NRS 048-4:2021

Edition 3

ELECTRICITY SUPPLY —
QUALITY OF SUPPLY

PART 4: APPLICATION PRACTICES FOR NETWORK SERVICE PROVIDERS

This document is not a South African National Standard

NRS Association

N R S

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

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Foreword

This part of NRS 048 was compiled by representatives of the South African Electricity Supply Industry (ESI), in a working group appointed by the NRS Association. The working group membership included representation from the National Energy Regulator of South Africa (NERSA), customers (including formal representation of the Energy Intensive User Group).

The working group was guided by recommendations in international (IEC and Cigré) standards and technical reports, and by reports, data, and experience available locally. This edition ofNRS048-4 was prepared specifically with the introduction of independent power producers in mind and the subsequent requirements these installations would place on Network Service Providers (NSP). It identifies the requirements of NSPs of NERSA, and provides practical guidelines on how these can be implemented by NSPs. A key development covered in this edition is the recommendation of a single set of criteria for developing emission limits for both NSP and customer installations.

Recommended planning levels have been revised and are given in this edition; they have been based on recent international recommendations made by Cigré Working Group C4.103 and the development by IEC Sub-Committee 77A/WG8 of technical reports IEC 61000-3-6, IEC 61000-3-7 and IEC 61000-3-13.

This edition also takes into account the revision of NRS 048-2 and the development of the international power quality measurement specifications (IEC 61000-4-30). The clauses on interruption performance reporting covered in this part of NRS 048 should be read in conjunction with NRS 048-6.

Some of the guidelines in this part of NRS 048 have not been implemented consistently by all NSPs in the past. It is therefore to be expected that these may take some time to become implemented consistently.

This part of NRS 048 was prepared by the NRS 048 working group which, at the time of publication, comprised the following members:

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This edition supersedes NRS 048-4:2009 (edition 2).

Reference is made in B.3.8 to “arbitration”. In South Africa the Electricity Regulation Act, 2006 (Act No. 4 of 2006) declares the National Energy Regulator of South Africa (NERSA) as the Arbitrator.

NRS 048 consists of the following parts, under the general title *Electricity supply – Quality of supply:*

Part 2: Voltage characteristics, compatibility levels, limits and assessment methods.

Part 4: Application practices for NSPs.

Foreword (concluded)

Part 6: Measurement and reporting of medium-voltage network interruption performance.

Part 7: Application practices for customers. Part 8: Measurement and reporting of extra high voltage (EHV) and high-voltage (HV) network interruption performance.

Part 9: Load reduction practices, system restoration practices and critical and essential load requirements under system emergencies.

Annexes D, E, F and G form an integral part of this document. Annexes A, B, C, H, I, J, K and L are for information only

Introduction

As part of the regulatory framework for the management of power quality, the application of NRS 048 is intended to optimize and minimize the combined cost of supply and use of electricity on an overall national basis.

This part of NRS 048 provides specific technical practices for transmission and distribution network service providers (licensees) on the management of power quality. This edition of NRS048-4 was prepared specifically with the introduction of Independent Power Producers (IPP) in mind and the subsequent requirements these installations would place on NSPs, particularly with respect to meeting Grid Code requirements.

As in the case of the voltage characteristics, compatibility levels and limits specified in NRS 048-2, this part of NRS 048 has been developed with due consideration of important international developments, particular those related to IEC SC 77A Working Group 8 (IEC 61000-3-6, IEC 61000-3-7, IEC 61000-3-13 and IEC 61000-3-14), Cigré Technical Brochure TB261, *Power quality indices and objective,* and Cigré Working Group C4.103.

In order to comply with the voltage quality requirements in NRS 048-2, an approach is outlined for the calculation of a specific customer's fair proportioned allocation of total allowable pollution (emission limits) at a given point of common coupling (PCC)and at the Point of Connection (POC) in the case of IPP's. It further provides recommended planning levels and calculation methods for determining emission limits as well as minimum allowable emission levels for voltage and current harmonics. This part of NRS 048 thus serves to assist in the preparation of customer supply contracts and IPP's. Where no contracts are in place, this part of NRS 048 may further be referenced by NSPs, customers and IPPs as the reasonable basis for evaluating emission levels from existing installations. In this sense, it would be applicable to customers and IPPs as well. This part of NRS 048 also serves to define conditions under which concessions can be made by NSPs where load customers, and in some cases IPPs, request higher levels of distortion. Management of distortion levels for IPPs is dealt with in the Grid Code for Renewable Power Producers: Power Quality Guideline. In such cases the risk that the distribution or transmission NSP can accept, and the risk that the customer may be required to accept in applying these concessions are defined.

International standards and technical reports that deal with power quality have been adopted as SANS standards. This part of NRS 048 provides guidance on how these standards should be applied in the context of the South African regulatory framework.

Specific requirements with regard to power quality complaints management are also included.

NRS 048 does not cover safety requirements, network design or equipment performance, nor does it address issues of negligence or liability.

Keywords

apportioning, emission limits, power quality management, quality of supply

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ELECTRICITY SUPPLY – QUALITY OF SUPPLY

Part 4: Application practices for network service providers

1. Scope

1.1 This part of NRS 048 provides technical guidelines for transmission and distribution NSPs to support the management of power quality in accordance with the requirements of NRS 048-2. It includes technical procedures for the connection of new customers and the evaluation of existing customer plant emission levels regarding harmonics, voltage unbalance and voltage flicker during contract negotiations.

1.2 This part of NRS 048 recommends network planning levels for parameters for use by network service providers in planning to achieve the required compatibility at points of common coupling (PCCs).

1.3 This part of NRS 048 addresses general power quality monitoring requirements (both voltage quality and interruption performance), good practices for monitoring, and some important systems requirements.

NOTE Specific requirements for the reporting of interruption performance are covered in NRS 048-6 and NRS 048-8.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

National Energy Regulator of South Africa (NERSA), *The South African Transmission and Distribution Grid Codes*.

NRS 047-1, *Electricity supply – Quality of service – Part 1: – Minimum standards.*

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

NRS 048-6, *Electricity supply – Quality of supply – Part 6: Measurement and reporting of medium-voltage network interruption performance*.

SANS 61000-4-30/IEC 61000-4-30, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods.*

3. Terms, definitions and abbreviations

For the purposes of this document, the definitions given in the South African Transmission and distribution Grid Codes apply.

3.1 Terms and definitions

Customer: a legal entity that contracts directly with the service provider for the provision of distribution and transmission services. These include generators, distributors, end-use customers and retailers

Distributor: a legal entity that owns or operates/distributes electricity through a *distribution system*

Embedded generator: a legal entity who operates a *unit*, other than a *co-generator*, that is not *connected to the TS*.

Generator: a legal entity licensed to engage in the production of electricity through a *unit* or *power station*.

Network service provider: a legal entity that is licensed to provide network services through the ownership and maintenance of an electricity network.

Point of common coupling (PCC): the electrical node where more than one customer is connected.

Point of connection / connection point: the electrical node on a power system where a customer's assets are physically connected to the network service providers assets

3.2 Abbreviations

CVT: capacitive voltage transformer

HVDC: high-voltage direct current

IEC: International Electrotechnical Commission

IPP: independent power producer

IR: incident report

NERSA: National Energy Regulator of South Africa

NCR: non-conformance report

NSP: network service provider

PCC: point of common coupling

QMS: quality management system

QOS: quality of supply

RPP: renewable power producer

SAIDI: system average interruption duration index

SAIFI: system average interruption frequency index

SVC: static var compensator

SWER: single-wire earth return

THD: total harmonic distortion

VT: voltage transformer

4. Practices for the management of power quality performance levels

NOTE The management of power quality performance levels refers to the interventions that a NSP undertakes in order to ensure that measured performance complies with minimum requirements.

4.1 NSP obligations

A NSP is required to

a) comply with the minimum technical performance requirements defined by the compatibility levels in NRS 048-2 (or, where applicable, specifically contracted levels) at the customer point of connection to the network under the application conditions defined in NRS 048-2;

b) take economically reasonable measures to minimize the frequency and severity of events for which compatibility levels are not defined, for example voltage dips and interruptions; and

c) implement a quality management framework*,* for the purpose of interacting with customers to actively address voltage dip and interruption performance levels. The specific requirements for implementing this framework are discussed in clause 8 of this part of NRS 048.

4.2 Principles

4.2.1 The basic principles in 4.2.2 to 4.2.6 apply to the management of power quality performance levels.

4.2.2 The compatibility levels in NRS 048-2 (or where otherwise contracted, the contracted levels) define NSP performance requirements for the purpose of evaluating performance to individual customers, as well as for the purpose of annual regulatory technical performance reporting.

4.2.3 In order to comply with the above compatibility levels, a NSP shall define a set of internal objectives for the purposes of:

a) allocating customer and IPP emission limits;

b) planning, designing and operating its networks; and

c) assessing internal performance trends.

These internal objectives, termed “planning levels”, are generally chosen to be better than or equal to, the compatibility levels. The planning levels will typically differ for the various voltage levels (i.e. LV, MV, HV, and EHV). A NSP may choose to define different planning levels for different networks (i.e. the planning levels in different MV networks may differ). Recommended planning levels for the various voltage categories in South African networks are provided in annex A. In the absence of specifically defined planning levels, these recommended levels shall be considered to apply.

NOTE A margin is often defined between the compatibility level and planning level in order to make allowance for deviations from the many assumptions made in co-ordinating emissions from the different customer installations connected to the network (e.g. the manner in which emissions from various sources are summated).

4.2.4 In order to manage the combined impact on the quality of the voltage on the electricity supply network, the NSP shall allocate customer emission limits on a fair and consistent basis. Clause 5 defines the general requirements for such a fair and consistent approach to allocating emission limits. The manner in which such limits can be implemented may be:

a) through the specification of emission limits in customer contracts or supply agreements (see an example in annex B);

b) through reference in customer contracts, supply agreements, or by-laws to the general provisions of this part of NRS 048; and

c) by specifying a requirement for customers or contractors to demonstrate compliance with the relevant emission limits before connection of the plant.

4.2.5 In the planning, design, and operation of its networks, the NSP shall address technical issues such as the following in relation to voltage quality performance:

a) harmonic resonances that may arise due to the installation of shunt capacitors, or due to changes in the fault levels (inductive impedance) of the network where existing shunt capacitors are located;

b) harmonic emissions from a NSP's own plant (e.g. harmonic emission from static var compensators (SVC) and high-voltage direct current (HVDC) systems). The approach shall be aligned with that of allocating customer emission limits, as discussed in clause 5;

c) voltage unbalance (also under-balanced load conditions) generated by asymmetrical line impedances that arise primarily as a result of electromagnetic coupling between the phase conductors;

d) voltage unbalance that arises as a result of single-phase load connections at HV (e.g. single- and dual-phase traction), MV (e.g. dual-phase and SWER systems), and LV (individual customer connections);

e) rapid voltage changes that arise as a result of equipment switching (e.g. shunt capacitors, reactors); and

f) where applicable, the guidelines for the calculation of voltage drop in distribution systems for residential areas in NRS 034-1 should be followed.

NOTE Although higher fault levels are beneficial in that these may result in a smaller impact of customer emission levels on the supply voltage, NSPs need to timeously inform customers on any material changes to the expected maximum fault levels so as to enable appropriate actions to be taken to ensure that the fault current rating of customer equipment is not exceeded.

5. Practices for the management of customer and NSP plant emission levels

NOTE The management of emission levels refers to the interventions that a NSP undertakes in order to limit the impact of a given customer, or group of customers, on the quality of the voltage on the electricity supply network.

5.1 NSP obligations

A NSP is required to

a) allocate maximum emission levels (emission limits) to both load customers and IPPs based on consistent and fair methods as defined in this part of NRS 048; and

b) enforce such limits so as to ensure compliance with the minimum requirements of NRS 048-2 (or otherwise contracted compatibility levels).

5.2 Principles

5.2.1 The impact of emission levels from a large customer or IPP connected to the HV network can have as large an effect on a group of customers as a smaller customer connected closer to this group of customers at MV or LV, as fault levels at MV and LV tend to be much lower. This implies that emission limits need to be co-ordinated from the high-voltage busbar to the low-voltage busbar (see figure 1).

5.2.2 For fairness and consistency in the South African context, the basic principles in 5.2.4 to 5.2.10 shall apply in the allocation and enforcement of emission limits.

5.2.3 In the case of LV customer equipment connected direct to the electricity supply network, emission limits are defined for individual equipment in the relevant SANS/IEC/NRS standards (see annex C).

5.2.4 In the case of customer installations connected at LV, MV, HV, and EHV, maximum emission levels shall be determined for each supply point to the plant. Suggested Calculation methods, based on the relevant SANS/IEC technical reports, are provided in annex D.

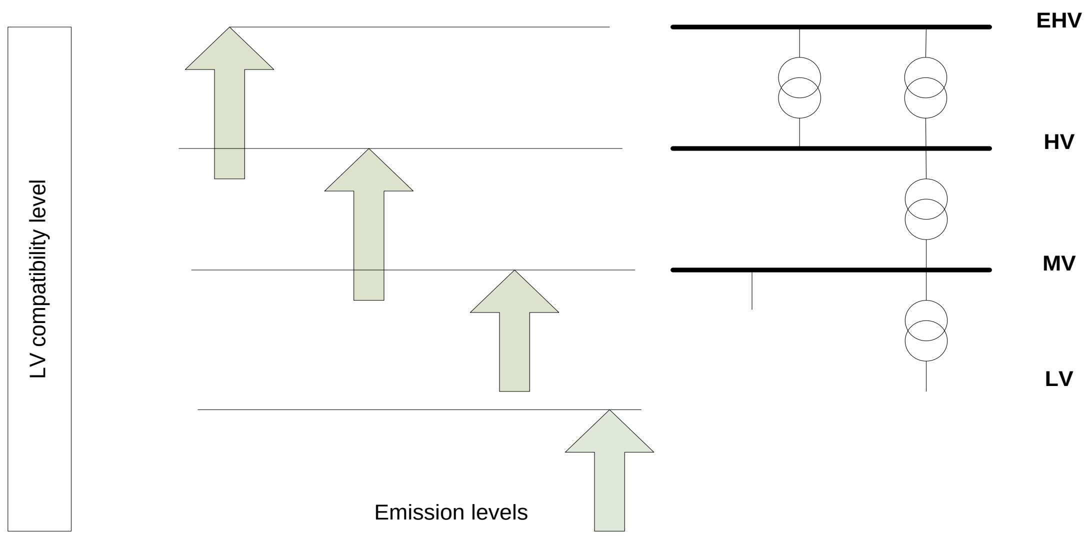

Figure 1 — Emission co-ordination from EHV to LV illustrating the customer emission levels at each voltage level – the sum of which, at the LV level, is required to be equal to or less than the LV compatibility level

5.2.5 In the case of NSP equipment that generates harmonics, voltage fluctuations, and unbalance, maximum emission limits shall be determined using the same principles as those applied to customers connected at these voltage levels.

NOTE Examples of such equipment include static var compensators (SVCs) and HVDC terminal stations.

5.2.6 NSPs shall ensure that system fault levels and harmonic impedances are appropriately and reasonably managed, particularly in the case of shunt capacitor bank installations in order to avoid excessive amplification of harmonic voltages due to resonance.

NOTE 1 Where a NSP installs capacitors, the installation should as far as possible be so designed and operated as to avoid resonances at dominant harmonic frequencies. The resonant frequencies of a network capacitor installation change with network configuration. Network operating states and reasonable contingencies should be considered when such designs are undertaken. Amplification of the system impedance (due to shunt bank installations) in excess of three times the linear impedance (i.e. $Z_h > 3.h.Z_1$ where *h* is the harmonic order and Z_1 is the network impedance at 50 Hz) may be considered excessive.

NOTE 2 Harmonic resonances (particularly at higher harmonic frequencies) can arise as a result of line resonances, and might not be under the control of the NSP.

5.2.7 The recommended planning levels in annex A should form the basis for the allocation of emission limits. A NSP may choose to define specific planning levels for a given network, based on technical considerations related to the co-ordination of voltage quality between its various networks.

5.2.8 It is anticipated that emission limits will generally be agreed upon and contracted between the parties before connection of the installation or through a revision of the contract in the case of an existing installation. Where no such prior agreement exists, the calculation methods in annex D, D.1 to D.5, may be used as the basis for assessing whether measured emission levels from a given installation are acceptable.

NOTE 1 In some cases, NSPs may choose to simply specify (e.g. in a contract) that NRS 048-4 shall be the means by which maximum emission limits shall be assessed. However, this approach should be considered with caution, as both parties may need to incur future expense to rectify a situation that could have been foreseen and resolved to the mutual benefit of the parties at the contracting stage.

NOTE 2 A model format for the inclusion of emission limits in a customer contract is provided in annex B.

5.2.9 NSPs may, at their discretion, determine the basis (if any) for the conditional relaxation of emission limits (for load customers and where applicable, qualifying IPPs) in terms of stage 3 assessment in D.4. This shall, however, be done in a manner that is both fair and consistent in relation to the impact on the performance levels to and emission limits allocated to other customers.

NOTE There might be legal or contractual reasons that prohibit stage 3 apportionments.

5.2.10 The need to undertake measurement, assessment and enforcement of emission limits is generally based on the need to address cases where compatibility or planning levels are exceeded. Given the complexity of such measurements, it is not a requirement for NSPs to enforce emission limits where such compatibility or planning levels are not in danger of being exceeded. It is therefore anticipated that NSPs will from time to time monitor voltage quality levels and use these as a trigger to investigate where levels are approaching or exceeding the relevant compatibility or planning levels. This requirement does not apply to IPPs that must comply with the Grid Code.

5.2.11 The following requirements for disturbance emissions shall apply to customers *less than 5 MVA.*

The power quality levels of disturbance shall meet the following requirements, as specified in table 1.

Table 1: Limits on allowable levels of disturbance

1	2
Voltage quality parameter	**Emission limit**
Short-term flicker (P_{st})	0,35
Voltage unbalance	0,2 %
Current total harmonic distortion (THD)	5 %
Voltage total harmonic distortion (THD)	1%

The current Total harmonic distortion (THD) shall be calculated as follows:

$$THD = \sqrt{\sum_{h=2}^{50}\left(\frac{I_h}{I_1}\right)^2}$$

5.2.12 The following requirements for disturbance emissions shall apply to customers greater than 5 MVA:

Power quality and voltage regulation impact shall be monitored by the NSP at the PCC. The customer shall monitor power quality, using an IEC 61000-4-30 Class A compliant power quality monitoring device, and shall provide an assessment against the power quality requirements of the NSP of the impact on power quality concerning the following disturbances at the PCC:

a) voltage fluctuations;

   i) flicker

b) high-frequency currents and voltages;

   i) harmonics up to the 50th harmonic

c) unbalanced currents and voltages; and

   i) deviation in magnitude between three phases, and

   ii) deviation in angle separation from 120° between three phases.

d) the customer will generally follow the supply network frequency.

5.2.13 Voltage and current quality distortion levels emitted by the customer at the *PCC* may not exceed the apportioned limits as determined by the relevant *NSP*. The calculation of these emission levels shall be based on international and local specifications. The allocation shall be fair and transparent.

NOTE 1 Where compliance to the emission limits need to be confirmed at the time of connection, appropriate measurements need to be taken.

NOTE 2 In general, planning levels are defined as internal objectives for the design and operation of NSP networks. Where a party perceives that the above principles have not been applied, provision is made in clause 8 in this part of NRS 048).

6. Practices for the co-ordination of power quality performance levels between network service providers

6.1 General

The ability of a distribution NSP to comply with the requirements of NRS 048-2 is affected by both customer emission levels, and the levels of “background” voltage quality provided by the transmission network and other distributor networks connected to the distributor’s network. The co-ordination of power quality performance levels between NSPs refers to the interventions that NSPs apply at the interface points between their networks in order to ensure that the impact of each other’s networks and customers’ networks are suitably managed.

6.2 NSP obligations

Transmission and distribution NSPs are required to co-ordinate and manage power quality performance levels from their respective networks in order to comply with NRS 048-2 (or otherwise contracted) requirements at end-customer plants.

6.3 Principles

6.3.1 The basic principles in 6.3.2 to 6.3.4 apply in the co-ordination of power quality parameters.

6.3.2 NSPs shall agree on the manner in which emission and background levels are managed in order to achieve the overall planning levels at a given interface.

6.3.3 Where plant harmonic emission limits are defined as harmonic voltages, NSPs shall agree on the manner in which harmonic impedance information is provided by the parties for the purpose of converting voltage emission limits to current limits.

6.3.4 Voltage dip and interruption performance shall be managed.

NOTE Typically both historical performance and end-customer concerns are used as the basis for performing an assessment of the annual performance levels.

6.3.5 Where a NSP perceives that the above principles have not been applied fairly, provision is made in terms of clause 8 of this specification

7. Practices for monitoring and reporting of power quality performance

7.1 NSP obligations

NSPs are responsible for monitoring power quality for the purposes of

a) providing annual performance statistics to the NERSA;

b) managing NSP requirements to comply with NRS 048-2 (or with specific contractual requirements, where applicable); and

d) ad-hoc investigations (including the enforcement of emission limits, when necessary).

7.2 Principles

7.2.1 The basic principles in 7.2.2 to 7.2.6 apply for the measurement and reporting of power quality parameters.

7.2.2 Reporting requirements for interruption performance, as defined in NRS 048-6 and NRS 048-8, apply.

7.2.3 The sample (number and location) of sites to be monitored for the purpose of providing annual performance statistics on voltage dips, voltage magnitude, voltage unbalance, flicker and voltage harmonics should be agreed upon between a NSP and NERSA from time to time.

7.2.4 The measurement and assessment criteria applied when the performance to a specific customer or at a specific site is being evaluated, shall be those defined in NRS 048-2.

7.2.5 Class A measurement methods as defined in SANS/IEC 61000-4-30 shall apply for contractual and dispute resolution purposes. Class S measurement requirements defined in SANS/IEC 61000-4-30 may be applied in all other applications (including in general compliance surveys and annual reporting to the NERSA). Power quality monitoring devices shall comply with the requirements of SANS 1816.

7.2.6 The criterion for evaluating the voltage quality performance of the NSP's networks as a whole shall be that 95 % of monitored sites in each voltage type (i.e. EHV, HV, MV, LV) shall comply with the compatibility levels defined in NRS 048-2.

7.2.7 Where system performance is evaluated for less than 20 sites in total, the 95 % criterion may be relaxed. In this case not more than one site shall be allowed to exceed the compatibility levels over the measurement period.

NOTE The 95 % criterion is based on acceptance of the fact that many factors may contribute to compatibility levels being exceeded from time to time (e.g. individual customer emission levels may be exceeded due to a failure of mitigation equipment, or significant harmonic resonances may arise due to network reconfiguration). In order to ensure that overall system performance is managed to comply with the system criteria from one year to another, sites exceeding the compatibility levels need to be addressed by the NSP.

7.3 Technical consideration

7.3.1 Measurement transducers

7.3.1.1 The technical considerations in 7.3.1.2 to 7.3.1.7 with regard to transducers should be taken into consideration.

7.3.1.2 Electromagnetic voltage transformers may be used for the determination of network harmonic voltage magnitudes (see NOTE 1). Capacitive voltage transformers (CVTs) may be used only where special techniques are applied. Under no circumstances shall the (uncompensated) secondary output of the capacitive voltage transformer be used for harmonic voltage measurement. Where compensation techniques have been shown to comply with accuracy requirements, the compensated CVT output signal may be used. High-voltage dividers and capacitive bushing tap-off techniques, which comply with the required accuracy, may otherwise be used where electromagnetic voltage transformers are not available.

NOTE 1 Accuracy of VT's may influence the measurement result of voltage harmonics especially at the higher order harmonics.

7.3.1.3 Where harmonic measurements are undertaken, care should be taken that any equipment connected to the secondary winding of a voltage transducer does not generate harmonic currents (e.g. rectifier power supplies).

7.3.1.4 Where unbalance measurements are undertaken, care should be taken that the loading on the secondary windings of the VT is equal on the three phases.

7.3.1.5 The use of protection class VTs is not recommended for unbalance measurements, but may be applied for harmonic and flicker measurements.

7.3.1.6 The use of CVTs for the measurement of voltage unbalance should be undertaken with caution, as damage to capacitors in the capacitor divider stack can significantly affect the measured voltage.

7.3.1.7 The use of CVTs for flicker measurements should be undertaken with caution, as low-frequency voltage fluctuations may not be accurately reflected at the secondary winding of the CVT.

7.3.2 Measurement instrument connections

7.3.2.1 The technical considerations in 7.3.2.2 to 7.3.2.3 with regard to the connection of instruments should be taken into consideration.

7.3.2.2 For general reporting purposes, voltage measurements on solidly grounded systems shall be reported on a phase-to-ground basis, and voltage measurements on all other systems shall be reported on a phase-to-phase basis (see notes 2 and 3 to 7.3.2.3).

7.3.2.3 Where the dip performance to a specific customer plant is being evaluated, the connection method of the instrument (i.e, phase-to-phase or phase-to-ground) may be considered in order to match the connection method of sensitive equipment in the plant.

NOTE 1 Generally in South Africa this implies phase-to-ground measurements on HV and EHV networks, phase-to-phase measurements on MV systems, and phase-to-ground measurements on LV systems.

NOTE 2 Where an instrument is able to provide both phase-to-phase and phase-to-ground measurements, the instrument may be connected phase-to-ground in a non-solidly earthed system, but the reported performance is required to be based on phase-to-phase measurements. This would allow single-phase faults to be identified on the phase-to-phase system on the one hand (looking at the line-to-ground data), and the actual dip propagation from the phase-to-phase system to a downstream phase-to-ground system to be reported in terms of the impact on customer plant (single phase-to-ground faults do not normally affect the downstream plant).

7.3.3 Measurement site categories

7.3.3.1 Measurement sites, for the purposes of reporting voltage dip and waveform quality performance, are categorized into three types of site, i.e.

a) type A - permanent sites (where it is intended to connect measuring instruments for more than three years);

b) type B - semi-permanent sites (where it is intended to connect measuring instruments until a particular problem has been addressed); and

c) type C - temporary sites (where measuring instruments are connected for the purpose of investigation).

7.3.3.2 The technical considerations given in 7.3.3.3 to 7.3.3.6 reflect good practice with regard to the connection of instruments at these sites.

7.3.3.3 Type A sites are important sites that either provide good general coverage of the NSP's network or that supply key or sensitive customers. Measurements at these sites shall be evenly distributed across the NSP's network in order to ensure good representation of the system's performance. With the exception of sites of type VII, as defined in table 1, these are considered as permanent sites and the performance levels at these sites shall be reported to the NERSA. Type VII sites may be moved after a period of 12 months and reported as such.

7.3.3.4 The following parameters shall be measured and reported:

a) site categories 1 to 4 (voltage magnitude, voltage unbalance, voltage THD and voltage dips);

b) site category 5 (voltage magnitude, voltage unbalance);

c) site category 6 (voltage magnitude, voltage unbalance); and

d) site category 7 (voltage magnitude).

NOTE 1 The requirements for broad network coverage and measurement at specific customer sites are in some cases contradictory. These sites are sometimes not located at customer connection points.

NOTE 2 In providing NERSA with a list of type A sites, it is anticipated that a NSP will be in a position to demonstrate that the coverage of the network by this type of sites is appropriate, based on the indicative number of instruments and the general instrument placement guidelines in table 1.

NOTE 3 It is intended that type A sites will be used for tracking performance in the future, and that a NSP will be required to motivate removal of any such sites from the list of type A sites provided to NERSA.

7.3.3.5 Type B sites are sites measured for the purpose of quality assurance (i.e. typically areas in which problems are known or suspected, and the aim is to identify the cause of the problems and to resolve these). These are semi-permanent or permanent sites, and they will not be included in the report to NERSA.

NOTE 1 The reason why these are not reported to NERSA may be

a) due to the short measurement period; and

b) because several instruments may be installed for longer periods in a known bad area in order to understand the power quality problem and to track improvements.

NOTE 2 It is not intended that type A sites be reclassified as type B sites.

7.3.3.6 Type C sites are sites measured for the purpose of investigating customer complaints (i.e. typically to demonstrate compliance). These will typically be temporary or semi-permanent sites.

7.3.4 Number of sites to be monitored

7.3.4.1 The indicative number of type A monitored sites may be determined from table 1. The indicative number of type B sites is 10 % of the total number of type A instruments (in the case of site categories I to VII). The number of type C instruments will be based on the number of investigations required to specifically address customer complaints.

Table 1 — Indicative number of sites to be monitored as type A sites

1	2	3	4
Site Category	**Description**	**Number of sites to be monitored**	**Instrument connected**
1	All EHV measurement points	All	EHV points of supply (see 7.3.4.7)
2	All HV Transmission measurement points	At least one point of supply at each substation (normally the highest HV supply voltage where several points of supply exist in the substation)	HV busbar
3i	All HV non-Transmission supply points were the network supplying this point or networks being supplied from this point predominantly consists of underground networks.	50 % of such HV PCCs	HV PCC, supply point, or MV supply point
3ii	All HV non-Transmission supply points were the network supplying this point or networks being supplied from this point predominantly consists of overhead networks.	50 % of HV/HV substations	Either of HV busbars
4i	All MV supply points (at HV/MV substations) were the network supplying this point or networks being supplied from this point predominantly consists of underground networks.	20 % of HV/MV substations OR 50 % of HV/MV substations where the load supplied is predominantly taken (at the MV side) by commercial or industrial customers served by the NSP	MV busbar at HV/MV substation that supplies MV networks where supply is predominantly taken by commercial/ industrial customers served by the NSP
4ii	All MV supply points (at HV/MV substations) were the network supplying this point or networks being supplied from this point predominantly consists of overhead networks.	20 % of HV/MV substations OR 50 % of HV/MV substations where the load supplied is predominantly taken (at the MV side) by commercial or industrial customers served by the NSP	MV busbar at HV/MV substation that supplies MV networks where supply is predominantly taken by commercial/ industrial customers served by the NSP
5	Interfaces between NSPs at MV	50 % of sites where NSPs supply more than one end customer (e.g. excluding sites where water pump installations are supplied).	MV metering point
6	All supply points on MV Networks supplying customers where the PCC is at MV.	0,1 % of PCCs that supply customers with PCC at MV	MV or LV metering point
7	LV customers (excluding those under site category VI)	0,005 % (1 in 20 000) sites	Preferably toward the end of the NSP’s LV feeder
8	Traction supplies	No indicative minimum – addressed as type B or C sites.	N/A
9	Independent Power Producers	No indicative minimum – addressed as type B or C sites.	POC

7.3.4.2 The provisions in 7.3.4.3 to 7.3.4.10 shall be taken into consideration when the location of instruments connected at the different categories of site is being assessed.

7.3.4.3 Where an instrument can be located at a point other than the point indicated and this has been mutually agreed upon between the parties (end customer and NSP, or between NSPs), this instrument shall be considered as complying with the requirement.

7.3.4.4 Where an instrument can be located in such a manner as to comply with more than one site type, this instrument shall be considered as complying with the requirement.

7.3.4.5 Where a site is monitored by one NSP, and the data can be provided to another NSP, this instrument can be considered as complying with the requirements of each NSP (if the site is one that falls into one of the above categories of both NSPs).

7.3.4.6 In the case of each of the site categories above, the instruments should be distributed evenly across the network (i.e. not limited to specific areas), and evenly across the range of expected performance. The NSP shall provide a description of how well the network is covered.

7.3.4.7 Harmonic measurements using capacitive voltage transformers might not be accurate, and should be assessed separately where problems are suspected.

7.3.4.8 A rural customer shall be a customer supplied by an MV network with overhead MV lines according to NRS 048-2 (table 11, network type B). This type addresses single customers supplied direct from the MV network (i.e. because no other customers are supplied at LV, the PCC is at MV).

NOTE Monitoring of "urban" customers is considered to be largely addressed by the requirements for sites of type IV, given the high fault levels and short feeders associated with type IV sites.

7.3.4.9 The instruments in table 1 are based on the assumption that NERSA will specifically allow for the cost of such instruments to be installed, and that NERSA will agree with the NSP on the actual number of instruments and the time frame in which the instruments will be installed.

7.3.4.10 In the case of a substation where two (or more) busbars are operated in a permanently open state, the individual busbars shall be considered as separate sites.

7.3.5 Minimum statistical monitoring performance requirements

7.3.5.1 The annual average data availability for the identified set of type A sites shall be 95 % (defined as the total number of hours that the data was measured by all instruments divided by the total number of measured site-hours for the year) (see note 1).

7.3.5.2 The annual availability at an individual site shall be better than 80 %. In addition, no individual monitored type A site shall remain unmonitored in accordance with the above requirements for more than four weeks continuously (see note 2).

7.3.5.3 Where the measurement period spans between 330 days and the full year, the number of voltage dips shall be annualized (i.e. the dip performance shall be determined as the number of measured dips × the total number of days in the year divided by the number of days measured). If the measurement period spans less than or equal to 330 days, the site shall be reported as not conforming for the purpose of dip measurements (and the annualized figure provided).

7.3.5.4 The accuracy of the monitoring instruments shall be validated at intervals of less than five years. Validation undertaken by an assessment of the accuracy of an appropriate sample of instruments of the same type (manufacturer, model, and similar age) shall be considered sufficient. (see note 3).

NOTE 1 In the case of interruptions, the data might reflect a lack of information related to some parameters – however, this will still be considered as the data being available.

NOTE 2 In some cases this may not be possible (e.g. where physical damage to a substation has occurred).

NOTE 3 Validation of accuracy does not imply calibration. Most processing in modern instruments happens in the digital domain – the error associated with drift over time is therefore expected to be minimal.

8. Practices for the customer power quality management

8.1 NSP obligations

NSPs are responsible for implementing a power quality management system that effectively addresses

a) communication to new customers on power quality performance levels that need to be taken into consideration in the design of the plant;

b) management of customer power quality complaints (i.e. the resolution of complaints, and record keeping of complaints information); and

c) a report on the management of complaints in accordance with NRS 047-1

NOTE The processes and principles described in section 8 pertain to load customers. Independent power producers are managed separately.

8.2 Principles

8.2.1 Figure 2 summarizes the process of addressing customer power quality concerns related to dips and interruptions from the initial interactions in connecting the customer (e.g. the establishment of a contract) to any complaints that might from time to time be escalated to the regulator.

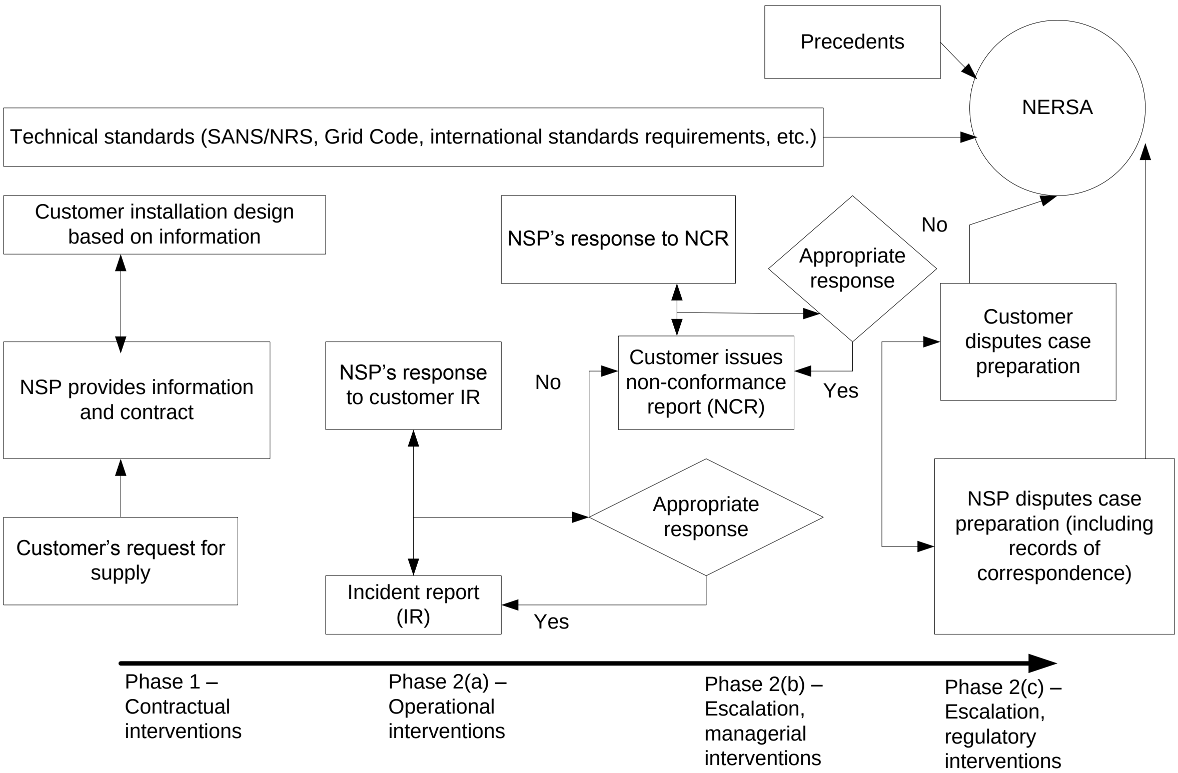

Figure 2 — Process for addressing power quality concerns

8.2.2 The basic principles in 8.2.3 to 8.2.8 apply.

8.2.3 In the process of connecting non-residential customers to the supply network, a NSP is to communicate the following power quality information to the customer (see annex B for an example of contractual provisions in a supply contract):

a) the NSP's technical performance obligations, i.e. NRS 048-2 or otherwise, contracted voltage quality performance levels;

NOTE NRS 048-2 requires that customers be clearly informed of any proposed deviations from the compatibility levels defined in the specification which may be included in the contract (e.g. where a customer wishes to connect a three-phase motor in a predominantly single-phase network).

b) indicative voltage dip statistics of the network to which the customer is to be connected;

NOTE 1 In the case of small customers, these statistics may be generic for the type of network to which the customer is to be connected. In the case of larger customer installations, this information could be derived from actual measurements, where available.

NOTE 2 Where no specific information is available, the generic statistics for South African networks in NRS 048-2 may be applied.

c) emission limits with which the installation shall comply (see clause 5);

d) the customer's obligation to specifying suitable plant immunity requirements (i.e. to ensure suitable compatibility with the voltage quality, dip, and interruption performance levels), based on the information provided by the NSP.

e) the customer's obligation to install suitable protection equipment to avoid damage to the plant or process, should events take place which could cause such damage;

8.2.4 In the case of both new and existing customers, a NSP is required to communicate to the customer the process by which a customer can lodge a power quality complaint or claim, and the manner in which this may be escalated to the NERSA.

8.2.5 Once the customer plant is in operation, a NSP is required to

a) resolve, within reasonable technical and economic constraints, any power quality complaints that might arise;

NOTE The nature of the resolution of a complaint will depend on the specific situation. In cases where no economically practicable solution is available for dip and interruption performance problems, resolution may be limited to a suitable explanation of why an improvement cannot be effected.

b) keep record of customer complaints; such records shall be kept for a minimum of three years; and

c) inform a customer of the process of escalation of the complaint, should this not be resolved to the satisfaction of the customer.

8.2.6 Should the customer wish to escalate the complaint, the NSP shall facilitate the submission of a Non-conformance Report (NCR) for review and response by the management of the NSP.

8.2.7 Should the complaint not be resolved at NSP managerial level, the dispute may be mediated by NERSA. At this stage the NSP shall provide the necessary information related to the processing of the complaint, and a motivation why the complaint could not be resolved to the satisfaction of the customer.

8.2.8 The level of interaction between the NSP and its customers will depend on the nature of the customer. NSPs may choose to implement managed contracts with larger customers (i.e. a formal method of addressing individual events that affect the customer). The power quality concerns of smaller customers will generally be addressed through the normal complaints procedure (e.g. the contact centre).

8.3 Technical considerations

8.3.1 Subject to and in addition to provisions in the relevant sections *of the South African Grid Code,* the technical considerations in 8.3.2 to 8.3.5 apply with regard to power quality provisions in customer contracts.

8.3.2 The system characteristics that applied at the time for the allocation of emission limits shall be specified. As a minimum, it is recommended to indicate the fault level under normal (healthy) network conditions, as well as the notified maximum demand of the customer.

8.3.3 Contracts should require customers to have power-factor corrected equipment that operate correctly, to avoid excessive overvoltages or undervoltages to other customers on the electricity supply network. It is important not only to avoid other customers being affected by the abnormal voltage, but also to ensure that the life expectancy of plant, particularly of transformers, is not reduced.

8.3.4 The conditions for any additional emission allowances under the stage 3 assessment criterion (see annex D, D.4) should be clearly defined in the contract (i.e. the conditions under which the load customer's emission levels may need to be reduced).

8.3.5 It is not possible for NSPs to guarantee to maintain quality of supply at historically perceived levels owing to the need to expand networks and to increase their utilization. Further, owing to the lack of valid historical data on performance, it is not possible to undertake to maintain QOS on a broad network basis. Specific commitments in respect of QOS are possible and are usually the subject of contracts with customers.

8.3.6 As far as practicable, the following guidelines should be followed:

a) all official correspondence should be directed through a specified customer liaison officer;

b) all documentation used in the correspondence should be clearly dated;

c) the contractual clauses should as far as possible be finalized before the customer's equipment specifications are issued. The customer should be made aware of any pending clauses that could affect the equipment's compliance with the NSP's requirements; and

d) all parameters should be communicated and agreed to by the relevant engineer(s) and operations manager(s).

Annex A – Recommended planning levels for voltage categories in South Africa

(informative)

A.1 Recommended planning levels for harmonic voltages

The indicative values given in table A.1 should be used as recommended planning levels for harmonic voltages unless the NSP has established its own planning levels for a specific site (generally based on a specific technical motivation for modifying planning levels at that site).

Table A.1 — Recommended planning levels for harmonic voltages (as a percentage of the rated voltage of the power system)

1	2	3	4	5	6	7	8	9
Odd harmonics (non-multiples of 3)			**Odd harmonics (multiples of 3)**			**Even harmonics**		
Order	**Harmonic voltage %**		**Order**	**Harmonic voltage %**		**Order**	**Harmonic voltage %**	
h	MV	HV/EHV	*h*	MV	HV/EHV	*h*	MV	HV/EHV
5	5,0	2,0	3	4,0	2,0	2	1,8	1,4
7	4,0	2,0	9	1,2	1,0	4	1,0	0,8
11	3,0	1,5	15	0,3	0,3	6	0,5	0,4
13	2,5	1,5	21	0,2	0,2	8	0,5	0,4
17	1,6	1,0	> 21	0,2	0,2	10	0,4	0,4
19	1,2	1,0				12	0,2	0,2
23	1,2	0,7				> 12	0,2	0,2
25	1,2	0,7						
> 25	$0{,}2 + 0{,}5\frac{25}{h}$	$0{,}2 + 0{,}5\frac{25}{h}$						
NOTE Total harmonic distortion (THD): ≤ 6,5 % in MV networks and ≤ 3 % in HV networks.								

A.2 Recommended planning levels for interharmonic voltages

The indicative values given in table A.2 should be used as recommended planning levels for interharmonic voltages unless the NSP has established its own recommended planning levels.

Table A.2 — Recommended planning levels for interharmonic voltages (as a percentage of the rated voltage of the power system)

1	2
Supply	**Interharmonic voltage %**
HV/EHV	0,2
MV	0,2

Annex A
(continued)

A.3 Recommended planning levels for unbalance

The indicative values given in table A.3 should be used as recommended planning levels for voltage unbalance unless the NSP has established its own recommended planning levels.

Table A.3 — Recommended planning levels for unbalance

1	2
Supply	**Unbalance**
EHV	0,8
HV	1,4
MV	1,8

NOTE 1 The above recommended values ensure that a contribution from LV customers and unbalanced load connections can be accommodated for a compatibility level of 2 % at LV.

NOTE 2 The above recommended values are based on transfer coefficients of 0,9 from MV to LV and of 0,95 from HV to MV, and a summation law exponent of 1,4. The allocation is based on an equal share of unbalance contribution at each of the voltage levels.

A.4 Recommended planning levels for voltage flickers

The indicative values given in table A.4 should be used as planning levels for short-term voltage flicker severity (P_{st}) and long-term flicker severity (P_{lt}) unless the NSP has established its own planning levels for a particular system.

Table A.4 — Recommended planning levels for flicker

1	2	3
Supply	P_{st}	P_{lt}
HV/EHV	0,8	0,6
MV	0,9	0,7

General experience shows that flicker produced at EHV or HV sometimes significantly attenuates at lower voltages. Proportionally higher planning levels are recommended where the flicker reduction factor from HV to LV (transfer coefficient) is known. The transfer coefficient of flicker between HV and LV is defined as the ratio of the P_{lt} values, measured at the same time at both locations, i.e.

$$T_{\mathrm{PltAB}} = \frac{P_{\mathrm{lt\,LV}}}{P_{\mathrm{lt\,HV}}} \quad \text{(Equation A.4.1)}$$

A margin that allows for flicker contribution from MV and LV loads is in such cases also necessary, for example, the contracted long-term flicker severity for individual HV and EHV points may be given (using a 20 % margin) by P_{lt} = 0,8 / $T_{Plt\,(LV)(\,HV)}$.

A.5 Recommended planning levels for rapid voltage changes

Compatibility levels are not defined for rapid voltage changes (these are largely addressed by flicker requirements). Table A.5 provides indicative planning levels for rapid voltage changes as a percentage of nominal voltage (i.e. $\Delta U/U_N$, in %) under normal operating conditions. These limits depend on the number of changes in a given period of time (r).

Annex A
(concluded)

Table A.5 — Indicative planning levels for rapid voltage changes as a function of the frequency of repetition

1	2	3
Repetition rate of changes in a period of time *r*	**Rapid voltage change as a percentage of nominal voltage** $\Delta U/U_N$ %	
	MV	HV/EHV
$r \leq 1$ per day	6	3-5
$1 < r \leq 4$ per day	5	3-4
$r \leq 1$ per hour	4	3
$1 < r \leq 10$ per hour	3	2,5

NOTE 1 At HV/EHV, the permissible voltage change has a wide range due to the significant range of voltage levels covered (e.g. >35 kV to 500 kV).

NOTE 2 Higher values may be permitted under abnormal system conditions.

A.6 Measurement and assessment methods

The measurement and assessment methods applied when the measured voltage quality is evaluated against the above planning levels shall be those specified for assessing performance against compatibility levels in NRS 048-2.

In the case of rapid voltage changes, the permissible voltage change $\Delta U/U_N$ and repetition rate *r* should be applied so that the number of changes of magnitude $\Delta U/U_N$ do not exceed the number specified for a given rate within the total time period corresponding to the rate.

A.7 Recommended planning levels for voltage magnitude

Appropriate planning levels should be defined by system planners to ensure that compatibility levels are not exceeded.

NOTE Recommended planning levels may be addressed in future editions of this part of NRS 048.

Annex B – Example of contractual provisions related to power quality in a supply contract

(informative)

B.1 Voltage quality – The network service provider's obligation

B.1.1 The Network Service Provider shall maintain the voltage quality of the supply to the customer in accordance with the compliance criteria defined in NRS 048-2.

B.1.2 In the event of non-compliance with NRS 048-2 by the NSP, the NSP shall take appropriate measures to rectify the voltage quality as soon as is practicable.

B.1.3 The NSP, shall at its own cost, take the necessary corrective action when the sum of consumer contribution at the point of common coupling exceeds the compatibility levels as specified in NRS 048-2 provided that all consumers connected to the point of common coupling have complied with their individually allocated apportionment.

B.2 Voltage quality – The customer's obligation

B.2.1 The customer shall ensure that any voltage distortions or deviations caused by its load or equipment shall not at any time exceed the limits specified in B.3.4, B.3.5 and B.3.6.

B.2.2 The quality of supply limits specified in B.3.4, B.3.5, and B.3.6 are based on the following fixed values:

a) Minimum design operating fault level (three-phase): kA (.................................kiloampere);

b) Network maximum design loading: MVA (........................ megavolt ampere); and

c) CUSTOMER notified maximum demand: MVA (........................ megavolt ampere).

B.2.3 The quality of supply limits specified in B.3.5, B.3.6, and B.3.7 shall, if necessary, be revised if any of the fixed values in B.3.2 change.

B.2.4 The point of common coupling/POC as applicable shall be the .... kV busbar at the NSP'S .... substation under normal operating conditions.

B.2.5 The maximum allowable contribution in harmonic voltage caused by the CUSTOMER at the point of common coupling/POC as applicable shall be:

Annex B
(continued)

Harmonic Order	2	3	4	5	6	7	8	9	10	11
Voltage (%)										
Current (Ampere)										
Harmonic Order	12	13	14	15	16	17	18	19	20	21
Voltage (%)										
Current (Ampere)										
Harmonic Order	22	23	24	25	26	27	28	29	30	31
Voltage (%)										
Current (Ampere)										
Harmonic Order	32	33	34	35	36	37	38	39	40	41
Voltage (%)										
Current (Ampere)										
Harmonic Order	42	43	44	45	46	47	48	49	50	
Voltage (%)										
Current (Ampere)										
Group HD	1	2	3	4						
Voltage (%)										
Current (Ampere)										

B.2.6 The maximum permissible contribution to flicker at the point of common coupling shall be:

a) short-term flicker (determined over a 10 min period), P_{st} = ...; and

b) long-term flicker (determined over a 2 h period), P_{lt} = ...

B.2.7 The maximum permissible contribution to voltage unbalance at the point of common coupling shall be:

Percentage voltage unbalance = ...

B.2.8 Should any one of the limits specified in B.3.5, B.3.6 and B.3.7 be exceeded, the customer shall reduce loading or install corrective equipment at his own expense or take such other measures as might be necessary to reduce the voltage distortion caused by the customer’s load or equipment within the specified limits. The NSP shall, in the event of an infringement by the customer of the limits as specified herein, inform the customer thereof in order that corrective measures can be implemented by the customer.

Annex B
(continued)

Corrective measures shall be implemented by the customer after an infringement has occurred or where circumstances justify it within a period of time as may be agreed upon between the parties. If agreement on the period to be allowed for the customer to correct any infringement of the specified limits cannot be reached within 30 (thirty) days of the infringement occurring, the period shall be determined by arbitration (see foreword).

B.2.9 The customer shall give adequate notice in writing to the NSP of intended extensions or upgrading of the customer's plant or the installation of power factor correction equipment, or any other changes (or both) which may impact on the power quality or impedance at the point of common coupling to the NSP's system (or a combination of these) to enable countermeasures to be taken timeously.

B.2.10 The customer shall install, operate and maintain suitable overvoltage and undervoltage protection equipment.

B.3 Voltage dips

B.3.1 Voltage dip performance is a function of factors such as environmental conditions, network topography, the proximity of generators connected to the grid, and system maintenance and operation. Customer plant voltage dip sensitivity is a function of the design of the customer's process and the equipment used within the plant. Indicative voltage dip performance levels are described in Part 2 of NRS 048. It is incumbent on the customer to take these into consideration in the design and specification of its plant. If required, more specific dip performance data may be requested by the customer from the NSP, and will be provided by the NSP where such performance data is available.

B.3.2 The customer shall use reasonable endeavours to minimize the number of voltage dips and interruptions at the point of common coupling that originate from the plant due to faults or switching operations (or both). In the event of a voltage dip or an interruption, which affects any of the NSP'S other customers, the parties should agree to share information regarding the incident and to pursue any remedial plans as may be reasonably required.

B.3.3 The NSP shall manage voltage dip and interruption performance at the customer's point of delivery in accordance with the requirements of clause 8 of this document.

a) in terms of the said quality management system, the customer shall provide the NSP with an incident report specifying the date and time of any voltage dip or interruption event that affects the customer, as well as the impact of the voltage dip event on the customer's plant;

b) the NSP shall then provide the customer with information on the cause of the voltage dip or interruption event (if such cause is known) and where appropriate, what remedial action, if any, is to be taken. The intention of the reporting process is for the parties to jointly manage the number, causes and effects of such voltage dip events;

c) should the customer be dissatisfied with the manner in which the incident reports are dealt with by the NSP, the customer may send the NSP a Non-conformance Report, in writing, detailing the reason for issuing the Non-conformance Report; and

d) should the customer not be satisfied with the NSP's response to the Non-conformance Report sent to the NSP, the customer may choose to lodge a formal complaint with NERSA.

Annex B
(concluded)

B.4 General responsibilities of customers

B.4.1 The customer shall take reasonable measures to minimize any losses or damage (or both) that arise from interruptions, voltage variations (including voltage dips), voltage distortions, voltage unbalance, surges, undervoltages and overvoltages in the supply to the plant.

NOTE Although this format contact is not intended for domestic LV customers, it should be noted that NRS 048-2 specifically states that such reasonable measures may be considered as being limited to lightning surge suppression and the impact of interruptions to specific sensitive equipment in the case of domestic LV customers.

B.4.2 The customer shall take all reasonable measures to use the supply of electricity in such a way that the use does not negatively affect the quality of supply of electricity by the NSP to other customers or to the NSP where the sensitivity of such customers' equipment is not unreasonably high and the relevant quality of supply to the customer is in accordance with this agreement at the time that the other customers of the NSP were negatively affected.

Annex C – Referenced standards for the co-ordination of power quality levels

(informative)

C.1 General

The list of standards in this annex serves to guide NSPs when requirements for the specification of monitoring equipment are referenced and for communicating emission and equipment immunity requirements with customers. The standards listed are those available at the time of publication of this edition of this part of NRS 048. Only the number and title of the standards are listed (together with a short description), as it is anticipated that the latest edition (and amendments) will apply. Where IEC standards have been adopted as South African standards, these are indicated as SANS/IEC standards.

C.2 Emission limits

The following standards apply in the case of equipment that is connected direct to the electricity supply network:

SANS 61000-3-2/ IEC 61000-3-2	Limits for harmonic current emissions (equipment input current ≤ 16 A per phase) *Description of equipment current emission requirements.*
SANS 61000-3-3/ IEC 61000-3-3	Limits of voltage changes, rated current ≤ 16 A: *Description of equipment current emission requirements.*
SANS 61000-3-4/ IEC 61000-3-4	Limitation of emission of harmonic currents, rated current > 16 A: *Description of equipment current requirements.*
SANS 61000-3-5/ IEC 61000-3-5	Limitation of voltage fluctuations and flicker, rated current > 16 A: *Description of equipment emission requirements.*
IEC61727 NRS 097-2-1	Photovoltaic (PV) systems - Characteristics of the utility interface

C.3 Equipment immunity

The following standards may be referenced in the case of customer equipment:

SANS 61000-4-13/ IEC 61000-4-13	Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests: *Description of test requirements and resulting immunity classes.*
SANS 61000-4-14/ IEC 61000-4-14	Voltage fluctuation immunity test: *Description of test requirements and resulting immunity classes.*
SANS 61000-4-27/ IEC 61000-4-27	Unbalance, immunity test: *Description of test requirements and resulting immunity classes.*
SANS 61000-4-11/ IEC 61000-4-11	Voltage dips, short interruptions and voltage variations immunity tests: *Description of test requirements and resulting immunity classes for single-phase equipment.*
IEC 61000-4-34	Voltage dips, short interruptions, and voltage variations immunity test: *Description of test requirements and resulting immunity classes for three-phase equipment.*
SANS 61000-6-1/ IEC 61000-6-1	Immunity for residential, commercial and light-industrial environments.
SANS 61000-6-2/ IEC 61000-6-2	Immunity for industrial environments.
SANS 61000-6-3/ IEC 61000-6-3	Emission standard for residential, commercial and light-industrial environments.
SANS 61000-6-4/ IEC 61000-6-4	Emission standard for industrial environments.

(concluded)

C.4 Power quality measurement

The following standards apply in the context of measurement instrumentation:

SANS 61000-4-30/ IEC 61000-4-30	Power quality measurement methods: *Description of class A measurement methods. Note: class B requirements in IEC 61000-4-30 ed. 1 are acceptable for existing devices. It is expected that over time these will be replaced with devices compliant with SANS/ IEC 61000-4-30 class A.*
SANS 1816	Electricity supply – Quality of supply: Power quality instruments. *Description of class B measurement methods applicable in South Africa, and instrument (hardware and performance) requirements.*
IEC 61000-4-15	Flickermeter, functional and design specifications.

Annex D – Calculation methods for determining emission limits and assessing emission levels for installations connected to the electricity supply network

(normative)

D.1 Overview

The objective of the practices defined in D.1 to D.5 is to limit the combined emission levels from all individual customer installations and IPP's, taking the system characteristics into consideration, so that the measured voltage quality levels have a high probability of not exceeding the planning levels. The criteria for a fair and consistent approach to setting emission limits for customer, IPP's and NSP equipment installations are based on the size of the installation (maximum demand, in MVA, in the case of customer installations, or rating, in MVA, in the case of NSP installations, or maximum export capacity, in MVA, in the case of IPPs), as well as the system characteristics (capacity, fault level, and system impedance) at the point of common coupling (point of connection for IPP's).

This annex provides the general framework for the calculation of emission limits for installations connected to HV, MV, and LV networks. It does not address requirements for equipment used by residential customers; the latter requirements are addressed by the relevant emission / equipment standards and test methods given in annex C.

D.2, D.3, D.4, and D.5 provide specific equations and tables for the calculation of harmonic limits, unbalance limits, flicker limits and rapid voltage change limits. The principles are based on the international recommendations in IEC/TR 61000-3-6, (harmonics), IEC/TR 61000-3-7, (voltage fluctuations), IEC/TR 61000-3-13, (unbalance), and IEC/TR 61000-3-14 (LV installations).

NOTE Subject to the specified requirements in this part of NRS 048, guidance on the setting of emission limits can be found in technical reports IEC/TR 61000-3-6 (harmonics), IEC/TR 61000-3-7 (voltage fluctuations), IEC/TR 61000-3-13 (unbalance), and IEC/TR 61000-3-14 (LV installations).

The general framework for developing emission limits requires simplified methods to be applied for smaller installations, and more complex evaluations to be undertaken for loads that might have a significant impact on the voltage quality. In terms of this general framework, three stages of evaluation are defined which may be used in sequence or independently.

D.2 Stage 1: Simplified evaluation

If the customer capacity (customer maximum notified demand or generator maximum export capacity) is less than 0.2% of the fault level, no detailed apportionment is required in terms of harmonics or voltage unbalance, provided that the following assumptions are met:

a) the current system distortion is sufficiently below the planning level that a new installation will not cause the planning level to be exceeded; and

b) for harmonic producing loads, the amplification factor is not expected to exceed a factor of two.

The standard emission values provided in table D.1 will be used for all customers apportioned under Stage 1. In order to limit the number of managed contracts, no detailed apportioning will be done for loads with a NMD less than 5MVA or generators with a weighted power less than 5MVA (Category A and B (≤5MVA), in terms of the RPP Power Quality Guideline), provided that these generators meet the requirements of the NRS 097-2 series of documents.

The standard emission levels for these loads or generators to be included in the customer connection agreement/standard conditions of supply are listed in table D.1.

Annex D
(continued)

Conservative criteria may be defined for the automatic acceptance of installations (end-users) that are small in relation to the system capacity) at the various voltage levels (as such small installations will have a low probability of having a significant effect on the overall levels of voltage quality on the system). This avoids the need for a detailed evaluation of the plant and system characteristics.

Specific criteria for applying stage 1 evaluation are recommended in D.2 to D.5.

In addition to this, some minimum limits of emission may be defined (see table D.1).

Table D.1 ─ Generic emission limits defined for individual installations evaluated under stage 1 (including load installations with embedded generation)

1	2
Voltage quality parameter	**Emission limit**
Short-term flicker (P_{st})	0,35
Voltage unbalance	0,2 %
Current total harmonic distortion (THD)	5 %
Voltage total harmonic distortion (THD)	1%

These generic emission limits would typically also apply to customers who install EG in parallel with load, i.e. not installations with the purpose of generating. In the interest of fair and equitable allocation of emission limits, the process for generators and customers should be the same.

For IPP's a similar approach is to be followed in accordance with the RPP Power Quality Guideline, The RPP Power Quality Guideline is a document that guides RPP's on a method to prove compliance to the Power Quality requirements as set out by the NSP. The Power Quality emission guideline is an annexure to the Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission System (Ts) or the Distribution System (Ds) In South Africa.

D.3 Stage 2: Emission limits based on actual system characteristics

If an installation does not comply with stage 1 criteria, the specific characteristics of the customer's or IPP's installation should be evaluated together with the absorption capacity of the system. The absorption capacity of the system is derived from the planning levels and is apportioned to individual installations according to their demand with respect to the total system capacity. The disturbance level transferred from upstream voltage levels of the system to lower voltage levels should also be considered when the planning levels to individual customers and IPP's are being apportioned.

The principle of this approach is that, if the system is fully utilized to its designed capacity and all individual customers and IPP's have emission levels similar to their individual limits, the total disturbance levels will be equal to the planning levels taking into account system characteristics, coincidence factors related to the operation of the various installations, transfer factors between different voltage levels and the summation effect of installations.

The criteria for developing emission limits under stage 2 assessment need to be clearly defined to ensure fairness and consistency in allocating emission levels to individual customers. Such criteria are recommended in annex E, E.2, annex F, F.2 and annex G, G.2.

Annex D
(continued)

D.4 Stage 3: Acceptance of higher emission levels on a conditional basis

D.4.1 Under some circumstances, a customer may request emission levels that exceed the basic limits allowed for under stage 2 criteria. In such cases, the customer and the NSP may agree on special conditions that facilitate connection of the installation. A careful study of the actual and future system characteristics will need to be carried out in order to determine these special conditions. Such conditions should ensure that the risk of exceeding the planning levels is low, and that the fair allocation of emission limits to other customers will not be negatively impacted.

NOTE Some customers, e.g. RPPs selected via the government REIPPPP, are not eligible for stage 3 emission limits due to the PPA and selection processes.

D.4.2 The following considerations may allow a conditional increase in emission limits under stage 3 assessment:

a) some installations do not produce significant emission levels because of the nature of the plant (e.g. a large aluminium smelter does not generate significant flicker levels). Therefore some of this unused emission capacity of the system may be available for utilization on a temporary basis (i.e. in the above example, as long as the aluminium smelter is in operation);

b) the general summation laws applied in E.2, F.2 and G.2 may be too conservative in some instances;

c) some installations may never operate simultaneously;

d) the actual transfer coefficient may be less than that hypothesized;

e) proportionally increasing and re-allocating planning levels between HV or MV may therefore be considered, to take account of local phenomena such as special attenuation effects or absence of unbalanced load installations at a certain voltage level;

f) an installation may comply with its emission limits under normal system conditions, and exceed the stage 2 emission limits only occasionally under degraded conditions (e.g. when nearby generation plant is out of service); and

g) the pre-existing voltage quality levels on the system may be used to allow more emissions when the phase angle of the emissions caused by a particular installation can be controlled in such a manner as to oppose the existing levels on the system (this may typically apply for part of the background unbalance level which is not randomly varying and for installations where it is possible to choose to which phase to connect the installation under consideration (for example, in the case of unbalance and large single-phase loads).

D.4.3 Acceptance of higher customer emissions will nearly always be on a conditional basis, and in accordance with the conditions included in the supply contract.

D.4.4 Temporary stage 3 limits may typically apply

a) as long as spare supply capacity remains available in the system for allowing more emissions;

b) as long as most other customers do not make full use of their normal stage 2 emission limits; and

c) for the time needed for a new installation in order to implement additional corrective measures whenever needed.

Annex D
(continued)

NOTE It is generally good practice to include in the contract the measures that will be taken by the customer to reduce emission levels, and those to be taken by the NSP in the event that the conditions under which the increased emission limits are agreed, are not met.

D.4.5 Where higher emission limits cannot be accommodated by the NSP, and all mitigation measures with the customer plant have been considered, alternative measures may be explored on the network (e.g. connection of the installation at a higher voltage level, an increase in system fault level, or installation of mitigation technologies on the network). The cost of such actions will generally be allocated to the customer. See figure D.1.

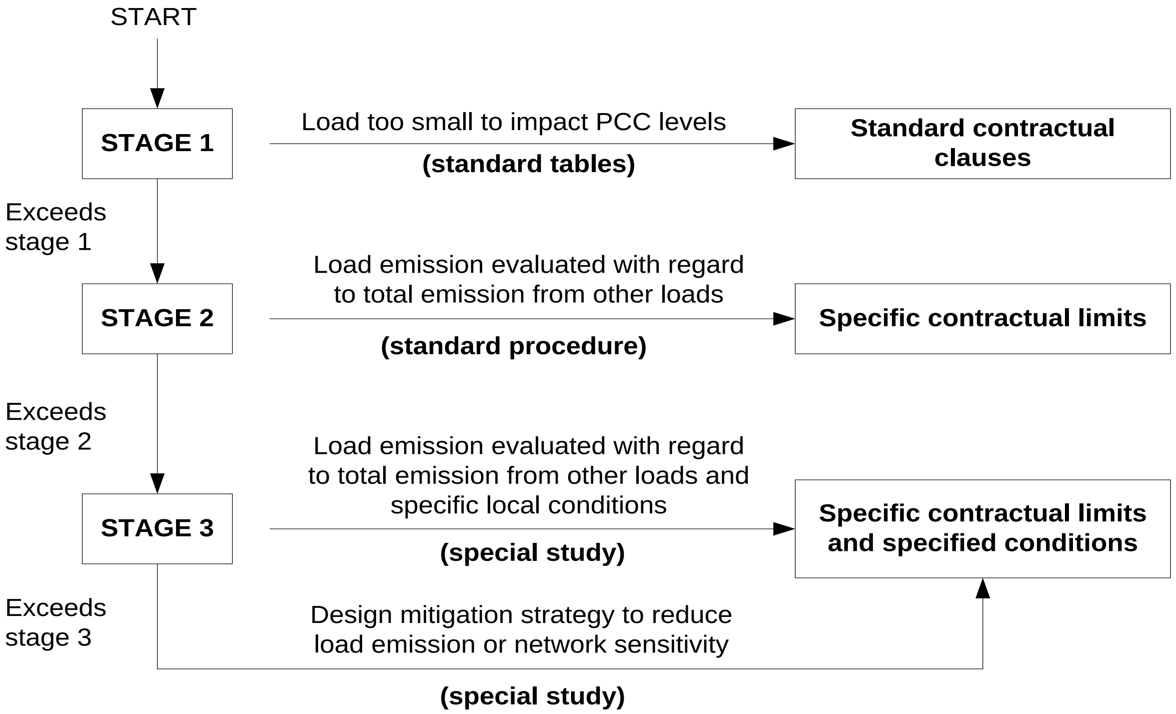

Figure D.1 — Illustration of the emission evaluation procedure, and the manner in which emission limits are addressed in contracts

Annex D
(continued)

D.5 General principles in the calculation of emission limits

D.5.1 Definition of an emission level

The emission level from an installation into the power system is the magnitude of the disturbing voltage (or current) vector, which is caused by the considered installation at the point of evaluation. In the case of harmonics or unbalance, the general concept can be illustrated by the vector U_{di} in figure D.2.

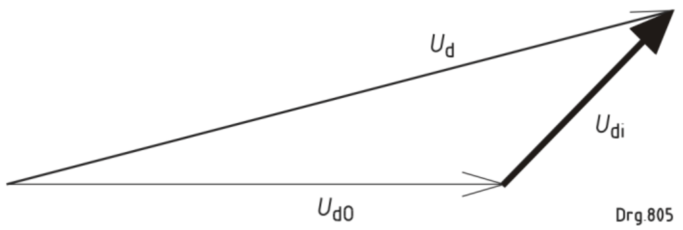

Figure D.2 — Illustration of the emission vector U_{di} and its impact, together with the level of disturbance U_{d0} caused by all other installations without the installation under consideration being connected, on the level of disturbance U_d at the point of evaluation

Where the emission vector results in increased levels of disturbance on the network, the emission level (i.e. $|U_{di}|$) needs to be less than the emission limits assessed according to the relevant subclauses in this part of NRS 048.

In the case of harmonics, the interaction between the supply system and the customer's installation may in some cases result in amplification or in reduction of the voltage distortion level at a given harmonic order (i.e. due to the creation of a parallel or a series resonance condition). This is possible even where the plant itself does not generate harmonics of this order. As this document addresses the EMC co-ordination requirements, such resonance situations need to be taken into consideration in the assessment of actual emission levels.

D.5.2 Summation law

The general summation law (in equation D.1) is recommended for calculating the combined effect of emissions from several installations. This equation is an empirical approximation of the vectoral contributions of the emission levels from each installation, based on knowledge of the magnitudes of the individual emission levels, and can be calculated as follows:

$$E = \sqrt[\alpha]{\sum_i E_i^{\alpha}} \qquad \text{(Equation D.1)}$$

where

E is the magnitude of the combined contribution for the aggregated sources of emission;

α is a summation exponent;

E_i is the magnitude of the individual emission levels for each individual installation.

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(concluded)

Indicative values for the summation coefficients are defined for each voltage quality parameter in E.2, F.2 and G.2.

NOTE The summation exponent is in reality a function of the chosen value of the probability for the actual value not to exceed the calculated value, and the degree to which individual emission levels vary randomly in terms of magnitude and phase. Where specific information is known for the installation and system, the indicative values may be adjusted by the NSP. In particular, smaller summation indices may be required in the case of very few large installations connected to a common point in the network.

D.5.3 System capacity

The system capacity, denoted by S_t, is the total supply capacity of the considered system including provision for future load growth (in principle, S_t is the sum of the capacity allocations of all installations including that of downstream installations that are or can be connected to the considered system, taking diversity into consideration). S_t might also include the contribution from future generation, however, more detailed consideration will be required to determine its firm contribution to S_t and its effective contribution to the short-circuit level as well.

In general, the system capacity at a node will be increased when connecting generation. However, in the case of IPPs, this capacity might not be under the control of the transmission or distribution NSP and would not be regarded as firm / additional capacity. This is especially true in the case of RPPs, where the energy source may not be aligned with the load patterns.

Firm capacity is equal to N-1.

Where a system is not designed for N-1 contingencies, the system capacity is based on the maximum load that may be connected, taking diversity into account.

This implies that the generation capacity would generally not be added to the system capacity when allocating emission limits for loads.

The method described in this Annex allows for a reasonable margin, given that:

a) many QOS parameter emissions are reasonably random for different types of loads and equipment; and

b) for harmonics, allowing for a 3 times resonance (see Annex E), further allows a margin for a transmission or distribution NSP to manage the assessed levels.

It is recommended that the system capacity for IPPs be selected at double the system load capacity, i.e. $S_{tgen} = 2xS_t$.

D.5.3 Evaluation of emission levels

NOTE 1 The evaluation of emission levels depend mostly contractual agreement between the customer and supplier.

NOTE 2 Pre- and post-connection evaluation is often impractical.

NOTE 3 Managing long-term impacts on both sides of the point of connection may require more careful specification of emission limits as well as the evaluation of emissions during commissioning stages.

D.5.3.1 The paragraphs above have defined the general criteria for developing emission limits. The general criteria given in D.5.3.2 to D.5.3.5 apply in the pre- and post-connection evaluation of emission levels from the installation under consideration.

Annex D
(concluded)

D.5.3.2 The pre-connection assessment of the expected emission levels from an installation should consider the worst normal operating conditions and contingencies for which the system or the customer’s installation is designed to operate and that may last for more than 5 % of the time (e.g. where harmonic emission levels may be higher for expected levels of unbalance on the supply network, these need to be taken into consideration).

D.5.3.3 The emission level from an installation is considered as the contribution that the installation makes to the levels on the network (see note to D.5.3.4).

D.5.3.4 The post-connection assessment of the emission levels from a particular installation may require the assessment to be undertaken for short periods when the installation can be operated in one of its more severe states. This assessment needs to be considered in terms of the assessment indices defined below.

NOTE This implies that an installation with no harmonic-producing equipment, but that operates power factor correction capacitors that amplify the harmonic voltage at the PCC, is considered as producing harmonic emissions.

D.5.3.5 The following indices shall be used to compare the emission levels with the customer’s emission limits:

a) the 95th percentile weekly 10 min interval value of the voltage (or current) should not exceed the specified emission limit; and

b) in the case of harmonics, the greatest 95 % probability daily value of the r.m.s. value of individual parameter over 10 min periods, should not exceed the emission limit.

Appropriate attention to the transducer used. Appropriate selection of CT cores etc. Also see SANS/IEC 61000-4-30. Power quality instruments shall comply with the requirements of SANS/ IEC 61000-4-30.

Annex E – Determined emission limits - Hamonics

(normative)

E.1 Stage 1 criteria

The stage 1 criterion for the connection of harmonic-producing installations is shown below. The assumption is that loads, which are small in relation to the short-circuit capacity of the network, are not likely to introduce harmonic problems when connected.

$$\frac{S_i}{S_{SC}} < 0,2\% \qquad \text{(Equation E.1)}$$

where

S_i is the agreed upon maximum demand of the customer, in megavolt amperes;

S_{SC} is the network short-circuit power at the PCC, in megavolt amperes.

E.2 Stage 2 criteria

E.2.1 In the general case where a customer is connected at a defined PCC, the individual customer voltage emission limit is calculated as:

$$E_{U(h)i} = \sqrt[\alpha]{L_{U(h)}^{\alpha} - (T_{U(h)} \times L_{U(h)US})^{\alpha}} \times \sqrt[\alpha]{\frac{S_i}{S_t}} \qquad \text{(Equation E.2)}$$

where

$E_{U(h)I}$ is the individual customer harmonic voltage emission limit at the PPC;

α is the summation law exponent. The exponents in table E.1 are recommended;

$L_{U(h)}$ is the planning level for voltage harmonics in the (MV or HV) system under consideration (see table A.1);

$T_{U(h)}$ is the transfer coefficient of voltage harmonics from the upstream system to the system under consideration (it could be determined by simulation or measurements). For an initial simplified evaluation, the transfer coefficient from the upstream system can be taken as equal to 1. In practice however, it can often be less than 1 due to load damping or greater than 1 due to shunt bank or filter resonances. A transfer coefficient of 0.7 is recommended.

$L_{U(h)US}$ is the planning level for voltage harmonics in the upstream system (see table A.1: different planning levels may be needed to be defined by the NSP for intermediate voltage levels between MV and HV; this is why the general term of upstream system planning level is used);

S_i is the agreed apparent power of the customer installation i, for example, the notified maximum demand or the MVA rating of the considered installation (either load or generation);

Annex E
(continued)

S_t is the total supply capacity of the considered system including provision for future load growth (in principle, S_t is the sum of the capacity allocations of all installations including that of downstream installations that are or can be connected to the considered system, taking diversity into consideration). S_t might also include the contribution from anticipated dispersed generation, however, more detailed consideration will be required to determine its firm contribution to S_t and its effective contribution to the short-circuit level as well

Indicative values for the general summation exponents for harmonics are listed in table E.1.

Table E.1 — Summation exponents

1	2
Harmonic order	α
$h < 5$ $5 \leq h \leq 10$ $h > 10$	1 1,4 2

Individual voltage harmonic emission limits calculated below 0.1 %, shall revert to a limit of 0.1 % due to accuracy constraints of voltage transformers and PQ meters. Effectively, this means that the minimum individual voltage harmonic emission limit for all harmonics shall be 0.1 %.

E.2.2 The maximum current apportioned to the customer is then given by dividing the allocated voltage contribution by the specific network harmonic impedance at the PCC.

As a simplification, a NSP may allocate harmonic current emission levels according to the following equation:

$$E_{\mathrm{I(h)i}} = \frac{E_{\mathrm{U(h)i}}}{K.|Z_{\mathrm{o}}|.h}$$ (Equation E.4)

where

$E_{\mathrm{I(h)i}}$ is the allowable apportioned harmonic current of number *h* at the PCC, in amperes;

$E_{\mathrm{U(h)i}}$ is the percentage harmonic voltage emission of number *h* at the PCC allocated to the new customer, in volts;

$|Z_{\mathrm{o}}|$ is the maximum magnitude of the supply impedance of number *h* at the PCC for any normal system contingencies and states, in ohms;

K is the maximum expected resonance, a value of 3 is recommended;

h is the harmonic number.

An alternative option is to use the actual system impedance that is obtained by system simulation studies, where it is unlikely that the system impedance will change in the long term. This approach is, however very risky from an NSP perspective as it is virtually impossible to predict the state of the network in the future:

$$E_{\mathrm{I(h)i}} = \frac{E_{\mathrm{U(h)i}}}{|Z(h)|}$$ (Equation E.5 ~~E.3)~~)

Annex E
(continued)

Individual current harmonic emission limits shall be a minimum of 0.1% of the customers rated current (for IPP use the plant's MEC rating), due to accuracy constraints of current transformers and PQ meters.

E.2.3 A Group Harmonic approach current exceeds an be allowed by NSPs to allow limited exceedances of individual harmonics within a specified group.

With respect to the requirements for meeting harmonic emission limits provided by the NSP, the customer can be allowed to exceed individual limits by up to 50% (e.g. if the 5th harmonic limit is 1A, the customer may emit up to 1.5A) provided that the Harmonic Distortion (HD) band limit is met for the following specified bands: 2≤h≤13, 14≤h≤25, 26≤h≤39, 40≤h≤50.

The THD bands are defined as follows:

2≤h≤13:

$$HD_{IlimitG1} = \sqrt{\sum_{h=2}^{13} I_{limit}(h)^2} \qquad HD_{ImeasuredG1} = \sqrt{\sum_{h=2}^{13} I_{measured}(h)^2}$$

Contractual requirement: $HD_{ImeasuredG1} < HD_{IlimitG1}$

For 14≤h<25:

$$HD_{IlimitG2} = \sqrt{\sum_{h=14}^{25} I_{limit}(h)^2} \qquad HD_{ImeasuredG2} = \sqrt{\sum_{h=14}^{25} I_{measured}(h)^2}$$

Contractual requirement: $HD_{ImeasuredG2} < THD_{IlimitG2}$

For 26≤h≤39:

$$HD_{IlimitG3} = \sqrt{\sum_{h=26}^{39} I_{limit}(h)^2} \qquad HD_{ImeasuredG3} = \sqrt{\sum_{h=26}^{39} I_{measured}(h)^2}$$

Contractual requirement: $HD_{ImeasuredG3} < THD_{IlimitG3}$

For 40≤h≤50:

$$HD_{IlimitG4} = \sqrt{\sum_{h=40}^{50} I_{limit}(h)^2} \qquad HD_{ImeasuredG4} = \sqrt{\sum_{h=40}^{50} I_{measured}(h)^2}$$

Contractual requirement: $HD_{ImeasuredG4} < HD_{IlimitG4}$

The HD Band requirement is illustrated in figure E.1 for clarity.

Annex E
(concluded)

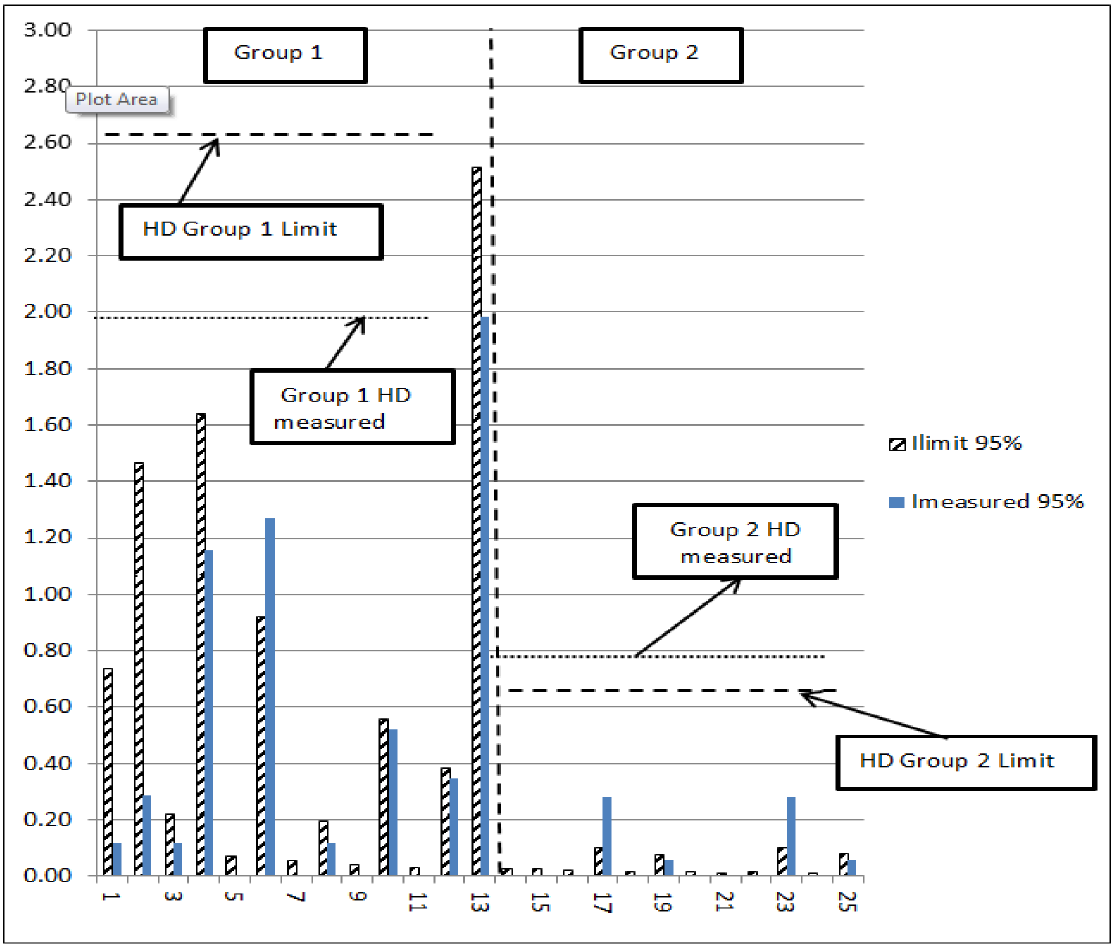

Figure E.1: Group HD Emissions Assessment

Figure E.1 shows the individual current harmonic measurements and limits as well as the HD bands measurements and limits for bands 2≤h≤13 (Group 1) and 14≤h≤25 (Group 2).

For HD band 2≤h≤13, it can be observed that the measured current for the 7th harmonic exceeds the limit, however the Group 1 HD measured is less than the limit set for the HD Group. The customer is deemed to meet the harmonic emissions requirements and does not need to take any actions.

For HD band 14≤h≤25, it can be observed that the measured harmonic currents for the 17th and the 23rd harmonic exceed their limits. Additionally, the Group 2 HD measured exceeds the Group 2 HD limit. In this instance the customer is required to take actions to ensure that the Group 2 HD harmonic emissions are reduced to below the limits.

The weekly sliding 95% values at each harmonic current shall be assessed against the emission limits specified by the NSP and the values which were calculated.

NOTE IEC/TR 61000-3-6 provides a more complex method of addressing the connection of installation in meshed HV and EHV networks, where the impact of harmonic emission levels may be more severe at remote points than at the PCC.

E.3 Stage 3 criteria

See D.4 for the general approach to accepting installations with higher emission levels.

Annex F – Determining emission limits - Unbalance

(normative)

F.1 General

The methods for calculating emission limits for unbalance given in this annex relate primarily to three-phase load connections (although the principles may be applied by NSPs to determine the impact of single-phase connections). It is expected that single-phase and dual-phase connections will be individually managed by s (see NOTE).

NOTE For example, three relatively large single-phase loads may be connected at a similar point if their load profiles are similar.

F.2 Stage 1 criterion

If the following criterion is fulfilled, the unbalanced load installation may be connected to the system without further examination:

$$\frac{S_{u_i}}{S_{sc}} \leq 0{,}2\,\% \quad \text{(Equation F.1)}$$

where

S_{ui} is the single-phase power equivalent of the load unbalance (line-to-line single-phase load equivalent or line-to-neutral load equivalent) of the installation i;

S_{sc} is the three-phase fault level at the point of evaluation.

This formula is also valid for line-to-neutral connected loads.

F.3 Stage 2 criteria

Emission limits of voltage unbalance that can be allocated to a specific customer at either MV or HV are given by

$$E_{u\ i} = \sqrt[\alpha]{k_{uE}} \cdot \sqrt[\alpha]{\left(L_u^{\alpha} - (T_{UM}.L_{uUS})^{\alpha}\right)\frac{S_i}{S_t}} \quad \text{(Equation F.2)}$$

where

E_{ui} is the voltage unbalance emission limit of the installation i supplied at the given voltage level (i.e. MV or HV), as a percentage;

α is the summation law exponent. In the case of unbalance caused by many three-phase or randomly connected single-phase installations, and in the absence of more detailed information on the manner in which the various installations contribute to unbalance levels, an exponent of 1,4 is recommended;

k_{uE} is the fraction of the global contribution to voltage unbalance that can be allocated for emissions from unbalanced load installations in the considered system (conversely $\langle 1\text{-}k_{uE}\rangle$ represents the fraction that accounts for system inherent asymmetries also contributing to voltage unbalance at the given voltage level). The value of k_{uE} can be different at different voltage levels, and will in most cases be less than 1. It shall be defined by the NSP (indicative values are provided in table F.1).

Annex F
(continued)

L_u is the planning level for voltage unbalance in the (MV or HV) system under consideration (see table A.3);

T_{UM} is the transfer coefficient of voltage unbalance from the upstream system to the system under consideration (it could be determined by simulation or measurements, and is the unbalance at the upstream busbar divided by the unbalance caused by this upstream unbalance at the busbar under consideration). For an initial simplified evaluation, the transfer coefficient T_{UM} from the upstream system can be taken as equal to 1. In practice however, it can often be less than 1, particularly due to the balancing effect of three-phase rotating machines connected to the downstream system. It is the responsibility of the NSP to define the relevant values depending on the system characteristics. A transfer coefficient of 0.9 is recommended.

L_{uUS} is the planning level for voltage unbalance in the upstream system (see table A.3). Different planning levels may be necessary to be defined by the NSP for intermediate voltage levels between MV and HV; this is why the general term of upstream system planning level is used;

S_i is the agreed upon apparent power of the customer installation i, or the MVA rating of the considered unbalanced installation (either load or generation);

S_t is the total supply capacity of the considered system including provision for future load growth (in principle, S_t is the sum of the capacity allocations of all installations including that of downstream installations that are or can be connected to the considered system, taking diversity into consideration). S_t might also include the contribution from anticipated dispersed generation, however, more detailed consideration will be required to determine its firm contribution to S_t and its effective contribution to the short-circuit level as well. IEC/TR 61000-3-13 provides further guidance on assessing S_t.

It may happen at some locations that the pre-existing level of unbalance is higher than the normal share for the existing installations. In this case the emission limit for any new installations can be reduced, a reconsideration of the allocation of the planning levels between the different voltage levels could be considered, or the system current unbalance absorption capacity could be increased.

For customers who have a low agreed power, equation F.2 might yield impractically low limitations. If the voltage emission limit at some unbalanced order becomes smaller than 0,2 %, it shall be set equal to 0,2 % (this is considered from the practical measurement point of view).

F.4 Stage 3 criteria

See D.4 for the general approach to accepting installations with higher emission levels.

Annex F
(concluded)

Table F.1 — Portion of unbalance for accounting for the system inherent asymmetries

1	2
System characteristics	**Indicative values of k_{uE} accounting for system asymmetries**
Highly meshed system with generation locally connected near load centres. Transmission lines fully transposed, otherwise lines are very short (few km). Distribution systems that supply a high density load area with short lines or cables and meshed systems.	0,8 – 0,9
Mix of meshed system with some radial lines either fully or partly transposed. Mix of local and remote generation with some long lines. Distribution systems that supply a mix of high density and suburban areas with relatively short lines (<10 km)	0,6 – 0,8
Long transmission lines generally transposed, generation mostly remote. Generally radial subtransmission lines partly transposed or untransposed. Distribution systems that supply a mix of medium and low density load areas with relatively long lines (>20 km). Three-phase motors account for only a small part of the peak load (e.g. 10 %).	0,5 – 0,6

Annex G – Determining emission limits - Flicker

(normative)

G.1 Stage 1 criterion

The connection of a fluctuating installation can be accepted without further analysis if the percentage of apparent power variations ΔS to the system fault level S_{sc} are within the following limits at the PCC. These limits depend on the number *r* of voltage changes per minute (a voltage drop followed by a recovery means two voltage changes).

Table G.1 — Stage 1 limits for the relative power variations as a function of the number of variations per minute

1	2
Number of voltage changes per minute *r* min^{-1}	$K=(\Delta S / S_{sc})_{max}$ %
$r > 200$ $10 \le r \le 200$ $r < 10$	0,1 0,2 0,4

G.2 Stage 2 criteria

Emission limits of voltage flicker that can be allocated to a specific customer at either MV or HV are given by

$$E_{P\,i} = \sqrt[\alpha]{\left(L_P^{\alpha} - (T_{PM}.L_{PUS})^{\alpha}\right)\frac{S_i}{S_t}} \qquad \text{(Equation G.1)}$$

where

E_{Pi} is the voltage flicker emission limit (P_{st} or P_{elt}) of the installation i supplied at the given voltage level (i.e. MV or HV);

α is the summation law exponent (see below);

L_P is the planning level for voltage flicker in the (MV or HV) system under consideration (see table A.4);

T_{PM} is the transfer coefficient of voltage flicker from the upstream system to the system under consideration. (It could be determined by simulation or measurements and is the flicker at the upstream busbar divided by the unbalance caused by this upstream flicker at the busbar under consideration.) For an initial simplified evaluation, the transfer coefficient T_{PM} from the upstream system can be taken as equal to 1. In practice however, it can often be less than 1, particularly due to the effect of three-phase rotating machines connected to the downstream system. A transfer coefficient of 0.9 is recommended. It is the responsibility of the NSP to define the relevant values depending on the system characteristics. (Use of a value of less than 1 should be undertaken with care as the loading on the busbar under consideration may impact this at different times of the day.);

Annex G
(concluded)

L_{PUS} is the planning level for voltage flicker in the upstream system (see table A.4: different planning levels may be needed to be defined by the NSP for intermediate voltage levels between MV and HV; this is why the general term of upstream system planning level is used);

S_i is the agreed upon apparent power of the customer installation i, or the MVA rating of the considered unbalanced installation (either load or generation);

S_t is the total supply capacity of the considered system including provision for future load growth (in principle, S_t is the sum of the capacity allocations of all installations including that of downstream installations that are or can be connected to the considered system, taking diversity into consideration). S_t might also include the contribution from anticipated dispersed generation, however, more detailed consideration will be required to determine its firm contribution to S_t and its effective contribution to the short-circuit level as well. IEC/TR 61000-3-7 provides further guidance on assessing S_t.

In general, a value of α = 3 ("cubic summation law") is recommended for P_{st} (or P_{lt}) summation provided that additional information is not available to justify a different value.

$$P_{st} = \sqrt[3]{\sum_i P_{sti}^3} \quad \text{(Equation G.2)}$$

$$P_{lt} = \sqrt[3]{\sum_i P_{lti}^3} \quad \text{(Equation G.3)}$$

The value of the exponent α depends on the characteristics of the main source of fluctuation. In general, the exponent decreases as the likelihood of simultaneous fluctuations increases, and the following recommendations can be made when additional information is available:

a) α = 4: should be used for the summation of flicker when simultaneous load fluctuations are very unlikely (e.g. specific equipment controls are installed so as to prevent simultaneous fluctuations);

b) α = 3: should be used for most types of flicker sources where the risk of coincident voltage changes is small. The majority of studies that combine unrelated disturbances fall into this type and it is recommended for general use;

c) α = 2: should be used where coincident load fluctuations are likely to occur (e.g. coincident melts on arc furnaces);

d) α = 1: should be used when there is a very high occurrence of coincident voltage changes (e.g. when multiple motors are started at the same time).

Annex H – Example of the manner in which power quality complains are processed

(informative)

The operational process for retail customers requires that fault reports, complaints, claims, and information requests be differentiated and treated as separate processes as illustrated in figure H.1.

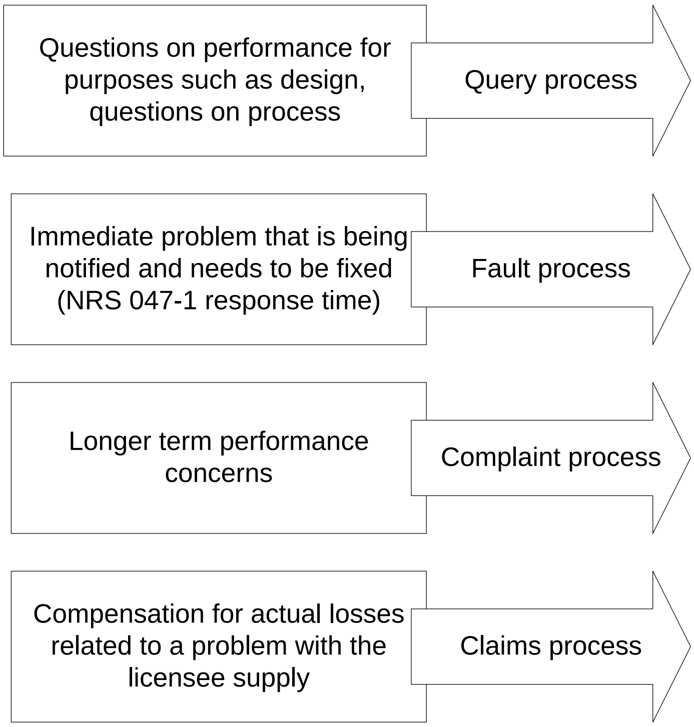

Figure H.1 — Four separate processes to deal with queries, faults, complaints, and claims

The flow diagram in figure H.2 illustrates how the above processes may be implemented. Each of the 14 steps are numbered on the flow diagram.

Annex H
(continued)

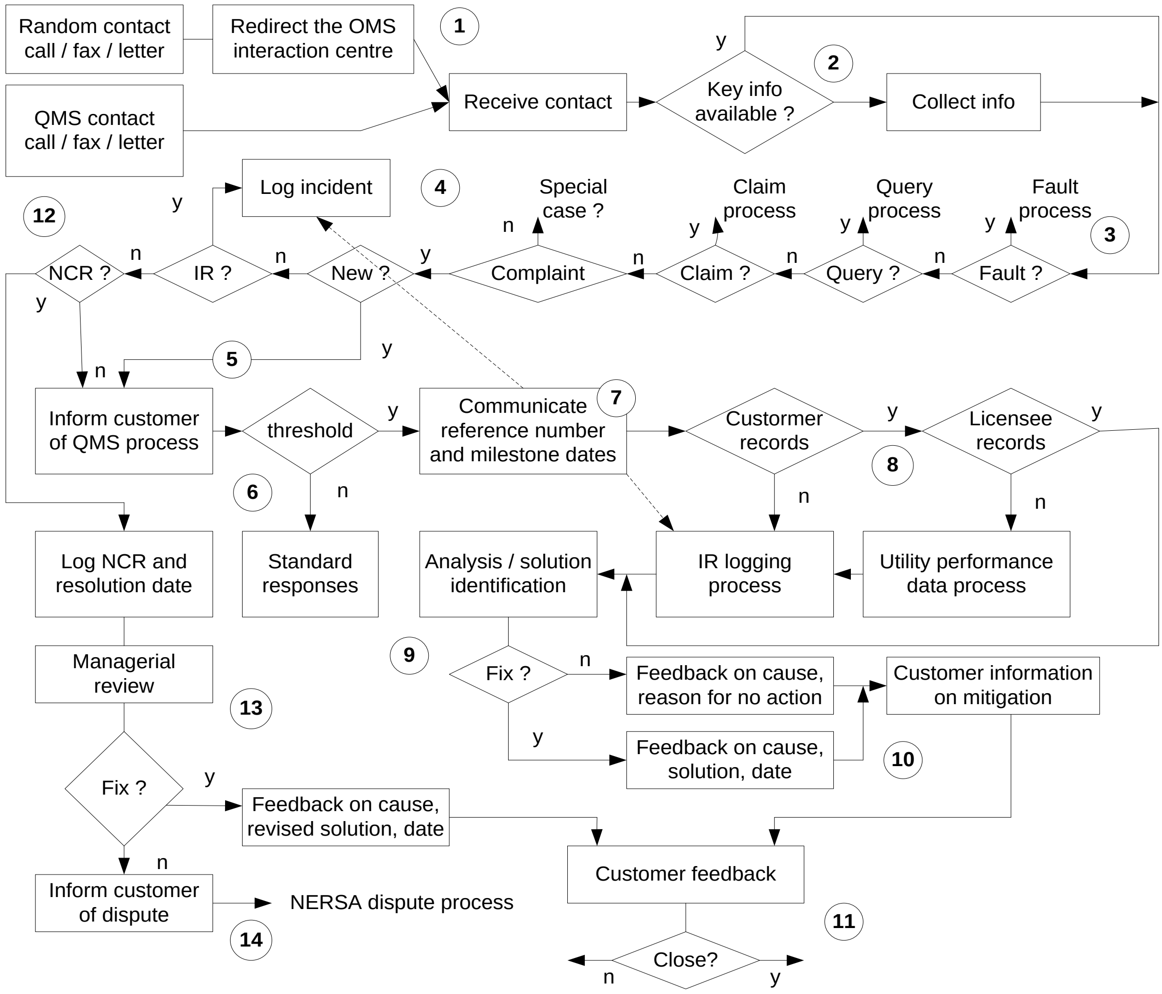

Figure H.2 — Implementation of operational process and managerial review

The steps in a) to h) are implemented.

a) Step 1: customer contacts that are not addressed to a central Power Quality Management contact centre are routed to this centre;

b) Step 2: key information on the nature of the problem is gathered to determine the relevant process (see annex J);

c) Step 3: the relevant process (information query, fault, claim, complaint) is activated;

d) Step 4: in the case of an Incident Report related to an existing (active) complaint, the details of the incident are logged. In this case the customer will have been allocated a reference number for the complaint;

e) Step 5: in the case of a new complaint, the customer is informed in detail of how the Power Quality Management process will address the complaint;

f) Step 6: for new complaints, a *threshold test* can be applied to determine if the customer can be satisfied by a standard response (see note 1). The customer is encouraged to call again if the related threshold comment is later found to be incorrect;

Annex H
(concluded)

g) Step 7*: Milestone dates* are communicated to the customers (see note 2 below), and a technical investigation is triggered;

h) Step 8: if the customer provides detailed records relating to the complaint and the NSP has records of the causes, an analysis is undertaken. If the customer does not have detailed records, an Incident Reporting process is initiated (i.e. when an event occurs, the customer contacts the contact centre to develop a history of events for analysis). If the NSP does not have suitable historical performance measurements, a method of measuring this performance may be instituted;

i) Step 9: after analysis of the gathered information, a decision to take corrective action or not is taken;

j) Step 10: the customer is advised of the decision. Information on customer mitigation options is also provided;

k) Step 11: after the milestone dates, the contact centre follows up with the customer;

l) Step 12: should a Non-conformance Report (an NCR) be instituted, this is logged. Records of NCRs will be kept for NERSA annual reporting purposes;

m) Step 13: a managerial review is undertaken. Should the managerial review indicate a need for measures to be taken, the customer is advised of the implementation plan. Feedback is again solicited by the contact centre; and

n) Step 14: should step 13 review indicate that no further action is appropriate, the customer is informed that the matter can be taken up with NERSA.

NOTE 1 Examples of threshold tests:

a) the complaint is as a result of specific known events that are not expected to re-occur on a regular basis;

b) the complaint is related to specific known events that may occur again, but where a solution has already been identified and is in the process of being implemented;

c) the complaint is related to problems outside the NSP's control (e.g. lightning);

d) the complaint is known to be within contracted performance levels; and

e) the complaint relates to several events in a short space of time only - i.e. not a sustained problem.

NOTE 2 Examples of milestone dates:

a) contact by technical staff (provided by contact centre);

b) expected communication of resolution decision (provided by technical staff);

c) expected implementation of the solution (provided by technical staff on communication of the resolution); and

d) feedback contact (provided by technical staff on communication of the resolution).

NOTE 3 Examples of reasons for an NCR being instituted:

a) Quality Management System is not operational;

b) lack of response;

c) feedback dates have not been met or are being re-negotiated;

d) inappropriate actions have been taken; and

e) actions have not been implemented by the milestone dates.

Annex I – Example of a format for capturing customer power quality complaints

(informative)

The investigation of a complaint typically requires the information given in table I.1 from a customer.

Table I.1 — Complaint information format

1	2
Reference No. (provided by NSP)	
Customer details	
Name	
Location (address, pole number)	
Problem definition	
What is the specific nature of the problem experienced?	
What equipment is affected?	
What are the date(s) and time(s) of known events?	
Measurements / inspections	
Has the customer's facility been inspected by an electrician? If yes, provide details of findings.	
Have measurements been taken by the customer? If yes, provide details of findings.	

The processing of a claim requires the information given in table I.2.

Table I.2 — Claims information format

1	2
Reference No. (provided by NSP)	
Customer details	
Name	
Location (address, pole number)	
What is the date and time of the loss? [a]	
Claim	
Please provide a list of affected equipment.	
Is there proof of physical damage to electrically connected equipment?	
Is there an indication that damage may be associated with a supply problem?	
What is the actual cost of repair (quotation/invoice)?	
Is there any indication that possible NSP negligence exists (i.e. not lightning)?	
What actions were in place at the time to prevent or limit the impact on the customer plant?	
NOTE The above claims information format should be adjusted to reflect the specific contractual provisions regarding liability for claims.	
[a] It is recommended that the customer be encouraged to submit a claim within three months of an event.	

Annex J – Example of a format for technical investigations

(informative)

The investigation of a complaint will typically be required to address *some* or *all* of the issues in table J.1 (note that the level of detail may both vary from investigation to investigation, and impact on the result of a dispute if this should be raised with NERSA).

Table J.1 — Technical investigation format

Reference No.	
1. Performance assessment	
What has been identified as the power quality problem (measurements or other methods)?	
Has a positive or negative trend been identified with the power quality phenomenon?	
2. Comparative benchmarking	
How does the above performance compare with the performance of other networks?	
What are the reasons for any significant difference in performance?	
3. Extent of the problem	
How many other customers are affected?	
How severely are these customers impacted?	
4. Problem cause analysis	
What are the specific causes of the problem?	
5. Standards	
Have any appropriate quality standards been exceeded (e.g. NRS 048-2)?	
Have there been compliance with relevant technical standards (maintenance, planning, operations)?	
Have any short-comings in the technical standards been identified?	
6. Customer measures	
What relevant equipment specifications did the customer apply / not apply?	
What mitigation or protection measures have been implemented by the customer?	
7. Solution identification	
What possible NSP solutions have been identified?	
What possible customer solutions have been identified?	
8. Economics	
What are the costs associated with the above NSP solutions?	
What are the costs associated with the above customer solutions?	
What are the costs associated with not implementing a solution?	
9. Recommendation	
What is the recommended solution?	
How is the cost of the solution apportioned between the customer and NSP?	
NOTE Where measurements are required, these are generally not undertaken within the customer plant. The purpose is to check performance at the supply point (and, where appropriate, confirm compliance with the voltage quality standards in NRS 048-2).	

Annex K – Example of a non-conformance report (NCR)

(informative)

Should a customer wish to raise a Non-conformance Report, the format in table K.1 is provided as an example. This report is forwarded for managerial review.

Table K.1 — Technical investigation format

<table>
<tr><td colspan="2">Non-conformance Report (NCR) Reference No. (provided by NSP):
Date received by NSP: (FOR OFFICIAL USE ONLY)</td></tr>
<tr><td colspan="2">1. Complaint reference details (customer incident report)</td></tr>
<tr><td>Complaint reference number provided to you by the NSP (if any):</td><td></td></tr>
<tr><td>First date of complaint:</td><td></td></tr>
<tr><td colspan="2">2. Customer details</td></tr>
<tr><td>Customer’s name:</td><td></td></tr>
<tr><td>Customer’s contact details:</td><td></td></tr>
<tr><td colspan="2">3. Identify the nature of the non-conformance being reported (select one or more incidents and provide details):</td></tr>
<tr><td>Manner in which the complaint was addressed</td><td></td></tr>
<tr><td>Suitability of the proposed solution</td><td></td></tr>
<tr><td>Solution implemented</td><td></td></tr>
<tr><td colspan="2">4. Response by NSP (FOR OFFICIAL USE ONLY)</td></tr>
<tr><td>Detailed response
- corrective action or
- reason for no corrective action</td><td></td></tr>
<tr><td>Date by which corrective action is to be taken (not applicable where no corrective action is to be taken):</td><td></td></tr>
<tr><td>Recommend that a dispute be raised between the parties for arbitration by NERSA (Y/N):</td><td></td></tr>
<tr><td colspan="2">5. Signature</td></tr>
<tr><td>Customer’s signature:</td><td>NSP/responsible person’s signature:</td></tr>
<tr><td>Date:</td><td>Date:</td></tr>
<tr><td colspan="2">Please note
a) This report will be reviewed by the NSP and returned within 30 working days.
b) A detailed response will be provided, either related to corrective action to be taken by the NSP, or with grounds for the NCR to be raised as a dispute between the parties which is to be arbitrated by NERSA.
c) This NCR will be reported in the statistics reported annually by the NSP to NERSA.</td></tr>
</table>

Annex L – Example of the format of a power quality charter

(informative)

An example of a Power Quality Charter is shown below. Details in this charter may be changed by the NSP ("**NSP**" below may be replaced by the name of the NSP).

POWER QUALITY CHARTER

(in accordance with the requirements of the National Energy Regulator of South Africa)

1. INTRODUCTION

NSP has developed a quality charter which defines its commitments to ensuring the delivery of electricity of appropriate quality, and of dealing with problems that customers may experience with regard to quality from time to time.

2. NETWORK DESCRIPTION

Where a *NSP* tries to minimize potential quality of supply problems arising in its networks, it should be noted that the network that supplies you will have a significant impact on the quality of the supply you experience.

2.1 Overhead networks

Networks of this type are exposed to environmental conditions (such as lightning, fires, high winds, pollution, and birds) and other factors (such as conductor theft, vandalism, accidents) that may result in several faults on the supply network in a given year. Each of these faults may result in:

a) several voltage depressions of several seconds each in short succession (often resulting in nuisance tripping of customer equipment);

b) supply interruptions lasting from several seconds to several hours (depending on the nature of the network); and

c) voltage deviations on one or more phases.

2.2 Underground networks

Networks of this type are not as exposed to environmental conditions but other factors (such as theft, construction damage) may result in faults on the supply network. These faults may result in:

a) voltage depressions of up to several seconds;

b) supply interruptions lasting from several seconds to several hours (depending on the nature of the network).

3. THE QUALITY OF YOUR ELECTRICITY

3.1 Quality of the voltage

The voltage is affected by other connected customers, and by the manner in which *NSP* manages the supply network. The quality of the electricity supplied to you shall be in accordance with the requirements of a national standard (NRS 048-2), as revised from time to time. Should these levels be found to be exceeded, the NSP will take remedial action where appropriate (i.e. if the problem persists).

Annex L
(continued)

3.2 Supply interruptions and voltage dips

It is not possible for the *NSP* to guarantee an uninterrupted supply. *NSP* undertakes best endeavours to minimize the number of dips and interruptions. Typical numbers of voltage dips experienced in South Africa are described in NRS 048-2.

NSP has a process for handing quality-related complaints. Should you experience problems with regard to the quality of your electricity, please address these to the relevant contact number or address below.

4. YOUR RIGHTS

4.1 Power outages and voltage problems (faults)

You are entitled to resolution of problems within the minimum requirements of the national standard on service quality (NRS 047-1). Examples of such problems are a power interruption, or if the electricity seems to be abnormally low or high (e.g. lights are very bright or dim).

4.2 The handling of complaints due to continuing supply problems

When you register a complaint, *NSP* will allocate a reference number. *NSP* will maintain copies of correspondence and information relating to the case against this number. The NSP will respond within 2 working days of receipt of the complaint with regard to the complaint*, and where further investigation is required, feedback will be provided to you within 30 working days.* Should you be dissatisfied with the outcome of your complaint or the manner in which it is handled, you may initiate a Non-conformance Report by requesting a form from *NSP*.

4.3 Claims for equipment damage

Where your electrical equipment has been physically damaged, you may submit a claim for the actual damages to this equipment. Note that such claims will only be settled by the NSP if

a) the event was due to negligence on behalf of the NSP or its contractors,

b) it can be demonstrated that the event directly responsible for the damage was an event on the NSP's network,

c) reasonable protection measures were in place.

NOTE For example that lightning damage will not result in a successful claim, as this is not related to negligence.

You are encouraged to submit such claims within 3 months of the event. Your claim will be processed within 90 days of receipt

4.4 Escalation of the complaint to the National Energy Regulator of South Africa

Should you feel that the manner in which your complaint was handled by the NSP is not acceptable, you are entitled to lodge the complaint with the National Energy Regulator of South Africa. The NERSA will require

a) a detailed description of the manner in which the NSP addressed the problem,

b) a detailed description of the complaint itself,

c) the reference number provided by the NSP for the case,

d) reasons why you believe that the complaint has not been acceptably managed.

Annex L
(continued)

5. YOUR RESPONSIBILITIES

5.1 Protection

It is your responsibility to take reasonable measures to protect your equipment against damage due to problems on the supply network. Examples of such events are:

a) lightning (e.g. electronic devices);

b) voltage deviations (e.g. motors); and

c) interruptions (e.g. critical appliances).

5.2 Use of electricity

It is your responsibility to use the electricity in such a way as not to cause problems to other customers (e.g. starting large motors, welding).

NOTE Equipment labelled with the CE-mark generally complies with international standards for connection to the supply network. *NSP* may be contacted, should you have any queries on the nature of your electrical appliances and their effect on the network.

5.3 Information related to a complaint and claims

When submitting a claim or complaint, it is your responsibility to provide accurate information (dates, times, effects on your equipment) related to your power quality.

6. CONTACT DETAILS

6.1 Power outages and voltage problems (faults)

In the case of a quality problem that requires immediate rectification, contact our 24 hour call centre at telephone number: ____________.

6.2 Complaints of recurring quality problems

In the case of recurring quality problems, please provide details of the nature of these problems by fax or letter to the address below, or telephone number ______________.

Fax ___________________________

Address ____________________________

(Non-conformance forms are also available at this address).

6.3 Claim for equipment damage

Should you feel that you have a claim against *NSP* that meets the above conditions, please submit this in writing to:

Fax ___________________________

Address ____________________________

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(concluded)

6.4 Questions and queries with regard to the quality of your supply

Should you have any questions with regard to this quality charter, your rights, your responsibilities, or general power quality issues, please contact _________________ between the hours of 8 a.m. and 4.30 p.m.

6.5 Contacting the National Energy Regulator of South Africa (NERSA)

The contact details for the National Energy Regulator of South Africa are as follows:

Attention: General Manager - Licensing, Compliance, and Customer Services, Electricity Regulator.

Please note that the NERSA will refer customers to the *NSP*, should this complaint not have been taken up with the *NSP*.

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