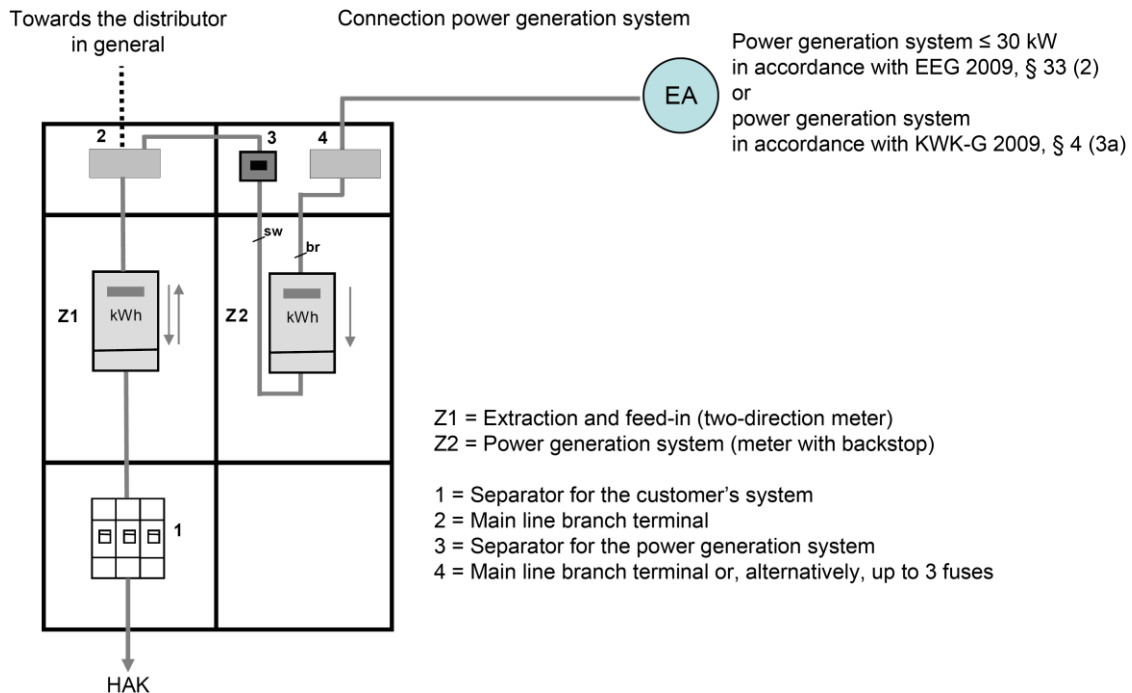
**C.4.2 Schematic representation**



**Figure C.5 — Measuring principle for the implementation of EEG 2009, § 33 (2) or KWK-G 2009, § 4 (3a)**

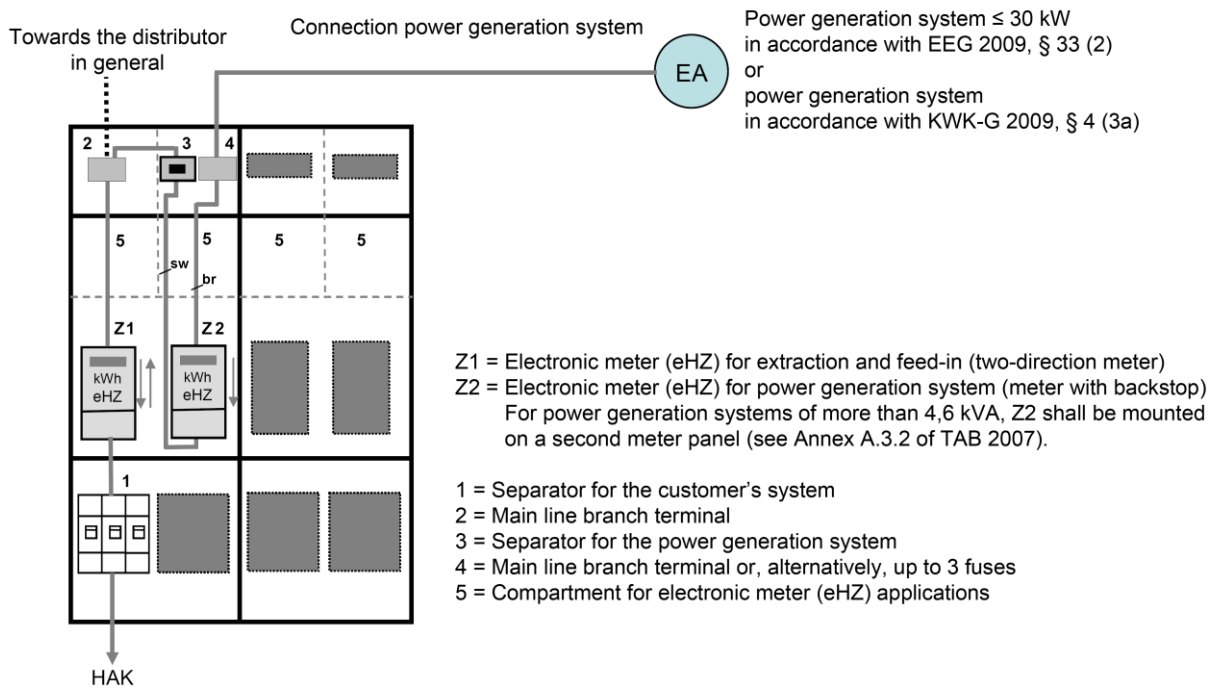
**C.4.3 Organisation of a central meter panel**

Figure C.6 and Figure C.7 show variants for the metering and meter panel organisation that are suitable for implementation of EEG 2009, § 33 (2) or KWK-G 2009, § 4 (3a) taking into consideration “Technische Anschlussbedingungen für den Anschluss an das Niederspannungsnetz” (Technical connection conditions for connections to the low-voltage network (TAB 2007) [3]) for conventional meter panels (three-point fastening) and meter panels with integrated fastening and contacting devices (BKE-I).



**Figure C.6 — Connection variant for a central conventional meter panel with three-point fastening**  
**Annex F**

(continued)

**Only upon co-ordination  
with the network operator****Figure C.7 — Connection variant for a central eHZ meter panel with BKE-I**

## **Annex G – Generation management network security management** (normative)

### **G.1 Generation management network security management**

NOTE While no South African utility currently has the required communication systems in place for LV systems, embedded generators may be NERSA exempt in providing on-line communication interfaces. However, should the utility require this in future, the embedded generator will provide the required interface at their own cost. Section G.1 provides the recommended requirements for such an interface. At the time of publication, basic communication requirements for category A3 generators are provided in the RPP Grid Code.

**G.1.1** In addition to requirements elsewhere in this specification, the embedded generator shall be able to control the following parameters as and where signals are sent by the utility:

**G.1.1.1** Active power control, typically a temporary reduction in active power output;

**G.1.1.2** Reactive power control, i.e. change of the operating power factor or power factor curve of the generator.

**G.1.2** For each operational state and/or operational point, the embedded generator must be able to reduce the output power to less than or equal to an active power set-point provided by the utility.

**G.1.3** Embedded generation systems with a power output capability of 100 kVA or more shall be able to control the output power in steps of 10 % or less of the rated active power.

**G.1.4** The embedded generator active power output shall reach the new set-point within a period of 1 minute. If this set-point cannot be reached within 5 minutes, the embedded generator shall disconnect from the system.

NOTE This implies that embedded generators without the capability to control the output power adequately or in adequate steps, shall disconnect from the system when a reduction in active power output is requested.

**G.1.5** Embedded generation systems with a power output capability of 100 kVA or more shall be able to control the reactive power (power factor) in steps of 5 % or less of the rated power.

**G.1.6** Reactive power shall reach the new set-point within a period of 1 minute. If this set-point cannot be reached within 5 minutes, the embedded generator shall disconnect from the system.

**G.1.7** According to the RPP Grid Code version 3.0, the accuracy of the control performed for both the active power and reactive power controls, and of the setpoint of both the active power and reactive power, shall not deviate by more than  $\pm 2$  % of the setpoint value or by  $\pm 0,5$  % of the rated power, depending on which yields the highest tolerance.

NOTE Appropriate communication protocols are under discussion with the Grid Code Advisory Committee and will be provided in a future edition of this document. This capability will then become compulsory for all new equipment.

### **G.2 Principles for network support**

As a rule, power generation systems of subcategory A3 shall be able to contribute to the static voltage stability in the utility network. Static voltage stability is the voltage stability in the low-voltage network at which the slow voltage changes are maintained within compatible limits in the distribution network. If required due to network related circumstances and by the utility, the embedded generator shall contribute to the static voltage stability in the low-voltage network.

Dynamic grid support, i.e. voltage stability in the event of voltage drops in higher voltage levels, is not required for embedded generators connected to low-voltage networks.



NOTE This requirement applies for units larger than 100 kVA only, smaller units on dedicated circuits (i.e. part of sub-category A3) are exempt.

### **G.3 Emergency personnel safety**

The safety of emergency personnel, e.g. fire brigade, shall be dealt with elsewhere.

DC installations will be covered by SANS 10142-X (future document).

A utility accessible disconnecter will be available to emergency personnel that will disconnect the a.c.

NOTE This clause will be superseded by requirements in the future SANS 10142-X document or other relevant requirements based on the Occupational Health and Safety act (Act No. 85 of 1993) as amended.

**G.3.1** Appropriate signage shall be installed. The requirements shall be cross-checked with requirements of SANS 10142-1. An example of signage as required by this section of NRS 097 is provided in 4.2.10.

**G.3.2** It is preferable that all SSEG be installed with emergency shutdown equipment. Examples of requirements are listed in G.3.2.1 to G.3.2.4. The manufacturer shall prove that the emergency shutdown processes and procedures are in line with current international best practices.

**G.3.2.1** All a.c. voltages should be shut off, regardless of the operating mode of the equipment at the time of shutdown.

**G.3.2.2** All fuel inputs to a SSEG (e.g. water feed to a hydro-generator, d.c. input to an inverter, etc.) should be shut off; regardless of the operating mode of the equipment at the time of shutdown.

NOTE PV panels cannot be switched off.

**G.3.2.3** Equipment that have emergency shutdown capabilities, shall have a "fireman's switch" installed in accordance with SANS 10142-1 at the time of installation in order to activate emergency shutdown.

NOTE The d.c. from PV panels and/or battery storage will be assumed to be live.

**G.3.3** The absence of emergency shutdown capabilities will be indicated on signage referred to in G.3.1.

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IEC 60898-2, *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations – Part 2: Circuit-breakers for a.c. and d.c. operation.*

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SANS 10199, *The design and installation of earth electrodes.*

SANS 61000-3-2/IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current  $\leq 16$  A per phase).*

SANS 61000-3-3/IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current  $\leq 16$  A per phase and not subject to conditional connection.*

SANS 61000-3-4/IEC 61000-3-4, *Electromagnetic compatibility (EMC) – Part 3-4: Limits – Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A.*

SANS 61000-3-5/IEC 61000-3-5, *Electromagnetic compatibility (EMC) – Part 3-5: Limits – Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A.*

SANS 61000-3-11/IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current  $\leq 75$  A and subject to conditional connection.*

SANS 61000-3-12/IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current  $> 16$  A and  $\leq 75$  A per phase.*

VDE 0126-1-1, *Automatic disconnection device between a generator and the public low-voltage grid.*

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CLC/TS 50549 Requirements for generating plants to be connected in parallel with distribution networks

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