STANDARD

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DT CT	DT CT Integration	for TESCOD	**CMDT for MD (Dx)**

Contents

Foreword

This standard sets out the minimum technical and statutory requirements for the connection of Embedded Generators to Eskom Distribution's electrical networks.

This standard serves to fulfil Eskom Distribution's obligation under Section 8.2 (4) of the South African Distribution Code: Network Code:

> "The Distributor shall develop the protection requirement guide for connecting Embedded Generators to the Distribution System to ensure safe and reliable operation of the Distribution System".

For information on pricing and contractual requirements with regard to the connection and operation of Embedded Generators, the user is referred to Distribution Policy *34-193: Purchasing of energy from embedded distribution generators*.

In this document, references to "Eskom" shall mean the Distribution Division of Eskom Holdings Ltd. In some instances, the term "Distributor" has been used in place of "Eskom" in anticipation of the standard's broader application in the electricity distribution industry in South Africa. In this context, "Distributor" includes Eskom Distribution, and any municipal entity that might adopt this standard.

Revision history

Date	Rev.	Compiler	Remarks
Sept 2007	A	S.J. van Zyl	Original issue for work-group comments.
Nov 2007	B	S.J. van Zyl	Extensive revision to incorporate work-group feedback.
Nov 2007	C	S.J. van Zyl	Revised Section 4.5.4.2 (SCADA Controls) to indicate possible requirement of Eskom remote control of interconnection circuit-breaker.
			Rewrote Section 4.6.2 (Quality of Supply).
Dec 2007	D	S.J. van Zyl	Rewrote Section 4.5.3 (Metering).
			Document issued for TESCOD comments.
Feb 2008	E	KEC	Incorporated changes agreed upon by work-group and KEC.
Mar 2008	0	S.J van Zyl	Document published.

Authorisation

This document has been seen and accepted by:

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This standard shall apply throughout the Distribution Division of Eskom Holdings Limited.

Acknowledgement / Development team

This document is based upon Eskom Guideline ESKAGAAG2 “Minimum requirements for the connection of non-Eskom generating plant to the Eskom electrical networks” that was compiled in 1995 by a working group led by Graeme Topham. ESKAGAAG2 in turn was based upon Engineering Recommendation G.59 “Recommendations for the connection of private generating plant to the Electricity Boards’ Distribution Systems” issued by the Electricity Council, and prepared for use in relation to the United Kingdom’s system.

The present document constitutes a complete revision of the old document, with contributions made by the following working group members:

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Keywords

Embedded Generator, Co-generator, Interconnection

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N. Jenkins, R. Allan, P. Crossley, D Kirschen, G Strbac. *Embedded Generation*. IEE Power and Energy series 31. 2000.

Network Protection & Automation Guide, Alstom, July 2002.

ESB Networks, Conditions Governing Connection to the Distribution System, Doc Ref: DTIS-250701-BDW, March 2006.

ESKASACL2 Rev.4, Terminology relating to the direction of power flow.

ESKASACL3 Rev.2, Functional measurement requirements for network management.

1. Scope

This standard sets out the minimum technical and statutory requirements for the connection of Embedded Generators to the Eskom Distribution Medium Voltage and High Voltage electrical networks.

This document applies to systems where the generating plant may be paralleled with the Eskom Distribution network either permanently, periodically or temporarily. This document does not apply to generating plant that does not operate in parallel with the Eskom grid (e.g. own use customer generators or stand-by generators). Eskom's requirements for stand-by generators are detailed in ESKAGAAG2. Requirements of ESKAGAAG2 pertaining to generators that are operated in parallel with the Eskom Distribution network are superseded by the requirements of this document.

The intention is that this interconnection standard, or one of broadly similar requirements, shall also apply to Embedded Generators connecting to municipal electricity networks which, in turn, are supplied by Eskom. This way, technical requirements for the point of connection between the supply authority and the Embedded Generator need not be replicated between Eskom and the supply authority.

The current revision of this standard does not apply to generator interconnections at Low Voltage, or generators of capacity less than 100kW. Any sources of generation, that are not covered in this standard, seeking parallel connection to the Distributor, shall be subject to special application.

The standard provides for generic interconnection requirements and shall be applicable to all different types of generators, prime movers etc. In certain cases (e.g. wind generating technology) it may be necessary to supplement the requirements of this standard with additional technology-specific requirements.

For information on pricing and contractual requirements with regard to the connection and operation of Embedded Generators, the user is referred to Distribution Policy 34-193: *Purchasing of energy from embedded distribution generators*.

2. Normative references

Parties using this standard shall apply the most recent edition of the documents listed below:

South African Legislation:

Electricity Regulation Act 6 of 2006.

Occupational Health and Safety Act No 85 of 1993.

South African Distribution Code (all parts).

South African Grid Code (all parts).

International and National Standards:

IEC 62271-100: High-voltage alternating-current circuit-breakers.

IEEE 1547.1, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

NRS 029, Current transformers for rated a.c. voltages from 3,6kV up to and including 420kV.

NRS 030, Electricity distribution – Inductive voltage transformers for rated a.c. voltages from 3,6kV up to and including 145kV for indoor and outdoor applications.

NRS 031, Alternating current disconnectors and earthing switches (above 1000V).

NRS 037-1, Telecontrol Protocol for stand-alone remote terminal units.

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 guidelines for utilities.

NRS 054, Rationalized User Specification – Power Transformers.

NRS 057-4, Electricity metering Part 4: Code of practice

SANS 1019, Standard voltages, currents and insulation levels for electricity supply.

International and National Standards (Protective Relays):

IEC 60068-2-1, Environmental testing — Part 1 Cold.

IEC 60068-2-2, Environmental testing — Part 2 Dry Heat.

IEC 60068-2-30, Environmental testing — Part 30 Damp heat, cyclic (12h + 12h cycle).

IEC 60255-30, Electrical relays Part 3: Single input energizing quantity measuring relays with dependent and independent time.

IEC 60255-6, Electrical relays Part 6: Measuring relays and protection equipment.

IEC 60255-21, Electrical relays Part 21 Vibration, shock, bump and seismic tests on measuring relays and protection equipment (All sections).

IEC 60255-22, Electrical relays Part 22 Electrical disturbance tests for measuring relays and protection equipment (All sections).

SANS IEC 60529, Degrees of protection provided by enclosures (IP Code).

SANS IEC 61000-4, Electromagnetic compatibility (EMC): Test and measurement techniques (All sections).

Eskom Standards:

ESKPVAAN6, *Apportioning of quality of supply parameters*.

ESKASAAW2, *Generator excitation system standard for power station*.

Distribution Standards:

Note: in cases where documents are still to be re-published using the revised document numbering system, the future document classification and number is indicated in brackets following the existing reference code.

SCSASAAL9, MV and LV Reticulation Earthing.

SCSASACB6 (DST 34-906), Medium Voltage Earthing Practice.

DSP 34-392, Specification for digital transducer based measurement system for electrical quantities.

DST 34-462, Standard design for Distribution protection schemes.

DST 34-540, Distribution Standard for the application of Sensitive Earth Fault protection.

DST 34-542, Distribution voltage regulation and apportionment limits.

Distribution Test and Maintenance Procedures:

Note: in cases where documents are still to be re-published using the revised document numbering system, the future document classification and number is indicated in brackets following the existing reference code.

SCSPVAAS9 (DPC 34-1039), Procedure for the maintenance of d.c. supply equipment.

DISPVAEB6 (DPC 34-1033), Voltage transformer test procedure.

DISPVAEC6 (DPC 34-1035), Current transformer test procedure.

DISPVAED1 (DPC 34-1395), Over current and Earth fault relay test procedure.

DISPVAEF9 (DST 34-1043), Maintenance of vantage nickel cadmium cells.

DISPVAEG1 (DST 34-759), Maintenance of L/M/H range nickel cadmium batteries.

DISPVAEQ6 (DPC 34-1036), Procedure for testing of Circuit-Breakers.

DPC 34-1034, Isolator test procedure.

3. Definitions and abbreviations

3.1 Definitions

3.1.1 Co-generator: a source of electrical power that complies with types I, II or III below:

Type I: Projects utilizing process energy which would otherwise be underutilized or wasted (e.g. waste heat recovery).

Type II: Primary fuel based generation projects which produce, as part of their core design, other usable energy in addition to electricity (e.g. Combined Heat and Power projects).

Type III: Renewable fuel based projects where the renewable fuel source is both the primary source of energy, and is a co-product of an industrial process (e.g. use of bagasse and/or forestry waste from the sugar and paper industries).

3.1.2 Distributor: Eskom Distribution and any public electricity supply utility (e.g. municipality) that might adopt this standard.

3.1.3 DNP3: (Distributed Network Protocol) is the preferred communications protocol used for the control of electricity on transmission and distribution networks as per NRS 037-1.

3.1.4 Embedded Generator's authorized person: The person appointed by the Embedded Generator in terms of the appropriate act to sanction the return to service of plant after major maintenance or repair.

3.1.5 Embedded Generator's responsible person: The person appointed by the Embedded Generator in terms of the appropriate act to receive communications and take necessary action in accordance with instructions from the system controller.

3.1.6 Embedded Generator: a legal entity that operates or desires to operate a generating plant that is or will be connected to the Distribution network. This definition includes all types of connected generation, including co-generators and renewables. Alternatively, the item of generating plant that is or will be connected to the Distribution network.

3.1.7 High voltage: the set of nominal voltage levels greater than 44 000V and up to and including 220 000V. [SANS 1019]

3.1.8 Island: a portion of the utility's distribution network energized solely by one or more Embedded Generators.

3.1.9 Loss-of-grid protection: Relay protection designed to detect the loss of connection to the utility network and trip the Embedded Generator to prevent it from energizing an island.

3.1.10 Low voltage: nominal voltage levels up to and including 1kV. [SANS 1019]

3.1.11 Medium voltage: the set of nominal voltage levels greater than 1 000V and up to and including 44 000V. [SANS 1019]

3.1.12 Point of Common Coupling (PCC): The electrical node on the Distributor's network, electrically nearest to a particular Embedded Generator's installation, at which more than one customer is or may be connected or metered.

3.1.13 Point of Utility Connection (PUC): The circuit-breaker and associated ancillary equipment (instrument transformers, protection, isolators) that connects the Embedded Generator facility to the Distribution network. The PUC forms the point of demarcation between the assets of the Distributor, and those of the Embedded Generator.

3.1.14 Point of Generator Connection (PGC): The circuit-breaker and associated ancillary equipment (instrument transformers, protection, isolators) that connects a generator to any electrical network. Where more than one such circuit-breaker exists, the PGC shall be the circuit-breaker electrically closest to the generator.

3.1.15 Secure Supply Point (SSP): That point on the Distributor's network at which a single upstream contingency will not result in the islanding of an Embedded Generator with a portion of the supply network.

3.1.16 Stand-by generator: a legal entity that operates or desires to operate a generating plant so as to provide a stand-by supply in the event of a loss of the grid electricity supply. The stand-by generator's plant will only be connected to the Distribution network for maintenance load testing, and only if the requirements of this standard have been fulfilled.

3.1.17 System controller: The person on shift at the Eskom Control Centre.

3.2 Abbreviations

3.2.1 ac: Alternating Current

3.2.2 ARC: Auto Reclose

3.2.3 CB: Circuit-Breaker

3.2.4 CT: Current Transformer

3.2.5 DC or **dc**: Direct Current

3.2.6 EG: Embedded Generator

3.2.7 HV: High Voltage

3.2.8 LV: Low Voltage

3.2.9 MCOV: Maximum Continuous Over Voltage

3.2.10 MV: Medium Voltage

3.2.11 NEC/R: Neutral Earthing Compensator with Resistor

3.2.12 PCC: Point of Common Coupling

3.2.13 PGC: Point of Generator Connection

3.2.14 pu: per unit

3.2.15 PUC: Point of Utility Connection

3.2.16 QOS: Quality of Supply

3.2.17 SCADA: Supervisory Control and Data Acquisition

3.2.18 SSP: Secure Supply Point

3.2.19 SEF: Sensitive Earth Fault

3.2.20 ROCOF: Rate of Change of Frequency (protection)

3.2.21 RTU: Remote Terminal Unit

3.2.22 VT: Voltage Transformer

4. Requirements

4.1 General requirements

By way of introduction to the detailed technical requirements of subsequent sections, this section serves to outline the broad principles on which the standard is based.

4.1.1 Open access to networks for safe operation

An Embedded Generator (EG) may connect to the utility network at any time provided safety can be assured.

EGs are required to operate within legal power quality limits. Eskom and the Municipalities are held liable for deviations from legal power quality limits that their customers may experience. Therefore no EG shall continue to energise any portion of the network that has been unintentionally islanded on a section of the Distributor's network. Disconnection shall occur at the PUC upon detection of an unintentional island. The primary concern is for human safety, plant protection and power quality, in that order.

The Eskom National System Operator and/or Regional Control Centres reserve the sole right to permit the operation of intentional islands within the Eskom Distribution network. EGs permitted to operate intentional islands shall adhere to the procedures and operating requirements as stipulated by the System Operator/Regional Control Centre.

The EG shall be responsible for protecting his/her own assets. Notwithstanding this, unnecessary tripping of EGs presents quality of supply and network stability problems and should be avoided where possible.

Safe operation of the distribution network, power system stability and security of supply are paramount and require that the Distributor be responsible for specifying predetermined minimum protection, measurements and SCADA requirements to the EG.

It is the responsibility of the EG to establish synchronism between the EG's network and the Distributor's grid supply prior to paralleling the two networks. Detailed technical and statutory requirements for synchronising onto the power network are stipulated in Section 4.4.2.

The neutral earthing philosophy to be applied shall be in accordance with Section 4.5.3. The neutral points of generator transformer windings galvanically connecting the EG to a Distributor at HV shall be solidly/effectively earthed, while those of MV connected generators/transformers will not be earthed.

NOTE: Partially graded neutral insulation may not be used for generator transformers for connection to a utility network at MV.

Where it is necessary for Eskom to provide any electrical lines, or other electrical plant, or for any other works to be carried out to enable the connection of embedded generation to its networks, Eskom may require payments in respect of any expenditure incurred in carrying out this work.

4.1.2 Redundancy

The failure of any single component or system will not result in unsafe operation. Thus:

a) No generator shall be connected to the Distributor's network via a single circuit-breaker.

b) Primary system protection provided at the PUC shall be duplicated elsewhere within the EG's facility. Refer to Section 4.6.2.1.

c) Primary loss of grid protection shall be provided at the PUC, but this protection shall be backed-up elsewhere in the Distributor's network (e.g. live-line close blocking).

d) The DC supplies at the Point of Utility Connection (PUC) and Point of Generator Connection (PGC) shall be independent of one another and shall be subject to continual monitoring.

4.1.3 Ownership

PUC represents the point of demarcation between the Distributor and the EG, examples of which are given in Annex A. This standard does not stipulate the specific ownership of plant used at the PUC. The only exceptions are the Eskom metering equipment, remote terminal units and communications infrastructure. These will be Eskom owned, operated and maintained. Specifics regarding the ownership of other plant, including the instrument transformers, must be agreed between the participants. Nevertheless, the following ownership regimes are preferred:

1. The EG owns, operates and maintains the PUC circuit-breaker. Specifically, the EG shall own the circuit-breaker and associated instrument transformers and protection and the isolator to be installed between the PUC circuit-breaker and the Distributor's network. The specific point of demarcation between the utility and the EG shall be the Distributor-side terminals of the isolator. The clamps or cable terminations made at this point shall be the responsibility of the Distributor.

OR

2. The Distributor owns, operates and maintains the PUC equipment. Specifically, the Distributor shall own the circuit-breaker and associated instrument transformers and protection and the isolator to be installed between the PUC circuit-breaker and the EG's facility. The specific point of demarcation between the utility and the EG shall be the EG-side terminals of the isolator. The clamps or cable terminations made at this point shall be the responsibility of the EG.

Each party shall be responsible for the commissioning, operation and maintenance of plant installed on their side of the PUC. The Eskom-owned metering equipment, remote terminal units and communications infrastructure will be commissioned, operated and maintained by Eskom irrespective of its specific location.

All equipment at the PGC, except the Eskom metering, telecontrol and communications equipment, shall be owned, operated and maintained by the EG.

Where the PUC and the PGC are the same point, Eskom shall install a second "back-up" circuit-breaker in line with the PUC/PGC circuit-breaker. The PUC/PGC shall fully comply with the PUC and PGC requirements of Section 4.6. The Eskom-owned circuit breaker shall provide the necessary back-up protection functions as indicated in Section 4.6.2.1.

4.1.4 Autonomy

Each party is to design, protect and maintain their own assets to industry best practice. The PUC represents the point of demarcation, and is a point of common interest. The standard provides minimum technical requirements for the equipment and functionality to be provided at the PUC. The PGC provides back-up to the protection functions of the PUC, and is also subject to minimum technical requirements imposed by the Distributor.

All of the required PUC functionality shall be provided at the PUC or in exceptional circumstances at an alternate location agreeable to both parties. All of the required functionality shall be provided at the same location. Any changes to the PUC or PGC will be agreed between the parties prior to implementation.

4.1.5 Audits

Owing to the strong interdependence between the EG and the Distributor, and so as to avoid duplication of equipment as far as possible, either party is entitled to perform technical audits of the other's equipment relevant to the interconnection. This specifically includes the PUC and PGC equipment and the metering equipment. Audits shall be performed with a minimum of 24 hours notice.

4.2 Legal requirements

The Electricity Regulation Act 6 of 2006 details the legislative requirements with regard to the generation, transmission, distribution and trading of electricity. In this regard, the operator of a grid-connected generator is required to hold a licence from the Regulator (Section 8). Operators of non-grid connected generators are not required to hold a license provided that the plant is designated only for own-use, and is not used commercially (Schedule II).

Section 47 (1) of the Act makes provision for the Regulator to, following consultation with licensees and other participants, set guidelines and publish codes of conduct and practice. The South African Grid Code and Distribution Code are examples of such codes of practice.

The South African Distribution Code includes a section of specific requirements for the connection of EG's. The Distribution Code (Section 8.4.1.1 (1)) requires that all EG's of nominal capacity greater than 10MVA shall in addition to the requirements of the Distribution Code, also comply with Section 3.1 of the South African Grid Code: Network Code.

Under Section 8.2 (4) of the South African Distribution Code: Network Code, each South African Distributor is required to develop a protection requirement guide for the connection of EG's. This standard serves to fulfil Eskom Distribution's obligation in this regard.

Each EG installation must be designed to comply with the Grid Code, Distribution Code and Eskom requirements detailed in this standard.

4.3 Operational safety

4.3.1 Operational and safety aspects

The EG must obtain from the relevant Distributor a written agreement to operate generating equipment in parallel with the Distributor's network. A plant diagram and schedule giving details of ownership, operation, maintenance and control of substation and generation plant shall be prepared, as agreed between the parties. The schedule shall include:

a) Names and contact details of responsible persons from both parties.

b) A description of any operating limitations with regard to the plant and/or the interconnection.

The EG shall ensure that all operating personnel are competent in that they have adequate knowledge and sound judgment to take the correct action when dealing with an emergency. Failure to take correct action may jeopardize the EG's and/or Eskom's systems.

EG shall ensure:

a) Except in the case of agreed unmanned facilities, that a responsible person is available at all times to receive communications from Eskom's system controller so that emergencies requiring urgent action by the EG can be dealt with adequately. Where required by Eskom, it will also be a duty of the EG's staff to advise the Eskom system controller immediately of any abnormalities that occur on the Embedded Generating plant which have caused, or might cause, disturbance to the Eskom system;

b) In the case of unmanned facilities that Eskom will have remote control facilities to trip and isolate the generator.

c) That where it is necessary for his employees to operate Eskom equipment (where provided), they have been designated in writing by Eskom as an "authorized person" for this purpose. All operations on the Eskom equipment must be carried out to the specific instructions of the Eskom system controller. In an emergency, a switch can be opened by anybody, without prior agreement in order to avoid danger. The operation must be reported to the Eskom system controller immediately afterwards.

4.3.2 Means of isolation

Every installation or network which includes an Embedded Generating plant must include a means of isolation, suitably labelled, capable of disconnecting the whole of the Embedded Generating plant infeed from the Distributor's network.

The means of visible-break isolation must be lockable, in the open position only, by a padlock. Rackable indoor metal clad switchgear is deemed acceptable for this function, provided that it is lockable.

The EG must grant Eskom rights of access to the means of isolation without undue delay. Eskom shall have the right to reasonably isolate the EG's network connection at any time as network conditions dictate. The means of isolation will normally be installed at the PUC, but may be positioned elsewhere with Eskom's agreement.

4.4 Generator capabilities and operation

4.4.1 Excitation control and governor requirements

The Distribution Code: Network Code requires all EG's of nominal capacity greater than 10MVA to comply with Section 3.1 of the South African Grid Code: Network Code. The requirements of the Grid Code apply specifically to synchronous generators/machines and not asynchronous generators. Section 3.1.3 of the same document stipulates the excitation system requirements for synchronous generators.

Synchronous generators shall be equipped with excitation controllers capable of connecting and operating on a network that may be subjected to voltages in a range between 95% and 105% of the nominal voltage.

Induction or asynchronous generators, which are not capable of voltage or reactive power control, are consumers of reactive power. The EG must thus supply reactive power compensation to correct the power factor to within ±0.90 at the PGC, unless otherwise negotiated with Eskom.

Inverter-type generating equipment can control its power factor over a wide operating range, typically ±0.75. Thus an EG connecting to the Distributor's network via an inverter shall be capable of adjusting the power factor to within a range of ±0.90, unless otherwise negotiated with Eskom.

The EG shall consult the Distributor's standards and shall familiarise themselves with the local operating conditions. The EG's normal operation shall not cause conditions on the network which are outside the accepted power quality standard limits. The generator's excitation control mode must best suit the local environmental conditions.

All EG units of nominal capacity larger than 50MVA shall conform to the continuous and short-duration frequency operating limits outlined in the Section 3.1.6 (Governing) of the South African Grid Code: Network Code. The Code states that the continuous operational range for the generation unit is between 48.5 Hz - 51.5 Hz. The same section of the code also stipulates the frequency vs. guaranteed operating time capability, as well as the requirements for governor control using a 4% droop characteristic, required by turbo-alternators.

EG units of nominal capacity ranging from 10MVA to 50MVA may or may not be required to comply with the requirements of Section 3.1.6 of the Grid Code: Network Code. Clarity on this issue shall be resolved in consultation with the Eskom System Operator/Regional Control Centre.

EG units of nominal capacity less than 10MVA are not required to comply with the governing and continuous frequency operational requirements as stipulated above.

4.4.2 Synchronization

All Embedded Generating plant other than mains excited asynchronous machines must be synchronized with the Eskom supply prior to making the parallel connection.

The voltage between the unit and the system prior to synchronizing shall not differ by more than the values specified in Table 1. Where the mode of operation of generating equipment is such that synchronizing of a machine or machines will occur at intervals of less than two hours, the voltage fluctuation at the PGC resulting from the generation capacity being connected shall not exceed 1 %.

Automatic synchronizing equipment shall be the preferred method of synchronizing. However, manual synchronization of the EG units is permissible on condition that synchronizing check relays (three phase comparators) are used by the EG in conjunction with the manual synchronizing, and that the EG's responsible person is authorised in writing to do so.

It is the responsibility of the EG to provide synchronizing facilities. Typical limits for synchronising parameters are given in Table 1 below:

Table 1. Typical synchronising parameter limits (IEEE 1547 p.12)

Aggregate rating of EG (kVA)	**Maximum Frequency Difference** Δf (Hz)	**Maximum Voltage Difference** ΔV (%)	**Maximum Phase Angle Difference** $\Delta\phi$ (Degrees)
S < 500	0.3	10	20
500 ≤ S < 1500	0.2	5	15
S ≥ 1500	0.1	3	10

4.4.3 Islanded operation

Intentional islanding of a generator with part of the Eskom network is not permitted unless specifically agreed to with Eskom.

For unintentional islanding, where a generator is synchronised with the Eskom network at the time that an upstream Eskom circuit-breaker opens, severing the connection between the generator supply and the grid supply, the generator shall cease to energise the local Eskom network within 2 seconds.

4.4.4 Fault ride through capabilities

This section is under consideration for a future revision of the standard.

4.5 Requirements for the Utility Network interface

4.5.1 Fault Infeed

When it is proposed to install Embedded Generating plant, consideration must be given to the contribution that the plant will make to the fault levels on the Distributor's network. The design and safe operation of the EG's and Distributor's installations depend upon accurate assessment of the fault contributions made by all plant operating in parallel at the instant of the fault. The EG shall discuss this with the relevant Distributor at the earliest possible stage. The EG shall provide all relevant information for the Distributor to be able to model the generator and its contribution to fault current.

Should the EG result in the increase of fault levels to such an extent that the Distributor's or customer's plant at the PCC is placed at risk, the EG shall apply fault current limiting measures to ensure that the fault levels are maintained at acceptable levels. The fault limiting solution applied shall be presented to the Distributor for acceptance prior to implementation.

4.5.2 Quality of Supply

Voltage quality parameters, i.e. voltage regulation, unbalance, flicker and harmonic distortion, at the PCC and other customer points of supply, may not exceed the compatibility levels or limits as prescribed in NRS 048-2 and Distribution Standard 34-542 due to operation of the EG. The rapid rate of voltage change limits, as set out in NRS 048-4, shall also not be exceeded by the EG. The actual polluting voltages and/or currents generated by the customer/EG will be apportioned as per standard Eskom apportioning methods (described Eskom document ESKPVAAN6 and NRS 048-4).

4.5.3 Neutral Earthing

This standard stipulates the neutral earthing philosophy to be applied on EG networks that are galvanically connected to the Eskom supply network. Adequate earthing of networks at other voltage levels within the EG plant is the responsibility of the EG, and is not stipulated herein.

The Distributor's networks may use effective, resistive or reactive earthing methods depending on the voltage level and local requirements. The magnitude of the possible earth fault current will depend on which of these methods is used. The EG's earthing arrangement must therefore be designed as follows:

a) In consultation with the Distributor such that the EG's system is compatible with the Distributor's system.

b) Such that the EG's plant safety is not compromised due to the above requirement.

The actual earthing arrangements will also be dependent on the number of machines in use and the EG's system configuration and method of operation.

Earthing may be achieved by the use of a busbar earthing transformer (e.g. NEC/R), the use of the star point of the generator, or by earthing the star point of the generator transformer.

Care should be taken with multiple generator installations to avoid excessive circulating third harmonic currents. It may therefore be necessary to restrict the earthing to the star point of a single machine and provide automatic transfer facilities of the generator star point earth to another machine in the event of the selected machine being tripped. The use of suitable generator transformers with delta windings may provide a means of avoiding excessive circulating harmonic currents.

Where used, the winding configuration of the generator transformer (e.g. Delta-Star, Star-Delta etc.) shall be such that zero sequence currents on the Distributor's network and EG systems are decoupled from one another.

Where transportable or mobile generating plant is used, it is essential that all earthing connections to the generator are effectively made prior to making off any phase connections or running the generator.

Under conditions of separation between the Distributor's network and the EG system, care must be taken to not run any part of any of the systems unearthed.

HV networks

HV networks are required to be effectively earthed. The HV generator transformer winding shall therefore cater for solid earthing of the neutral using a Star-connected winding at the side of the transformer connecting to the Distributor's network.

MV networks

Eskom's MV networks are resistively earthed at the source substation so as to limit earth fault currents to the typical ranges: less than 720A (Rural networks) and less than 1600A (urban networks). Refer to Distribution Standard SCSASACB6: *Medium Voltage Earthing Practice* for further information.

The preferred neutral earthing philosophy for MV-connected generators or generator transformers is that the MV neutral point be left un-earthed. This will serve to avoid issues of earth fault relay de-sensitization, as well as avoiding "circulating" zero sequence or triplen (i.e. 3rd, 6th, 9th etc.) harmonic currents between the distant earth connections.

With the EG not earthing the MV network, and in the case of the source tripping as a result of a line earth fault, the healthy line voltages will be raised to full phase-to-phase values. In addition, there is a possibility of resonant over-voltages arising from the generator transformer reactance and the line capacitance. Possible damage to surge arresters may be avoided by specifying arrester Maximum Continuous Over Voltage (MCOV) values at the full phase-to-phase voltage.

In the case of an agreed upon intentional island, the conditions of which are stipulated in Section 4.4.3, the MV star-point shall be earthed. The EG shall ensure that the star-point is resistively earthed the instant prior to intentional islanded operation, as per Eskom standard. The earth shall be disconnected prior to the reconnection to the grid for resumption of parallel operation.

In the absence of a MV neutral earthing point at the point of connection, line earth faults will be detected by phase-to-earth under-voltage and/or residual over-voltage protection (i.e. a neutral to earth VT), and also over-frequency protection as a result of the generator supplying a lightly loaded or unloaded island. Under-voltage protection located on the generator-side of the generator transformer may not be adequate on account of the voltage balancing effect of the transformer (depending on the winding configurations).

4.5.4 Prevention of out of synchronism closure

The Distributor shall provide synchronism check and/or live-line close blocking functionality on all circuit-breakers and/or pole-mounted switchgear between the Embedded Generator's PUC and the SSP. This shall serve as additional security against possible out-of-phase closure onto an islanded EG. Synchronising (auto or manual) shall remain the sole responsibility of the EG and this shall be done at the PUC, PGC, and/or elsewhere within the EG's plant.

4.5.5 Requirements for directional protection

In many cases, the fault current infeed from the EG to network faults will be a small fraction of the grid-supplied fault current. The fault current infeed from the generator may also decay rapidly with time. As a result, it is unlikely that the traditional non-directional overcurrent, earth fault and SEF protection applied to radial MV and HV Distribution networks will be rendered unsuitable by the presence of an EG. This must, however, be confirmed during the design phase of each project.

4.5.6 Auto-reclose dead-time settings on networks with Embedded Generation

Auto-reclose dead-time settings on all circuit-breakers between the PUC and the SSP shall be increased from the standard 3 seconds to at least 5 seconds so as to provide additional margin for the detection and isolation of possible power islands.

4.6 Requirements at the PUC and PGC

This section details the requirements for the primary- and control plant equipment to be installed at the PUC and PGC.

4.6.1 Primary equipment

4.6.1.1 Current Transformers

Current transformers shall be specified in accordance with NRS 029. Protection CTs shall be in compliance with the protection relay manufacturer’s requirements with regard to accuracy class. Metering circuits shall use Class 0.2 CTs. Refer to Section 4.6.4 for further requirements with respect to metering CT cores for Eskom use. Measurement circuits shall use Class 0.2 CTs or protection class CTs. Protection class CTs will typically be used for measurements where the measurement data is derived from a protection relay instead of a stand-alone transducer.

4.6.1.2 Voltage Transformers

Voltage transformers shall be specified in accordance with NRS 030. Metering and measurement circuits shall use VTs of accuracy class 0.2. Protection VTs shall be of Class 3P accuracy. The VTs shall be burdened so as to ensure accuracy within class definitions.

4.6.1.3 Isolator/Disconnector

The isolator fulfilling the requirements of Section 4.3.2 shall be specified in accordance with NRS 031.

The isolator shall include at least one normally-open and one normally-closed auxiliary status contact for use by Eskom for remote indication purposes. The contacts shall operate in the fully-open and fully-closed positions of the primary contacts respectively. These contacts may not be provided by a separate relay or device not forming an integral part of the isolator.

The isolator shall be lockable using a standard Eskom padlock:

a) Case: 35mm – 38mm high, 28mm – 40mm wide, 18 – 20mm thick; and

b) Shackle: 6mm diameter, 30mm-34mm length (in the locked position), 20mm width (minimum).

(Dimensions from Distribution Specification DISSCAAM8 Rev.1 *Specification for Master Locks and Master Keys for Electrical and Related Equipment*)

4.6.1.4 Circuit-Breakers

The circuit-breakers shall comply with the requirements of IEC 62271-100 and shall be suitably rated to interrupt the maximum prospective fault current at the PUC or PGC as appropriate.

To allow for network growth the fault interruption capability of circuit-breakers shall be chosen to be at least 30% higher than the maximum fault levels calculated in the initial integration study for the EG plant.

The maximum circuit-breaker operating times shall be as follows:

a) HV network: < 60ms

b) MV network: < 100ms

The circuit-breakers shall have a "maximum over-voltage" factor for switching conditions of IEC 62271-100 of 2.5pu or higher.

The circuit-breakers shall include at least one normally-open and one normally-closed auxiliary status contact for use by Eskom for remote indication purposes. These contacts may not be provided by a separate relay or device not forming an integral part of the circuit-breaker

4.6.2 Protection

4.6.2.1 Protection Overview

This section details the protection functionality that shall be installed at the PUC, irrespective of whether the same functionality is installed elsewhere within the EG's plant. Protection requirements are also stipulated for the PGC, providing back-up to the PUC protection. The protection systems shall provide adequate protection of the parts of the Distributor's network that could be supplied by the EG, either in parallel operation or under conditions of the EG supplying an intentionally islanded portion of the Distributor's network.

Further, the protection systems shall:

a) inhibit connection of the generating equipment to the Eskom supply unless all phases of the Eskom supply are energized and operating within the agreed limits;

b) disconnect the generator from the system when a system abnormality occurs that results in an unacceptable deviation of the voltage or frequency at the point of connection; and

c) prevent un-intentional islanding of the EG with a portion of the Distributor's network.

Table 2 includes a summary of specific protection functions that shall be provided at the PUC.

Note: The requirements of this section indicate Eskom's minimum requirements at the PUC and PGC so as to safeguard the Distributor's network in the event of faults within the EG's facility, or faults on the Distributor's network with a fault current contribution from the EG. In keeping with the requirements of the South African Distribution Code: Network Code, the EG may require additional protection (e.g. biased differential, Restricted Earth Fault, pole slipping protection, negative phase sequence overcurrent etc.) to safeguard his assets against damage due to abnormal events or faults on the power system.

Table 2. PUC protection requirements per voltage level

Protection Type	Section	HV	MV
Overcurrent, Earth Fault	4.6.2.3	Yes	Yes
Sensitive Earth Fault (SEF)	4.6.2.3	No	Note 1
Phase Under/Over Voltage	4.6.2.4	Yes	Yes
Residual over-voltage	4.6.2.5	No	Note 1
Under/Over Frequency	4.6.2.6	Yes	Yes
Loss-of-Grid	4.6.2.7	Yes	Yes
Check Synchronising / interlocking (Block dead line charge)	4.6.2.8	Yes	Yes
Reverse Power	4.6.2.9	Note 2	Note 2
DC Failure Monitoring	4.6.2.10	Yes	Yes
Note 1: Depends on neutral earthing philosophy adopted. Neutral voltage displacement protection will be applied on networks where the EG or generator transformer does not provide an earth connection to the Eskom network. Earth Fault and Sensitive Earth Fault protection will be required in the event that an earth connection is provided Note 2: Reverse power protection shall be applied in the event that the EG does not plan to, or is not permitted to export power to the grid, but which will be synchronised with the grid.			

Notwithstanding the requirements of Table 2 for the PUC, Table 3 lists the minimum protection functionality to be installed at the PGC.

Table 3 PGC Protection requirements

Protection Type	Section
Phase Under/Over Voltage	4.6.2.4
Under/Over Frequency	4.6.2.6
Auto synchronising	4.4.2
Reverse Power	4.6.2.9
DC Failure Monitoring	4.6.2.10
Negative Phase Sequence overcurrent	4.6.2.11

The Distribution Code: Network Code requires generators of nominal capacity greater than 10MVA to comply with Section 3.1 of the South African Grid Code: Network Code. The latter requires generators to be provided with back-up impedance and circuit-breaker fail protection in addition to the requirements of Tables 2 and 3 above. In addition, generators of capacity larger than 20MVA may require loss of field and pole slipping protection.

In the event that the PUC and the PGC are the same point (e.g. for MV directly-connected generators) the protection system at the combined PUC/PGC shall comply with the requirements of both Tables 2 and 3. In addition, the Distributor shall install a back-up circuit-breaker on the Distributor-side of the PUC. The back-up circuit-breaker (typically an auto-recloser) shall include protection functionality as indicated in Table 4.

Table 4. Back-up circuit-breaker protection requirements (combined PUC/PGC)

Protection Type	Section
Overcurrent, Earth Fault	4.6.2.3
Sensitive Earth Fault (SEF)*	4.6.2.3
Phase Under/Over Voltage	4.6.2.4
Under/Over Frequency	4.6.2.6
Check Synchronising / interlocking (Block dead line charge)	4.6.2.8
DC Failure Monitoring	4.6.2.10

* where applied at the PUC/PGC

4.6.2.2 General Protection Requirements

a) All protection relays used at the PUC and PGC shall comply with the type test requirements of Annex C.

b) Protection relay accuracy requirements of the following sections shall be defined as per IEC60255-3 and -6.

c) Except where the PUC and PGC are the same point, the PUC and PGC protection shall be totally independent of each other.

d) Protection clearance times and coordination shall comply with the requirements specified as a result of the EG integration fault studies.

e) If automatic resetting of the protective equipment is used (e.g. for an unmanned EG facility), the time delays must applied in consultation with the regional auto-reclose philosophy. The automatic reset must be inhibited for faults within the EG installation.

f) Each protection relay system shall include a sequence of event recording function that logs any settings change; settings group change, protection pick-up or trip operation, or change in circuit-breaker and/or input and output status.

g) The relay system installed at the PUC shall incorporate an oscillographic waveform recording function capable of storing at least five 15-cycle recordings at a sampling rate of 16 samples per cycle or higher. The waveform recording shall contain the three phase voltage, three phase current and neutral current signals from the PUC as well as all significant digital signals (i.e. protection tripping elements, circuit-breaker status, input and output contact status etc.). A recording shall be triggered upon any protection operation.

h) The event and waveform recordings shall be stored in non-volatile memory and shall be time stamped with a resolution of 1 millisecond real time. It shall be possible for the recordings to be made available in COMTRADE format.

i) Protection settings for all functions identified in Tables 2 and 3 to be applied at the PUC and PGC will be to Eskom's written approval. No changes to the settings shall be made without written consent from Eskom. The EG shall keep written record of all protection settings, and provide a signed electronic copy of the same to Eskom.

4.6.2.3 Overcurrent, Earth Fault and Sensitive Earth Fault protection

Overcurrent and earth fault protection shall provide Inverse Definite Minimum Time (IDMT) time-current characteristics. IDMT curves shall be in accordance with the requirements of IEC-60255-3: Type A, B and C curves (i.e. IEC Normal Inverse, Very Inverse and Extremely Inverse).

Overcurrent protection will be provided in all cases. Voltage-controlled overcurrent protection shall be considered in applications where the fault current contribution of EG decays with time.

Appropriate Earth Fault protection will be applied in all cases. Current-based detection is not appropriate in MV networks where the generator or generator transformer does not include a point of neutral earthing.

Sensitive Earth Fault protection will be applied on MV networks where the generator or generator transformer provides a point of neutral earthing to the Eskom network. SEF protection will be set in compliance with *Distribution Standard 34-540*.

Sensitive Earth Fault protection will use a Definite Time characteristic.

The overcurrent, earth fault and SEF protection shall be set to coordinate with the Eskom network protection as dictated by the integration fault studies.

4.6.2.4 Under and Over Voltage protection

Under- and over-voltage protection shall be provided. The voltage protection functions shall detect the effective (i.e. root mean square) or the fundamental component of each phase-to-phase voltage. Maximum operating times for the voltage protection are indicated in Table 3 below [IEEE 1547].

Table 3. Maximum operating times for voltage protection

Voltage range (% of nominal)	**Maximum Operate Time** (s)
V < 50%	0.2s
50% ≤ V < 90%	2s
110% < V < 120%	1s
V ≥ 120%	0.2s

In cases where the EG facility may import or export power from the Eskom network, the voltage protection may be supervised so as only to operate in the event of real and/or reactive power export by the facility to the network.

4.6.2.5 Residual over-voltage / neutral voltage displacement protection

Residual over-voltage (also known as neutral voltage displacement) protection shall be applied on MV networks where the generator or generator transformer MV neutral is unearthed. The voltage signal must be derived from a VT configuration that is capable of transforming zero-sequence voltage: three single phase VTs or three phase 5-limb VTs, with primary neutral earth connection. The residual voltage may be derived from a broken-delta configuration of the VTs, or may be calculated by the relay based on the measured phase-to-neutral voltages.

The pick-up and time delay of the residual over-voltage protection shall be chosen so as to grade with the current-based earth fault protection that is applied to the Distributor's network. It is preferred that the residual over-voltage protection uses an inverse voltage-time characteristic rather than a definite time characteristic. The residual over-voltage protection will be less sensitive and slower than the Distribution network protection. Refer to Annex D for a worked grading example.

4.6.2.6 Under and Over Frequency protection

Under- and over frequency protection shall be provided. The under- and over frequency protection relay shall be accurate to within 10 millliHertz of setting. Where an averaging “window” is used for the frequency measurement, this shall be limited to a maximum length of 6 cycles.

The frequency protection shall be set so as to allow generator operation within the frequency ranges stipulated in Section 4.4.1. Operation outside these ranges shall cause the EG to sever the connection with the Eskom network within 300ms.

In cases where the EG facility may import or export power from the Eskom network, the frequency protection may be supervised so as only to operate in the event of real power export by the facility to the grid.

4.6.2.7 Loss-of-Grid protection

Operation of an EG in an unintentional islanded mode with part of the distribution network constitutes a serious safety hazard to both equipment and personnel, and is to be avoided as far as is practicable.

The philosophy to be applied is that the detection of an islanding condition shall take precedence over the continuity of the generator’s grid connection (via the PUC). The generator must be disconnected from the Distribution network upon reasonable suspicion of islanded operation. Generators of capacity greater than 50MVA will typically include more definitive islanding detection methods (e.g. communication-assisted intertripping schemes); so as to further avoid nuisance tripping for non-islanding events.

Dedicated loss-of-grid protection will be applied at the PUC in all applications. An EG may be exempted from this requirement in the event that it is prohibited from exporting real power to the Distribution network by a suitable reverse power relay (see Section 4.6.2.9).

Loss-of-grid protection may take the form of Rate-of-Change of Frequency (ROCOF) or Voltage Vector Shift protection.

Table 4. Typical settings for loss-of-grid protection

ROCOF	Δf	0.2 – 1.0Hz/s (0.4Hz/s typical)
	Δt	40ms – 2s
	Time delay	200ms – 500ms
Voltage Vector Shift	ΔV	6° – 12° (6° typical. 12° on weak networks).

Where ROCOF or Voltage Vector Shift protection is not deemed suitable, a communication-based direct transfer trip scheme may be applied such as to disconnect the EG in the event of an island developing.

4.6.2.8 Check Synchronising / Block dead line charge

The circuit-breaker at the PUC shall be blocked from closing onto a de-energised Distribution network (block dead line charge). Charging of the EG network shall be permitted subject to synchronism check having been performed.

Synchronising shall be done at the PGC, in accordance with the requirements of Section 4.4.2. Where synchronising occurs at the PUC, for situations where the EG would island onto his own internal network, the PUC shall also adhere to the requirements Section 4.4.2.

4.6.2.9 Reverse Power protection

There are two principal applications of reverse power protection:

1) Prevention of generator motoring.

This shall be applied as standard at the PGC on all rotating generators.

The recommended setting for a reverse power relay is 10 – 20% of the maximum allowable motoring power. The operating time is typically 10 – 30s. The time delay is required to prevent maloperation during power swings or when synchronising the generator to the network [Jenkins p.177].

2) Prevention of power export to the grid

A reverse power protection relay may be installed at the PUC of an EG whose entire output will be consumed by the plant in which it is embedded. The reverse power protection relay will prevent unintended export of power to the Distributor's network, and may obviate the need for dedicated loss-of-grid protection (see Section 4.6.2.7). When serving as loss-of-grid protection, the reverse power protection relay shall be graded with time overcurrent protection in order to ensure ride-through during fault conditions. The clearance times shall comply with the requirements determined by the EG integration fault studies.

4.6.2.10 DC Failure Monitoring

DC failure within the EG facility is deemed a serious safety risk. The DC supplies provided for the PUC and PGC circuit-breakers and associated protection systems shall be subject to continual monitoring. Two separate DC alarms shall be provided per DC system:

a) Non-urgent DC alarm: an alarm activated when the battery voltage is lower than normal, or for any fault appearing on the AC supply to the battery charger.

b) Urgent low DC voltage alarm: an alarm activated when the battery voltage is such that the available capacity is less than 20% of the rated Ampere-hour capacity.

The EG shall initiate disconnection from the Distribution network immediately upon receipt of an urgent low DC voltage alarm.

4.6.2.11 Negative Phase Sequence Overcurrent

Negative phase sequence overcurrent protection shall be applied as a generator protection function, and shall serve to protect the generator against damage due to unbalanced loading, broken conductors or other asymmetrical operating conditions.

Negative sequence current components can be extremely harmful to the EG. Distribution network faults, by their nature, are a large contributor to negative sequence currents. The EG should be aware that negative phase sequence overcurrent protection must be effectively applied.

4.6.3 DC Systems

The circuit-breakers and associated protection systems at the PUC and PGC shall operate from independent DC supplies.

The DC supplies to the PUC and PGC shall be subject to continual monitoring as per Section 4.6.2.10. The EG shall cease to energise the Distributor's network upon critical failure of either the DC system at the PUC or that at the PGC or both.

The DC systems at the PUC and PGC shall be maintained in accordance with the applicable Eskom standard or an alternative written policy acceptable to Eskom. Eskom reserves the right to perform audits on the DC systems.

4.6.4 Metering

The metering arrangement adopted per EG application will depend on the specific conditions of the power purchase agreement. The following metering philosophy shall, however, apply to all EG interconnections:

a) Tariff metering and billing shall be done by the party selling the energy, using meters that are owned, commissioned and maintained by the selling party.

Note: In certain cases, Eskom will be both a buyer and a seller of the EG's electrical power output (from the same location) in which case, one Eskom and one EG meter will be installed at the same electrical node.

b) Where Eskom includes a tariff meter at the point of energy purchasing from the EG, this meter shall be used as the check meter for power purchased from the EG. Eskom will install a dedicated check meter at all other points of energy purchasing from the EG. The EG tariff meter shall constitute the main meter in these cases.

c) Tariff meters for the sale of electrical energy to Eskom will be located such that they measure the net energy exported by the EG, excluding the power consumed by its auxiliaries.

d) All Eskom-owned meters shall include facilities for automated remote downloading by Eskom. The meters shall be available for communication at any time. This requires that the VT supply to the meter is energized at all times or that the meter is provided with a separate 230V ac auxiliary supply (typically from the EG facility).

e) In cases where the Eskom metering system is installed within a customer- or EG-owned substation or industrial plant:

   i) Eskom may install its own instrument transformers for metering, or shall make use of suitable instrument transformers provided by the EG. In the latter case, this shall include:

      - A dedicated CT core per phase: accuracy as per NRS 057. The measurement cores shall preferably be of fixed ratio. Where multi-ratio cores are provided, the lowest ratio shall be capable of carrying the generator's full output current continuously. Eskom will use the lowest available ratio for metering purposes.

      - A three phase VT secondary input as per NRS 030, accurate to Class 0.2 and burdened within accuracy class requirements with the Eskom metering system and EG equipment connected. In the case of MV networks this shall be a 5-limb three phase VT or three single phase VTs. In the case of HV networks three single phase VTs will be suitable. The VT primary and secondary neutrals will both be earthed in all cases.

ii) EGs of nominal capacity less than or equal to 10MVA may use a combined CT/VT unit incorporating one CT per phase, and a three phase 5-limb VT in a single tank. In this case, it shall acceptable for the EG's and Eskom's meters to share the available CT cores. Other requirements for the CT and VT cores shall be as in (i) above.

iii) The EG must provide the civil works for the metering equipment to be installed by Eskom. Where Eskom-owned instrument transformers are to be used, these will be provided by Eskom together with the relevant standard steelwork and foundations.

f) All Eskom metering shall be done in secondary quantities with the necessary instrument transformer and/or pulsing factors applied by the remote data warehousing/billing system.

g) The EG shall not have direct access to data on any Eskom meter. The EG may request a copy of historical metering information from the Eskom data warehouse via their Eskom Customer Services representative.

h) All tariff and check meter(s) shall be time synchronized with South African Standard Time in order to ensure synchronised billing information.

4.6.5 Supervisory Control and Data Acquisition (for the Eskom Control Centre/s)

4.6.5.1 General requirements

There shall be an RTU at the PUC and at the PGC. Where these are the same location a single RTU may be provided.

The RTU(s) shall be in accordance with the relevant Eskom standard and shall be supplied, installed, commissioned and maintained by Eskom. The EG must provide the civil works in which the equipment will be installed by Eskom. RTUs at EG facilities with a total capacity of less than or equal to 20 MVA shall interface with the appropriate Eskom Distribution control centre. RTUs at EG's larger than 20 MVA shall consult with Eskom to determine whether its RTU(s) shall interface with only the regional Distribution control centre, or both the regional Distribution control centre and the National control centre.

4.6.5.2 Indications and Alarms

The preferred method of communication from the protection system to the RTU is an EIA-232 serial connection via the DNP3 protocol. If the preceding is not possible, hard-wired (i.e. mechanical, potential free contact) indications are permitted.

The following indications and alarms shall be provided to the RTUs by the EG:

1) PUC and PGC Circuit-Breaker open and closed indications (Double Bit)

2) Isolator open and closed indications (Double Bit) – only required from the PUC.

3) Non-urgent DC alarm (refer to Section 4.6.2.10)

4) Urgent low DC voltage alarm (refer to Section 4.6.2.10)

5) Protection trip indication

6) Manual trip indication

7) Auto synchronising failed

A hard-wired (i.e. mechanical, potential free) contact shall be provided to the RTU for the "Protection

Not Healthy" alarm. The "Protection Not Healthy" alarm shall be raised by any condition indicating that the protection system is unable to function according to its specification. This typically includes protection relay watchdog contacts, VT fuse fail indication, circuit-breaker SF_6 gas blocking alarm etc.

4.6.5.3 Controls

Remote circuit-breaker controls will typically only be required for Eskom-owned switchgear or in cases where the EG's facility will be unmanned. Switching of the EG's equipment by Eskom shall only be conducted under emergency conditions, or as arranged between the parties. Provision for the execution of these controls shall be made at the PUC by the PUC equipment owner.

4.6.5.4 Measurements

The following measurement requirements are in keeping with the requirements of ESKASACL3.

The following power system measurements shall be provided to supervisory via an EIA-232 serial interface to the RTU via the DNP3 protocol. Many modern protection relays include suitable measurement functions for this purpose.

Alternatively, should DNP3 serial communication not be possible, one or more 0 – 5mA transducers complying with the requirements of Distribution Specification 34-392 may be used as an alternative, although this is not preferred.

The quantities that shall be measured at the PUC and PGC and the required accuracies are as follows:

1) the true r.m.s. red-to-white phase voltage (kV): ± 0.5 %

2) the true r.m.s. white phase current (A), range 0 to 1.1 x full load: ± 0.5 %

3) the three-phase active power in kW/MW: ± 0.5 % (Import and Export)

4) the three-phase reactive power in kVar/MVar: ± 0.5 % (Import and Export)

5) the frequency (Hz): ± 0.1 %

Reference conditions for the accuracy measurements shall be as indicated in Distribution Specification 34-392.

The polarity of the measurements shall be such as to indicate positive readings for power export away from the busbar at which the measurements are made (as per Eskom Standard ESKASACL2).

The RTU and protection relay/transducer shall sample the analogue inputs once every second, or more frequently.

5 Tests

Full tests on the equipment needed to meet the requirements of this document must be carried out to the satisfaction of Eskom. These tests are the responsibility of the equipment owner. Tests carried out on equipment installed at the PUC and PGC, as well as loss-of-grid and synchronising tests must be witnessed by a representative of Eskom.

The test on primary equipment must be carried out on site with the equipment installed in its final position. Results from tests performed before delivery and installation are not acceptable.

The EG must keep a written record of all protection settings and of test results. A copy of this record should be available for inspection at the PUC or as required by Eskom.

Measurement and injection test equipment used in testing shall have a traceable calibration record, and shall be of suitable accuracy for the tests to be undertaken.

5.1 Pre-commissioning and Commissioning Tests

Tests to be conducted at the PUC and PGC are divided into two categories:

a) Pre-commissioning tests include all tests to be performed prior to the EG synchronising with the Distributor's network for the first time.

b) Commissioning tests: those tests that can only be completed during the first synchronisation of the EG with the Distributor's network, or thereafter. Commissioning tests shall be conducted upon written agreement of the Distributor after acceptance of the pre-commissioning test results.

Pre-commissioning and commissioning tests for equipment installed at the PUC and PGC shall be as per the requirements of Tables 5 and 6 below. Tables 5 and 6 also indicate the applicable synchronising tests to be conducted at every point at which auto-synchronising functionality is provided.

The applicable pre-commissioning and commissioning tests shall be repeated in the event of any firmware or software change on the control plant equipment, or any hardware component has been replaced, repaired or modified.

Table 5. Pre-commissioning Tests at the PUC and PGC

Equipment	Applicable Eskom Test Procedure	Test requirements
Primary Plant Equipment		
Current Transformers	DISPVAEC6	Insulation Resistance test. Ratio test. Magnetising test. Secondary resistance and burden test. Polarity test. Primary injection test. Visual inspection and application checks.
Voltage Transformers	DISPVAEB6	Insulation Resistance test. Ratio test. Lead and burden resistance test. Polarity test. Visual inspection and application checks.
Isolators	DPC 34-1034	Insulation Resistance test. Contact Resistance test. Contact Timing test. Visual inspection and application checks.
Circuit-breakers	DISPVAEQ6	Insulation Resistance test. Contact Resistance test. Timing Test. SF6 Gas/Oil tests. Miscellaneous and General Checks.
Control Plant Equipment		
Over Current, Earth Fault & SEF Protection	DISPVAED1	Insulation resistance test of CT, VT and DC circuits. Pick-up/Drop Off tests. Timing Characteristic Test. Directional limit tests (where applicable). Visual Inspection.
Voltage Protection	-	As per IEEE 1547.1 Section 5.2.
Frequency Protection	-	As per IEEE 1547.1 Section 5.3. See Note 1.
Loss-of-grid protection	-	As per IEEE 1547.2 Section 5.3 using appropriate frequency ramps.
Synchronisation	-	As per IEEE 1547.1 Section 5.4.1.
Reverse Power	-	As per IEEE 1547.1 Section 5.8.
DC Failure	-	Non-urgent and urgent DC failure alarms to be issued as per the requirements of Section 4.6.2.10.
Note 1. For Frequency relays employing an averaging technique, timing tests may be more appropriately done using ramp frequency changes in the range from ±50mHz/s to ±1Hz/s rather than a step frequency change as per IEEE 1547.1.		

Table 6. Commissioning Tests

Equipment	Applicable Eskom Test Procedure	Test requirements
Control Plant Equipment		
Unintentional islanding (PUC only)	-	As per IEEE 1547.2 Section 5.7.
Synchronisation (all points of synchronisation)	-	As per IEEE 1547.1 Sections 5.4.2, 5.4.3 or 5.4.4 as appropriate.

5.2 Maintenance Tests

Maintenance of the primary and control plant equipment shall be conducted according to the recommendations of NRS-089.

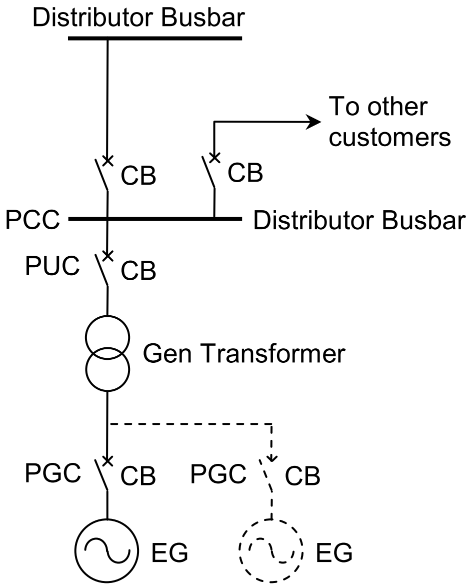
The control plant equipment at the point of connection shall be subject to routine inspection on a three year cycle, witnessed by a representative of Eskom. Major maintenance including secondary injection of all protection relays and testing of primary equipment (e.g. CTs, VTs, circuit-breakers etc) shall be conducted at intervals of 6 years. Major maintenance shall include repeating the unintentional islanding test conducted during commissioning.

Annex A – Summary of generator connection types

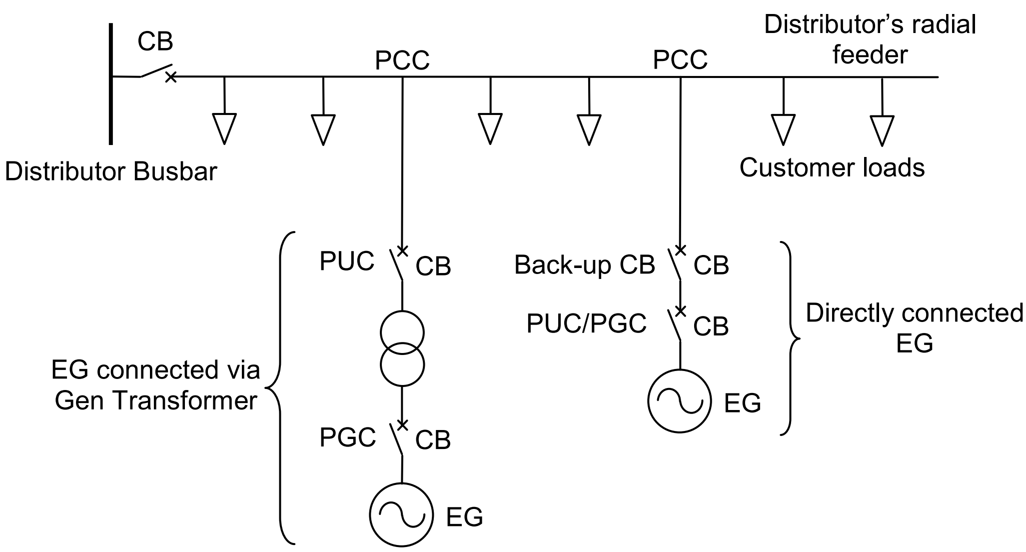
(Informative)

This section provides typical examples of generator connection types to which this standard shall apply, indicating the likely locations of the PUC, PGC and PCC in each case. The application of the standard shall not be limited to only these plant connection types.

Generator connection to Distributor busbar: The EG (or multiple EGs) in this case is connected directly to a Distributor busbar, usually via a generator transformer.



Radial line tee-in generator connection: The EG is connected via a tee-in on a radial distribution line, either via a transformer or directly. In the case of direct connection, the utility will install a back-up circuit-breaker after the PUC/PGC, since no EG is permitted to connect to the Distributor's network via a single circuit-breaker.



Annex B – Summary of plant types

(Informative)

This section provides a summary of the typical plant types to which this standard shall apply. The application of the standard shall not be limited to only these plant types.

Synchronous generator: A type of rotating electrical generator which operates at a speed that is directly related to system frequency. The machine is designed to be capable of operation in isolation from other generating plants. The output voltage, frequency and power factor are determined by control equipment associated with the generator. Under certain conditions, the synchronous generator may be paralleled with a network containing other generation. On disconnection of the paralleled connection, the synchronous generator will continue to generate at a voltage and frequency determined by its control equipment.

Mains-excited asynchronous generator: A type of rotating electrical generator which operates at a speed not directly related to system frequency. The machine is designed to be operated in parallel with a network containing other generation. The machine is excited by reactive power drawn only from the network to which it is connected.

The output voltage and frequency are determined by those of the system to which it is connected. On disconnection of the parallel connection, the mains-excited asynchronous generator will cease generation.

Power factor corrected asynchronous generator: A derivative of the mains-excited asynchronous generator where the machine is excited partly by the network to which it is connected and partly by a device of fixed capacitance connected locally to the machine. On disconnection of the parallel connection, the power factor corrected asynchronous generator may continue to generate electrical power at a voltage and frequency determined by the machine and system characteristics.

Self-excited asynchronous generator: A derivative of the mains-excited asynchronous generator where the machine is excited purely by a device of variable capacitance connected locally to the machine. The machine is capable of operation in isolation from a network containing other generation and in this respect is similar to the synchronous generator. Under certain conditions, the self-excited asynchronous generator may be operated in parallel with other generation, and on failure of that connection, the machine will continue to generate at a voltage and frequency determined by its control equipment.

Self-commutated static inverter: An electronic device to convert direct current (d.c.) to alternating current (a.c.) in which the output value of a.c. frequency and voltage is determined by control equipment associated with the device. It is similar to the rotating synchronous generator in that, under certain conditions, it may be connected in parallel with a network containing other generators. On failure of that connection, the device will continue to provide power at a voltage and frequency determined by its control equipment.

Line-commutated static inverter: A derivative of the self commutated static inverter where the output a.c. frequency and voltage are determined by the network containing other generation to which it must be connected. On disconnection of the parallel connection, the line-commutated static inverter will normally cease operation.

Annex C – Protective Relay Type Test requirements

(Normative)

Protective relays installed at the Point of Connection shall comply with the following international type test requirements.

Table B1. International standard type test requirements for protective relays

Item	Test	Standard	Test Level	Compliance Criteria
Auxiliary power supply				
1	Operating range		-	V_{Nom} – 20% to V_{Nom} + 10%.
2	Interruption	IEC 60255-11	-	For supply interruptions lasting less than 10ms, the device shall function as if no interruption had occurred.
3	A.C. ripple	IEC60255-11	-	Device shall function correctly with 12% 100Hz a.c. signal superimposed on the d.c. supply.
Power frequency magnetic field				
4	Steady State	SANS 61000-4-8	Class 4	30A/m continuous, 300A/m short duration, 50Hz
Insulation resistance				
5	Dielectric withstand	IEC 60255-5	-	2kV rms 50Hz for 1 minute between all terminals to case earth. Transverse tests between contacts shall also be performed to the above specification.
6	Insulation resistance	IEC 60255-5	-	Insulation resistance greater than 20MΩ when measured at 500Vdc
Environmental tests				
7	Cold	IEC 60068-2-1	-10°C or less	Operates within tolerance at -10°C (LCD screen operative)
8	Dry Heat	IEC 60068-2-2	+55°C or more	Operates within tolerance at +55°C
9	Cyclic Temperature and Humidity	IEC 60068-2-30	Test Db	25°C and 95% relative humidity/ 55°C and 95% relative humidity, 12 + 12 hour cycle
10	Enclosure protection	SANS 60529	IP53	Protected against ingress of dust particles, spraying water
Mechanical tests				
11	Vibration	IEC 60255-21-1	Class 2 (response and endurance)	Response: 1g, 10 - 150Hz, 1 sweep energised. Contacts should not close for longer than 2ms. Endurance: 2g 10 – 150Hz, 20 sweeps, unenergised contacts should not close for longer than 2ms.
12	Shock	IEC 60255-21-2	Class 1 (response and withstand)	Response: 5g, 11ms, 3 pulses in each direction, energised Withstand: 15g, 11ms, 3 pulses in each direction, unenergised
13	Bump	IEC 60255-21-2	Class 1	10g, 16ms, 1000 pulses unenergised.
14	Seismic	IEC 60255-21-3	Class 1	Test method A (single axis sine sweep test) 1 – 35Hz, 1 sweep.

Table B1. International standard type test requirements for protective relays (continued)

Item	Test	Standard	Test Level	Compliance Criteria
Impulse tests				
15	Electrical impulse (1.2/50 μs)	IEC 60255-5	-	5kV 1.2/50μs waveform, 0.5J
Electromagnetic compatibility				
16	1MHz Disturbance Burst	IEC60255-22-1 or SANS 61000-4-12	Class 3	2.5kV common mode, 1kV differential mode, 2s total test duration, 6 – 10 bursts
17	Fast Transient	IEC 60255-22-4 or	Class A (IV)	4kV, 2.5kHz 2kV, 5kHz on Comms ports
		SANS 61000-4-4	Class 4	4kV, 5kHz (power port) 2kV, 5kHz (I/O signal, data and control ports)
18	Electrostatic Discharge	IEC 60255-22-2 or SANS 61000-4-2	Class 3	6kV Contact Discharge, 8kV Air Discharge
19	Surge immunity	IEC 60255-22-5 or SANS 61000-4-5	- Class 3	2kV
20	Radiated Radio Frequency EM field immunity	IEC 60255-22-3 or SANS 61000-4-3	- Class 3	10V/m, 80MHz – 1GHz
21	Conducted Radio Frequency EM field immunity	IEC 60255-22-6 or SANS 61000-4-6	- Class 3	10Vrms, 150kHz – 80MHz

Annex D – Residual over-voltage protection grading example

(Informative)

Reference: Network Protection & Automation Guide, p309.

This section provides an example of the method to be used to grade the residual over-voltage protection at an MV point of connection with the current-based earth fault protection on the Distribution network.

The voltage pick-up must be set at a value corresponding to the current pick-up of the least sensitive earth fault relay on the network. The least sensitive current pick-up will typically occur on the source substation feeder circuit-breakers. For a relay that operates using the residual voltage, $3V_0$, the effective setting is given by Equation D.1.

$$V_S = \frac{I_S \times (3 \times Z_N)}{\text{VT Ratio}} \qquad \text{(D.1)}$$

Where:

V_S = Voltage setting of the residual over-voltage protection

I_S = Highest current setting of the Distribution network earth fault protection

Z_N = Earthing impedance

The time delay of the residual over-voltage protection, either definite time or using an inverse-time characteristic, must be chosen such that it operates after the slowest earth fault protection relay on the feeder.

Application example:

Consider a 22kV network that is supplied by two power transformers, each earthed via a 35.8Ω resistor to limit the earth fault current to 710A. The highest earth fault current pick-up applied on the network is 40A. The earth fault protection uses a normal inverse characteristic with a time multiplier of 0.2.

The voltage setting is calculated as follows:

$$V_S = \frac{I_S \times (3 \times Z_N)}{\text{VT Ratio}} = \frac{40A \times (3 \times \frac{35.8\Omega}{2})}{200} = 10.8V$$

The earth fault protection will operate in 470ms for a 710A fault. Assuming that the residual overvoltage protection uses a time-current curve given by the equation:

$$\text{Trip Time, } t = \frac{K}{\frac{\text{V}_\text{M}}{\text{V}_\text{S}} - 1}$$

Where:

K = Time multiplier

V_M = Measured voltage during the fault

V_S = Voltage setting.

For the residual over-voltage protection to operate in 870ms at 190V requires a setting of K = 14.5.

Annex E – Impact assessment

Impact assessment form to be completed for all documents.

1 Guidelines

- All comments must be completed.
- Motivate why items are N/A (not applicable)
- Indicate actions to be taken, persons or organisations responsible for actions and deadline for action.
- Change control committees to discuss the impact assessment, and if necessary give feedback to the compiler of any omissions or errors.

2 Critical points

2.1 Importance of this document. e.g. is implementation required due to safety deficiencies, statutory requirements, technology changes, document revisions, improved service quality, improved service performance, optimised costs.

The document serves to establish the technical standard for the interconnection of Embedded Generation to Eskom Distribution's networks. The standard sets out some key safety aspects relating to the interconnection of Embedded Generation and is central to the National Co-generation project.

2.2 If the document to be released impacts on statutory or legal compliance - this need to be very clearly stated and so highlighted.

The standard serves to fulfil the requirements of the South African Distribution Code: Network Code in so far as a protection interconnection standard for Embedded Generation is required of each Distributor.

2.3 Impact on stock holding and depletion of existing stock prior to switch over.

Not applicable

2.4 When will new stock be available?

Not applicable

2.5 Has the interchangeability of the product or item been verified - i.e. when it fails is a straight swop possible with a competitor's product?

Not applicable

2.6 Identify and provide details of other critical (items required for the successful implementation of this document) points to be considered in the implementation of this document.

A generic Power Purchase Agreement (PPA) and Connection Agreement for EG's has been developed separately to this document. A planning guideline for the integration of Embedded Generation is presently being developed, and will describe in detail the types of impact assessment studies required.

2.7 Provide details of any comments made by the Regions regarding the implementation of this document - None.

Annex E

(continued)

3 Implementation timeframe

3.1 Time period for implementation of requirements.

Not applicable.

3.2 Deadline for changeover to new item and personnel to be informed of DX wide change-over.

Not applicable.

4 Buyers Guide and Power Office

4.1 Does the Buyers Guide or Buyers List need updating?

No.

4.2 What Buyer's Guides or items have been created?

Not applicable.

4.3 List all assembly drawing changes that have been revised in conjunction with this document.

Not applicable.

4.4 If the implementation of this document requires assessment by CAP, provide details under 5

4.5 Which Power Office packages have been created, modified or removed?

Not applicable.

5 CAP / LAP Pre-Qualification Process related impacts

5.1 Is an ad-hoc re-evaluation of all currently accepted suppliers required as a result of implementation of this document?

No.

5.2 If NO, provide motivation for issuing this specification before Acceptance Cycle Expiry date.

Not applicable.

5.3 Are ALL suppliers (currently accepted per LAP), aware of the nature of changes contained in this document?

Not applicable.

Annex E

(continued)

5.4 Is implementation of the provisions of this document required during the current supplier qualification period?

Not applicable.

5.5 If Yes to 5.4, what date has been set for all currently accepted suppliers to comply fully?

Not applicable.

5.6 If Yes to 5.4, have all currently accepted suppliers been sent a prior formal notification informing them of Eskom's expectations, including the implementation date deadline?

Not applicable.

5.7 Can the changes made, potentially impact upon the purchase price of the material/equipment?

Not applicable.

5.8 Material group(s) affected by specification: (Refer to Pre-Qualification invitation schedule for list of material groups)

Not applicable.

6 Training or communication

6.1 State the level of training or communication required to implement this document. (e.g. none, communiqués, awareness training, practical / on job, module, etc.)

Workshops are presently being arranged with Distribution technical personnel to share the requirements of this standard.

6.2 State designations of personnel that will require training.

Project Engineers, EDFS staff, Field Services staff, Network Operators.

6.3 Is the training material available? Identify person responsible for the development of training material.

No training material is available at this stage.

6.4 If applicable, provide details of training that will take place. (E.G. sponsor, costs, trainer, schedule of training, course material availability, training in erection / use of new equipment, maintenance training, etc).

To be announced.

6.5 Was Training & Development Section consulted w.r.t training requirements?

No.

Annex E

(continued)

7 Special tools, equipment, software

7.1 What special tools, equipment, software, etc will need to be purchased by the Region to effectively implement?

None.

7.2 Are there stock numbers available for the new equipment?

Not applicable.

7.3 What will be the costs of these special tools, equipment, software?

Not applicable.

8 Finances

8.1 What total costs would the Regions be required to incur in implementing this document? Identify all cost activities associated with implementation, e.g. labour, training, tooling, stock, obsolescence

Project costing will be evaluated on a per-project basis via the normal Investment Committees, guided by the pricing policies for Embedded Generation presently under development.

Impact assessment completed by:

Name: Stuart van Zyl

Designation: Chief Engineer, Protection Discipline Specialist