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# NRS 048-2:2007

Edition 3

# ELECTRICITY SUPPLY — QUALITY OF SUPPLY

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

This document is not a South African National Standard

N R S

This specification is issued by
the Standardization Section, Eskom,
on behalf of the
User Group given in the foreword.

**Table of changes**

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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 Electricity Suppliers Liaison Committee (ESLC). The working group membership included customer representation, inter alia representation of the Energy Intensive User Group (EIUG).

This part of NRS 048 specifies compatibility levels, limits, voltage characteristics, and assessment methods, which can be used by utilities, their customers, and the National Energy Regulator of South Africa (NERSA) in managing the level of power quality supplied by licensees at the point of supply to individual customers. This part of NRS 048 is aligned with the *NERSA Directive on power quality*, which defines the basis for managing power quality in South Africa. In accordance with the Directive, the compatibility levels (and associated assessment methods) in this part of NRS 048 are minimum standards for licensing requirements. Limits have further been defined for some parameters to address voltage quality problems that might arise in short time periods. Voltage characteristics are defined where compatibility levels cannot be set. These voltage characteristics may be used in conjunction with historical performance at a given site for the management of voltage dip and interruption performance in accordance with the Directive.

The working group was guided by recommendations in international (IEC and Cigré), European (CENELEC), and North American (IEEE) standards and reports, as well as reports and data available locally. This third edition of this part of NRS 048 was prepared to take into account, where appropriate, developments in IEC, SANS, and other standards since the publication of the second edition of this part of NRS 048. In particular, the specifications in SANS 1816 and SANS 61000-4-30 and in power quality measurement standards have been included as normative requirements in this part of NRS 048. Compatibility levels for high voltage and extra high voltage have been introduced in this edition, based on the 2004 Cigré TB261. Where compatibility levels define external quality objectives of a licensee, planning levels define the internal objectives, and form the basis for allocating customer emission limits. This edition of NRS 048-2 also takes into account the revision of NRS 048-4, which comprehensively addresses the selection and use of planning levels. For this reason, the indicative planning levels published in previous editions of this part of NRS 048 have been removed.

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

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This edition supersedes NRS 048-2:2003 (second edition).

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 guidelines for utilities.*

*Part 6: Medium-voltage network interruption performance* (In course of preparation.)

Annexes A and B are for information only.

## Introduction

This part of NRS 048 covers voltage quality parameters that might affect the normal operation of the electricity-dependent processes of customers. Each of the voltage quality parameters is described and, where appropriate, compatibility levels, limits, and assessment methods are specified. These compatibility levels and limits provide measures of acceptable voltage quality at the point of supply to end customers of electricity utilities. The assessment method defines how measured values are statistically assessed over a given time. The assessed values are compared with the compatibility levels or limits.

For all the sites in any given power system at any given point in time, there is a spread of probabilities that a quality of supply (QOS) parameter has a specific value. This statistical spread of the levels of each parameter experienced by customers depends on several variables, which include the variations in load over time, and in geographic and climatic conditions. Figure 1 illustrates this concept for a parameter such as harmonics, which typically exhibits a normal distribution. Other parameters, for example voltage magnitude, which has upper and lower compatibility levels, could exhibit other probability distributions. Figure 1 also illustrates that for all the sites in any given power system at any point in time, there is also a spread of the probabilities of customers' equipment immunity levels.

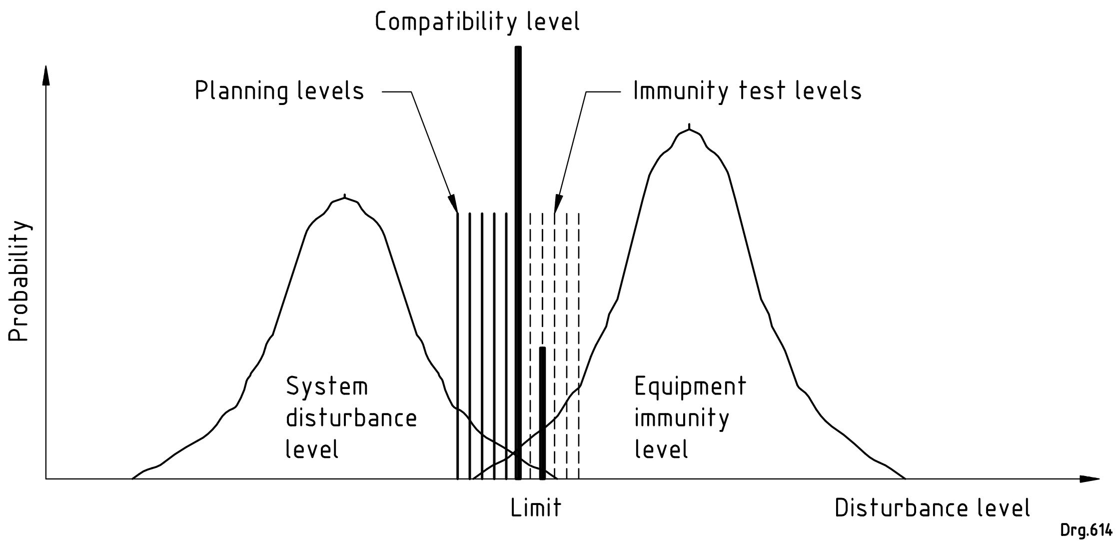


**Figure 1 — Illustration of the concept of compatibility levels**

The principle adopted in NRS 048 is to set compatibility levels such that they represent the 95 % probability levels for the upper limit of system disturbance levels. The figure also illustrates that for each parameter, licensees need to set planning levels, usually below (better than) the compatibility level. These planning levels form internal quality objectives, aimed at managing customer emission levels and system characteristics in order for the compatibility levels to be met. The choice of the network planning level at any point of supply will depend on the parameter under consideration, the confidence the licensee has in the data available for planning, and the type of equipment used by customers.

Recommended planning levels are provided in NRS 048-4.

Customers' equipment should, with the provision of mitigation equipment, if necessary, have immunity levels above the compatibility levels.

The statistical nature of the variation of QOS parameters is such that licensees cannot guarantee that the limits will never be exceeded. The aim of specifying limits is to ensure that excessively high levels of deviation are identified, so that they can be appropriately managed.

The compatibility levels and limits specified in this part of NRS 048 apply only at the point of supply to customers. A licensee is not required to comply with these levels and limits at other busbars in its network. Licensees (and unlicensed redistributors) responsible for generation, transmission and distribution are required to co-ordinate their contractual relationships with one another, based on the need to comply with the requirements of this part of NRS 048 at the point of supply to the customer. In general, inter-licensee agreements will have to provide for measurements in accordance with the principles set out in this part of NRS 048 and in NRS 048-4, accepting that the levels for QOS parameters at inter-licensee interfaces might be different from the levels for end customers specified in this part of NRS 048. NRS 048-4 gives guidance on the factors to be considered in setting QOS parameters in inter-licensee contracts, and provides recommended planning levels for some parameters, which may be used as a basis for such contracts.

Since there is a considerable diversity in the structure of the electricity distribution systems in different areas, arising from differences in load density, population dispersion, local network topography, etc., many customers will experience considerably smaller variations of the voltage characteristics than those described in this part of NRS 048.

Not all equipment and systems have been designed to operate optimally with the compatibility levels specified in this part of NRS 048. Customers and licensees need to take cognizance of the fact that existing installations might have been designed for, and might be operated at, lower levels of immunity. In particular, where equipment or system standards specify supply requirements outside the compatibility levels specified in this part of NRS 048, countermeasures might be required at the customer's plant in order to ensure acceptable performance.

Consideration was given to the following in setting the compatibility level for each parameter:

a) the compatibility levels are the levels of disturbances that can be expected in the environment, allowing for a small probability (< 5 %) of their being exceeded;

b) licensees are responsible for managing their networks and for negotiating customers' contracts to include measures to control customers' emission levels, so as to comply with the compatibility levels;

c) for some parameters, disturbance levels could rise; where present disturbance levels are below the compatibility level at the supply point, a licensee is not required to ensure that these do not increase, but is required to ensure that these do not increase beyond the appropriate compatibility level; and

d) the compatibility level is the level of disturbance for which, with a suitable margin, equipment operating in the relevant environment is required to have immunity.

Where applicable international standards exist, these have been referenced when this part of NRS 048 was being prepared. Where applicable, for specifying assessment methods, the weekly assessment criterion as used in EN 50160 has been adopted (as no assessment criteria have been specified in the relevant IEC standards). This will allow comparison of the QOS in South Africa with the QOS in Europe.

## Keywords

assessment methods, compatibility levels, power quality, quality of supply, quality of supply parameters, reliability of supply, voltage quality.

## Contents

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# ELECTRICITY SUPPLY — QUALITY OF SUPPLY

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

## 1 Scope

### 1.1 Purpose

This part of NRS 048 specifies the voltage characteristics, compatibility levels, limits and assessment methods for the quality of electricity supplied by South African licensees to end customers (see NOTE 1). This part of NRS 048 is intended to provide

a) the National Energy Regulator of South Africa (NERSA) with a means of evaluating and regulating the quality of supply (QOS) provided by licensees (see NOTE 2);

b) licensees and their customers with a reference for establishing appropriate QOS contracts;

c) licensees with QOS minimum standards and criteria for planning, designing, operating and managing their networks;

d) customers with standards and criteria for evaluating the QOS delivered by utilities (see NOTE 2), and

e) customers and equipment suppliers with standards and criteria to be taken into consideration when designing their plant and specifying equipment.

NOTE 1 It is important to note that the requirements of this specification apply only to the quality of electricity delivered to end customers. It is not intended to define the levels of quality at interfaces between transmission and distribution licensees. These shall be coordinated in terms of individual agreements between licensees to ensure that end customers' quality levels are met. Guidance on the development of such agreements is provided in NRS 048-4.

NOTE 2 The annual reporting requirements (i.e. instrumentation, data and data quality requirements) and system performance criteria (for example percentage of sites that exceed compatibility levels) are defined in NRS 048-4. It is intended that for the purpose of such reporting, the reporting and assessment methods in this part of NRS 048 will apply at each monitored site, and that the compatibility levels, as defined, will be the basis for assessing site performance for regulatory reporting purposes. NRS 048-6 has been specifically developed to address requirements for data management for the monitoring of interruption performance.

NOTE 3 It is intended that licensees will comply with the appropriate compatibility levels and limits specified in this part of NRS 048 in the case of each customer. In order to achieve this, NRS 048-4 provides guidance to licensees on the application of internal quality objectives (i.e. planning levels) in the design of networks and the connection of customer installations.

NOTE 4 Rapid voltage changes are given in annex A.

NOTE 5 Interhamonic voltages on LV networks are given in annex B.

## 1.2 Applicability to licensees

**1.2.1** Unless otherwise specifically agreed upon in a supply contract, it is intended that licensees will ensure that all QOS parameters to a specific customer, when assessed as specified in this part of NRS 048, will comply with the compatibility levels and limits specified in this part of NRS 048 under normal network operating conditions.

NOTE The requirements of this part of NRS 048 could be superseded in total or in part by the terms of a contract between an individual customer and a licensee.

**1.2.2** Normal network operating conditions exclude the following:

a) situations where the licensee provides a temporary supply to keep customers supplied during maintenance and construction work, which are not associated with normal contingencies under which the network was designed to operate, provided that customers have been notified (see NRS 047-1);

b) temporary actions taken to minimize the extent and duration of a total loss of supply arising from faults or equipment failure, which are not associated with normal contingencies under which the network was designed to operate; and

c) unavoidable circumstances (force majeure) such as

   1) war damage, uprising, pilfering, theft, sabotage, attack, malicious damage,

   2) damage of equipment caused by accidental and unavoidable occurrences attributable to a third party, or damage of material caused primarily by the unusual intensity of a natural event, should the usual precautions to prevent such damage not prevent it, or if the precautions could not be taken (see NOTE 1),

   3) extreme atmospheric phenomena which cannot be prevented because of their cause or their extent, and to which electrical networks, especially overhead networks, are particularly vulnerable (see NOTE 2), and

   4) industrial action such as a general strike outside the influence of the licensee that prevents normal operation of the network (see NOTE 3).

   NOTE 1 An occurrence attributable to staff or to a contractor of the licensee is NOT considered an unavoidable event.

   NOTE 2 The impact of lightning activity on electrical networks is NOT considered an unavoidable event.

   NOTE 3 Industrial action related to the licensee is NOT considered an unavoidable event.

**1.2.3** Normal network operating conditions include the following:

a) all reactive compensation conditions when the above exclusions are not in effect; and

b) normal contingencies under which the network has been designed to operate.

**1.2.4** It is not possible for a licensee to measure the QOS at all supply points. Should it be proven that the requirements of this part of NRS 048 have not been met, it is intended that a licensee put in place appropriate measures to comply with the requirements. Appropriate measures may include a specific plan that can take several weeks or months to implement. In cases where, on rare occasions only, the requirements are not met, the decision whether to take appropriate measures to rectify the cause could be influenced by the associated costs. Should a customer not be satisfied with the measures proposed or undertaken by the licensee, a non-conformance report may be instituted against the licensee in terms of the *NERSA Directive on power quality*.

Where compatibility levels or limits are exceeded at a customer's point of supply due to that customer's obligations with regard to QOS emission levels not being met, the licensee is not obliged to ensure that the associated compatibility levels are met as far as that customer is concerned unless the reason for such obligations not being met are due to network conditions other than those contracted for. Notwithstanding the QOS emission obligations not being met by a particular customer, the licensee remains responsible for meeting the compatibility levels and limits to any other customers connected to the network.

The licensee may be deemed to have supplied the required QOS, even if the standards are not achieved at the PCC, if countermeasures are installed by the licensee within the customer's network, and these have resulted in an acceptable QOS being provided to the customer load.

### 1.3 Application by customers

It is intended that customers' equipment will operate normally when the QOS parameters are within the specified compatibility levels and limits at the customers' points of supply.

The compatibility levels and limits specified in this part of NRS 048 should therefore be taken into consideration in equipment design specifications, also taking into consideration additional levels of disturbance that might be generated within a customer's plant.

Customers should also take appropriate precautions or protective measures to prevent, or at least limit, damage to equipment in the event when compatibility levels and limits are exceeded.

## 2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this part of NRS 048. All documents are subject to revision and, since any reference to a document is deemed to be a reference to the latest edition of that document, parties to agreements based on this specification are encouraged to take steps to ensure the use of the most recent editions of the documents listed below. Information on currently valid national and international standards can be obtained from Standards South Africa.

IEC 61000-4-15, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques –Section 15: Flickermeter – Functional and design specifications.*

National Energy Regulator of South Africa (NERSA). *NERSA Directive on power quality.* March 2002.[1)]

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

SANS 1816, *Electricity supply — quality of supply: Power quality instruments.*

SANS 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 part of NRS 048, the following terms, definitions and abbreviations apply.

1) Available from the National Energy Regulator of South Africa. PO Box 40343, Arcadia 0007, South Africa. Telephone: (012) 401-4600. Also available from World Wide Web: <www.nersa.gov.za>.

## 3.1 Definitions

**assessed level**
level used to evaluate the measured values at a particular site against the compatibility levels

NOTE The assessment criteria require both the measurement instrument to be defined, and a statistical criterion to be applied to the measured data points.

**compatibility level**
**electromagnetic compatibility level**
specified disturbance level at which an acceptable, high probability of electromagnetic compatibility should exist

[IEV 161-03-10/A]

Quality of supply (QOS) is described by a particular set of electromagnetic compatibility levels. These compatibility levels are used to set minimum standards. It follows that the compatibility level should be so chosen that the equipment connected to the supply network has a high probability of operating correctly, and that the supply network has a high probability of operating within the required limits.

**customer**
person or legal entity that has entered into an electricity supply agreement with a licensee

**declared voltage**
voltage declared by the licensee as the voltage at the point of supply

NOTE The declared voltage is typically specified in the supply agreement with the customer.

**depth (of a voltage dip)**
difference between the declared voltage and the residual voltage during a voltage dip event

[IEC 61000-2-8, modified]

NOTE 1 The depth may be expressed as a value, in volts, or as a percentage, or a per unit value relative to the declared voltage.

NOTE 2 Frequently the word “depth” is used in a descriptive, non-quantitative sense, to refer to the voltage dimension of a voltage dip, without the intention of specifying whether that dimension is expressed as the *residual voltage* or *depth*, as defined above. Care is needed to ensure that this meaning is clear in the context in which it is used.

**extra high voltage network**
**EHV network**
set of nominal network voltage levels that are used in power systems for bulk transmission of electricity in the range 220 kV $< U_n \leq$ 400 kV

[SANS 1019]

**flagged data**
in the case of any measurement time interval in which interruptions, dips or swells occur, the measurement results of all other parameters made during this time interval are flagged

[SANS 61000-4-30]

NOTE 1 The “flagging” concept avoids counting a single event more than once in different parameters, for example counting a single dip as both a dip and a flicker variation. Flagging is only triggered by dips, swells and interruptions. The detection of dips and swells is dependent on the threshold selected by the user, and this selection will influence which data are “flagged”.

NOTE 2 The flagging of data is applicable during measurement of power frequency, voltage magnitude, flicker, voltage UB, voltage harmonics and interharmonics, mains signalling and measurement of underdeviation and overdeviation parameters.

**high-voltage network**
**HV network**
set of nominal network voltage levels that are used in power systems for bulk transmission of electricity in the range 33 kV < $U_n$ ≤ 220 kV

[SANS 1019, modified]

**interruption**
phenomenon that occurs when one or more phases of a supply to a customer or group of customers are disconnected for a period exceeding 3 s

[NRS 047-1]

NOTE For the purposes of measurement an interruption is defined as a “reduction of the voltage at a point in the electrical system below the interruption threshold”. [SANS 61000-4-30].

**planned interruption**
interruption that occurs when a component is deliberately taken out of service (by the licensee or its agent) at a selected time, usually for the purposes of construction, preventative maintenance or repair

[NRS 047-1]

**unplanned interruption**
interruption that occurs when a component is taken out of service immediately, either automatically or as soon as switching operations can be performed, as a direct result of emergency conditions, or an interruption that is caused by improper operation of equipment or human error

[NRS 047-1]

**unplanned interruption on EHV and HV networks**

a) **momentary interruption**
unplanned interruption in the range > 3 s to ≤ 1 min

b) **sustained interruption**
unplanned interruption with a duration exceeding 1 min

NOTE 1 In general a one minute limit differentiates all automatic reclose events from events involving operator intervention. A one minute classification is commonly used internationally by transmission utilities.

NOTE 2 In some cases, transmission utilities may use a ≤ 10 s subclassification to cover three-phase auto-recloser events not related to generation supply points (the latter may have dead times of 20 s to 30 s and restoration times of up to 45 s).

**unplanned interruption on MV and LV networks**

a) **momentary interruption**
unplanned interruption in the range > 3 s to ≤ 5 min

b) **momentary interruption event**
where an interrupting device has a sequence of operations, and then holds, the momentary interruptions are considered one momentary interruption event

NOTE 1 Examples of such devices are reclosers or breakers that operate two, three or four times and then hold.

NOTE 2 The sequence of events is completed in a specified time not exceeding 5 min.

c) **sustained interruption**
unplanned interruption with a duration exceeding 5 min

**island network**
network that is normally operated without connection to the main grid

**licensee**
body, licensed by the National Energy Regulator of South Africa (NERSA), that generates, transmits or distributes electricity

NOTE Such a body can be a direct licensee, or an agent (subdistributor) of the licensee.

**low-voltage network**
**LV network**
set of nominal network voltage levels that are used for the distribution of electricity, the upper limit of which is generally accepted to be an a.c. voltage of 1 000 V or a d.c. voltage of 1 500 V

[SANS 1019, modified]

**medium-voltage network**
**MV network**
set of nominal network voltage levels that lie above low voltage and below high voltage in the range 1 kV $< U_n \leq$ 33 kV

[SANS 1019, modified]

**planning level**
level to which a licensee designs its network when it evaluates the impact on the supply system of all loads connected to the system

NOTE This level can differ from network to network, depending on the network structure and circumstances, and is typically lower than the compatibility level. Recommended planning levels are provided in NRS 048-4.

**point of common coupling**
**PCC**
point in a network where more than one customer is connected or is likely to be connected

**point of supply**
point at which the electrical installation *of a customer* (on any premises) is connected to the transmission or distribution system of the *licensee* (undertaker*)*

**power system frequency**
fundamental frequency
frequency of alternating voltage generated by power system generators

[SANS 61000-4-30]

**quality of supply**
**QOS**
technical parameters to describe the electricity supplied to customers, and that are used to determine the extent to which the needs of customers are met in the utilization of electricity

NOTE Sometimes “quality of supply” is used synonymously with “power quality”, which is defined as the ”characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters.”

[SANS 61000-4-30]

**rapid voltage change**
change in the magnitude of the supply voltage that occurs within the order of milliseconds.

NOTE The waveforms of typical rapid voltage changes are illustrated in figures A.2 and A.3 (see annex A).

**residual voltage of voltage dip**
minimum value of r.m.s. voltage recorded during a voltage dip

[SANS 61000-4-30, modified]

NOTE The residual voltage can be expressed as a value, in volts, or as a percentage, or a per unit value of the reference voltage.

**site**
physical point in the electricity supply network that has been categorized for the purpose of monitoring QOS

**standard voltage**
phase voltage of 230 V measured between a phase conductor and the neutral conductor, or a line voltage of $\sqrt{3} \times$ 230 V measured between phase conductors

**ten (10) minute r.m.s. value**
average (root mean square) value of all the samples taken during a 10 min period

**under-voltage event**
reduction in the supply voltage to a value less than the dip threshold voltage for a period of time exceeding 3 s, and which is not an interruption

**voltage dip**
sudden reduction in the r.m.s. voltage, for a period of between 20 ms and 3 s, of any or all of the phase voltages of a single-phase or a polyphase supply

NOTE 1 The duration of a voltage dip is the time measured from the moment the r.m.s. voltage drops below 0,9 per unit of declared voltage up to when the voltage rises above 0,9 per unit of declared voltage.

NOTE 2 The definition of a “voltage dip” in SANS 61000-4-30 is more generic, as the duration of a voltage dip is not internationally agreed upon. This definition is applicable in the case of the assessment and classification of dips as specified in this part of NRS 048.

**voltage flicker**
modulation of the amplitude of the supply voltage, perceived by the observer as a fluctuation of light intensity in electric lighting

NOTE The above definition is commonly used to refer to the QOS parameter that gives rise to flicker. SANS 61000-4-30 more fundamentally defines “flicker” as the “impression of unsteadiness of visual sensation by a light stimulus whose luminance or spectral distribution fluctuates with time.”

**voltage harmonics**
sinusoidal components of the fundamental waveform (i.e. 50 Hz) that have a frequency that is an integral multiple of the fundamental frequency

NOTE

– *Odd harmonics* are defined as the 3rd (150 Hz), 5th (250 Hz), etc.
– *Even harmonics* are defined as the 2nd (100 Hz), 4th (200 Hz), etc.
– *Interharmonics* are frequency components that are not an integral multiple of the fundamental frequency
– *Total harmonic distortion* (*THD*) is given by the following equation:

$$\mathrm{THD} = \sqrt{\sum_{\mathrm{h}=1}^{N} V_{\mathrm{h}}^{2}}$$

where

$N$ is the highest harmonic considered in the calculation;

$V_{\mathrm{h}}$ is the r.m.s value of the $h^{\mathrm{th}}$ harmonic or interharmonic voltage component, as a percentage.

**voltage regulation**
ability of the steady-state r.m.s. voltage to remain between the upper and lower limits

**voltage unbalance**
condition in a polyphase system in which the r.m.s. values of the line (phase) voltages (fundamental component) or the phase angles between consecutive line voltages are not all equal

[SANS 61000-4-30]

NOTE The unbalanced voltages can be represented by the sum of three sets of symmetrical vectors, i.e.

a) the positive sequence set that consists of three vectors all equal in magnitude and symmetrically spaced, at 120° intervals, in time-phase, their phase order being equal to the phase order of the system-generated voltages,

b) the negative sequence set that consists of three vectors all equal in magnitude and symmetrically spaced, at 120° intervals, in time-phase, their phase order being the reverse of the positive sequence phase order, and

c) the zero sequence set that consists of three vectors, all equal in magnitude and phase.

Voltage unbalance *UB* is usually expressed as a percentage and can be calculated by the following equation:

$$UB = \frac{V_{\mathrm{n}}}{V_{\mathrm{p}}} \times 100$$

where

$V_{\mathrm{n}}$ is the negative sequence voltage, in volts;

$V_{\mathrm{p}}$ is the positive sequence voltage, in volts.

Alternatively, simultaneous measurement of the three r.m.s. line-to-line voltages can be used to calculate unbalance by the following equation:

$$UB = \sqrt{\frac{1-\sqrt{3-6\beta}}{1+\sqrt{3-6\beta}}} \times 100$$

where

$$\beta = \frac{V_{12}^4 + V_{23}^4 + V_{31}^4}{\left(V_{12}^2 + V_{23}^2 + V_{31}^2\right)^2}$$

and where, for example,

$V_{12}$ represents the fundamental frequency, line-to-line voltage between phases 1 and 2.

## 3.2 Abbreviations

**IEC:** International Electrotechnical Commission
**NERSA:** National Energy Regulator of South Africa
**PCC:** point of common coupling
**pu:** per unit
**QOS:** quality of supply
**r.m.s:** root mean square
**SWER:** single-wire earth return
**THD:** total harmonic distortion
**UB:** unbalance

# 4 Requirements

## 4.1 Instrumentation

Instruments that are intended for measuring voltage parameters specified in this part of NRS 048 shall, in the case of class A measurements, comply with the requirements of SANS 61000-4-30, or, in the case of class B measurements, with SANS 1816.

NOTE 1 Requirements for class A measurements are appropriate for the purpose of comparing measured performance with standards in the case of a dispute on the accuracy of measurements. The less stringent requirements for class B measurements are appropriate in the case of surveys and monitoring for general compliance with standards.

NOTE 2 SANS 61000-4-30 specifies conditions under which data will be flagged (see 4.2.1.6). The flagging of data is applicable in the case of class A measurement performance during measurement of power frequency, voltage magnitude, flicker, voltage unbalance, voltage harmonics and interharmonics, mains signalling and measurement of underdeviation and overdeviation parameters. If any of the data from a level of aggregation is flagged, then the next level of aggregation includes the flagged data and is itself flagged. Flagged values, when applied in the assessment methods specified in this part of NRS 048, are to be ignored in the assessment. However, frequency measurements need to be specifically analysed to determine whether the measurement is suitable for comparison with the compatibility levels.

NOTE 3 Where instruments have in the past been purchased in accordance with SANS 1816, or where otherwise agreed upon with NERSA, these instruments may be applied in the case of class B applications in the foreseeable future.

## 4.2 Quality of supply parameters and assessment methods

### 4.2.1 Assessment requirements

#### 4.2.1.1 General

In order to evaluate the measured values at a particular site against the voltage characteristics, compatibility levels or limits, the measurement method and statistical criterion to be applied to the measured data points shall be defined. The general assessment requirements in 4.2.1.2 to 4.2.1.6 shall apply for individual QOS parameters specified in 4.2.2. In the case of other QOS parameters, the particular assessment requirements specified for that parameter shall apply.

#### 4.2.1.2 Reference voltages for measurements

Where applicable, parameters shall be defined as deviations from fixed reference voltages. In the case of LV networks, the reference voltage shall be standard voltage.

In the case of MV, HV, and EHV networks, the reference voltage shall be nominal voltage, or declared voltage (a fixed voltage as agreed to between the customer and the licensee, which may be greater or smaller than nominal voltage). It is recommended that the declared voltage be within 5 % of the nominal voltage.

All phases of the supply voltage shall be monitored. In the case of systems with solidly earthed transformer neutral points, the phase-to-earth voltages shall be measured. In the case of delta-connected systems, systems with impedance earthing, or unearthed systems, the phase-to-phase voltages shall be monitored.

#### 4.2.1.3 Assessment period

The assessment period shall be at least one week (seven consecutive days, starting at 00:00 on the first day and finishing at 00:00 after the last day has ended), except in the case of interharmonics, mains signalling and frequency.

For long-term measurements, an assessed weekly value shall be retained on a daily sliding basis. For example, a two-week measurement will result in eight weekly values.

#### 4.2.1.4 Retained values, single-phase systems

Determine the highest (and lowest in the case of voltage magnitude) 10 min r.m.s. value(s) which is (are) not exceeded for more than 95 % of the week, and retain the value(s) for comparison with the compatibility level(s).

Determine the highest (and lowest in the case of voltage magnitude) 10 min r.m.s. value(s) of the week and retain the value(s) for comparison with the limit(s).

#### 4.2.1.5 Retained values, multi-phase systems

For each set of weekly measurements and for each phase, determine the highest (and lowest in the case of voltage magnitude) 10 min r.m.s. value which is not exceeded for more than 95 % of the week's measurements. The most extreme value(s) is retained for comparison with the compatibility level(s).

For each set of weekly measurements and for each phase, determine the highest (and lowest in the case of voltage magnitude) 10 min r.m.s. value(s) of the week's measurements. The most extreme value(s) is retained for comparison with the limit(s).

#### 4.2.1.6 Exclusion of flagged and missing data

For long-term statistical measurements, the assessed values shall be based on the data that remain after flagged and missing data have been excluded, provided that not more than 10 % of the 10 min values have been excluded.

For specific investigation of a customer complaint, the assessed values shall be based on the data that remain after flagged and missing data have been excluded, provided that not more than 2 % of the 10 min values have been excluded.

### 4.2.2 Magnitude of supply voltage (voltage regulation)

#### 4.2.2.1 Standard and declared voltages

For customers supplied at LV, the standard voltage shall be $\sqrt{3} \times 230$ V phase to phase, and 230 V phase to neutral.

For customers supplied at other voltage levels, the magnitude of the declared voltage shall be as specified in the supply agreement.

Unless otherwise specified in the supply agreement, the declared voltage shall be the nominal voltage.

#### 4.2.2.2 Compatibility levels

Unless otherwise agreed upon in a supply contract, the compatibility levels for the magnitude of supply voltage shall be as specified in table 1.

**Table 1 — Deviations from standard or declared voltages**

| 1 | 2 |
|---|---|
| **Voltage level**<br><br>V | **Compatibility level**<br><br>% |
| < 500 | ± 10 |
| ≥ 500 | ± 5 |

#### 4.2.2.3 Limits

The voltage shall not exceed the voltage limits specified in table 2.

**Table 2 — Voltage limits for systems at nominal voltages of > 500 V**

| 1 | 2 |
|---|---|
| **Nominal voltage**<br><br>kV | **Maximum voltage**<br><br>kV |
| 400 | 420 |
| 275 | 300 |
| 220 | 245 |
| 132 | 145 |
| 88 | 100 |
| 66 | 72,5 |
| 44 and below | Nominal voltage + 10 % |

NOTE Limits are specifically introduced to ensure that extreme exceeding of equipment design standards is avoided.

#### 4.2.2.4 Assessment method

#### 4.2.2.4.1 Reference voltage for measurements

The requirements of 4.2.1.2 shall apply.

#### 4.2.2.4.2 Assessment period

The requirements of 4.2.1.3 shall apply.

#### 4.2.2.4.3 Retained values, single-phase systems

The requirements of 4.2.1.4 shall apply. In addition, the number of times that more than two consecutive 10 min values have been outside the higher or lower compatibility level shall be retained.

Data flagged in accordance with SANS 61000-4-30 (due to voltage dip or swell thresholds being exceeded) shall be retained.

#### 4.2.2.4.4 Retained values, multi-phase systems

The requirements of 4.2.1.5 shall apply. In addition, the number of times that more than two consecutive 10 min values have been outside the higher or lower compatibility level shall be retained.

Data flagged in accordance with SANS 61000-4-30 (due to voltage dip or swell thresholds being exceeded) shall be retained.

#### 4.2.2.4.5 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

### 4.2.2.5 Compliance criteria

**4.2.2.5.1** The criteria for compliance with compatibility levels or contracted values shall be as follows:

a) the highest and lowest of the assessed 95 % weekly values over the full measurement period shall not be outside the compatibility levels given in table 1 or the otherwise contracted voltage deviation (see NOTE 1); and

b) not more than two consecutive 10 min values shall exceed the higher applicable compatibility level given in table 1, and not more than two consecutive 10 min values shall be less than the lower applicable compatibility level given in table 1 or the otherwise contracted voltage deviation (see NOTE 2).

NOTE 1 The weekly assessment criterion addresses statistical fluctuations in voltage magnitude.

NOTE 2 Consecutive requirements are introduced to ensure that exceeding of equipment design standards for long periods in the week (for example during peak network loading) are avoided.

**4.2.2.5.2** The criteria for compliance with the limits shall be as follows:

The highest 10 min value over the assessment period shall not exceed the limits given in table 2.

### 4.2.2.6 Under-voltage events

Where the voltage supplied reduces to a value of less than 0,85 pu of the standard or declared voltage for more than 3 s on one or more phases, the event shall be logged as an under-voltage event.

NOTE 1 Such an under-voltage event might occur when there is an interruption of one or more, but not all, phases at the point of supply, resulting in undervoltage on the phases that remain connected. In such a case the interruption and the under-voltage events would be separately logged.

NOTE 2 In the case where, for example, there is an interruption as defined in 4.3, and an induced voltage or residual voltage remains on the line, a measuring instrument is likely to measure an under-voltage event.

### 4.2.3 Frequency

#### 4.2.3.1 General

The allowed frequency deviations for networks that form part of the national grid and for island networks differ. An island network is considered a network that is not normally connected to the national grid.

#### 4.2.3.2 Standard frequency

The standard frequency shall be 50 Hz.

#### 4.2.3.3 Compatibility levels

The compatibility levels for the frequency of the supply voltage shall be as specified in table 3.

**Table 3 — Deviations from standard frequency**

| 1 | 2 |
|---|---|
| **Network type** | **Compatibility level** |
| Grid | ± 2 % (± 1 Hz) |
| Island | ± 2,5 % (± 1,25 Hz) |

NOTE Under major transmission network or generation disturbance conditions, some parts of the network might be islanded in order to prevent a national blackout. These conditions can be considered as ”abnormal conditions”, and the values in the table do not apply (see 1.2)

#### 4.2.3.4 Limits

The limits for the frequency of the supply voltage shall be as specified in table 4.

**Table 4 — Maximum deviations from standard frequency**

| 1 | 2 |
|---|---|
| **Network type** | **Limit** |
| Grid | ± 2,5 % (± 1,25 Hz) |
| Island | ± 5 % (± 2,5 Hz) |

NOTE See the NOTE to 4.2.3.3.

#### 4.2.3.5 Assessment method

##### 4.2.3.5.1 Assessment period

The assessment period is a year (i.e. any 12 month period).

The class A measurement methods of SANS 61000-4-30 shall apply.

NOTE The power quality measurement method in SANS 61000-4-30 is based on 10 s measurements. Under-frequency load shedding occurs within several cycles. The SANS 61000-4-30 measurement method is not suitable for assessing under-frequency load shedding relay performance.

#### 4.2.3.5.2 Retained values

The measurement of frequency shall be carried out as specified in 4.1.

For grid networks, the frequency deviation for 99,5 % of one year shall be retained.

For island networks, the frequency deviation for 95 % of one year shall be retained.

#### 4.2.3.5.3 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

#### 4.2.3.6 Compliance criteria

The assessed levels to be compared with the compatibility levels and limits given in tables 3 and 4 respectively, shall be the individual measured values of frequency.

### 4.2.4 Voltage unbalance

#### 4.2.4.1 General

Voltage unbalance can be described in terms of the contribution of zero sequence and negative sequence voltages. In this part of NRS 048 only the contribution of the negative sequence voltages are given because the contribution of negative sequence voltages is the relevant component when the impact on equipment connected to the system is being considered (see the definition of "voltage unbalance").

#### 4.2.4.2 Compatibility level

The compatibility level for voltage unbalance on LV, MV and HV three-phase networks shall be 2 %.

The compatibility level for voltage unbalance on EHV three-phase networks shall be 1,5 %.

On LV networks where there is a predominance of single-phase or two-phase customers, a compatibility level of 3 % may be applied (see NOTE 1).

On MV and HV networks where there is a predominance of single-phase or two-phase customers, a compatibility level of 3 % may be applied, as long as the 2 % limit is not exceeded for more than 80 % of the time over the assessment period (see NOTES 1 and 2).

NOTE 1 It is anticipated that utilities would inform affected three-phase customers when being connected, that higher levels of unbalance might be experienced.

NOTE 2 The relaxation of the compatibility level to 3 % might apply in the case of unusual network or load configurations that mitigate against limiting the levels of unbalance to 2 %. Examples of such networks include HV networks historically designed to serve only single-phase loads (for example traction supplies), and rural MV networks with single-phase (SWER), or two-phase spurs or customers.

For this purpose, a HV or MV network with a predominance of single-phase or two-phase customers shall be interpreted as a network where

a) the size (maximum demand in MVA) of customers connected between phases or between phase and ground represent more than 60 % of the maximum load (maximum demand in MVA) on the feeder under consideration, and

b) the single-phase load represents more than 60 % of the energy (kWh) supplied for the 12 month period.

#### 4.2.4.3 Limits

Limits for voltage unbalance have not been specified.

NOTE 1 A limit for voltage unbalance on three-phase networks of 3 % at all times is under consideration.

NOTE 2 In the case of a single-phase MV fuse failure, the levels of voltage unbalance on three-phase LV networks may be significantly outside the limits until the problem has been rectified. Customers should protect plant against such extreme events. Such events are considered as interruptions (see 4.3.1.2) and the measured values will be flagged as potentially erroneous voltage unbalance measurements.

#### 4.2.4.4 Assessment method

##### 4.2.4.4.1 Reference voltage for measurements

The requirements of 4.2.1.2 shall apply.

##### 4.2.4.4.2 Assessment period

The requirements of 4.2.1.3 shall apply.

##### 4.2.4.4.3 Retained values

The requirements of 4.2.1.5 shall apply.

##### 4.2.4.4.4 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

#### 4.2.4.5 Compliance criteria

The highest of the assessed 95 % weekly values over the full measurement period shall be compared with the compatibility levels referred to in 4.2.4.2.

The highest of the assessed weekly maximum values over the full measurement period shall be compared with the proposed limits in 4.2.4.3.

### 4.2.5 Voltage harmonics and interharmonics

#### 4.2.5.1 General

The compatibility levels for voltage harmonics and interharmonics relate to quasi-stationary or steady state harmonic values and are specified for both long-term effects and short-term effects.

The long-term effects relate mainly to thermal effects on cables, transformers, motors, capacitors, etc.

Short-term effects relate mainly to disturbing effects on electronic devices that can be susceptible to harmonic distortion. The effects of transients are excluded (see 4.2.11).

#### 4.2.5.2 Long-term (thermal) effects

##### 4.2.5.2.1 Compatibility levels – LV and MV networks

The compatibility levels for individual harmonics on LV and MV networks are given in table 5.

The THD of the supply voltage, including all harmonics up to the order of 40, shall not exceed 8 %.

**Table 5 — Compatibility levels for harmonic voltages for LV and MV networks (Expressed as a percentage of the reference voltage)**

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **Odd harmonics** | | | | **Even harmonics** | |
| **Not multiples of 3** | | **Multiples of 3**[a] | | | |
| **Harmonic order** *h* | **Magnitude** % | **Harmonic order** *h* | **Magnitude** % | **Harmonic order** *h* | **Magnitude** % |
| 5 | 6 | 3 | 5 | 2 | 2 |
| 7 | 5 | 9 | 1,5 | 4 | 1 |
| 11 | 3,5 | 15 | 0,5 | 6 | 0,5 |
| 13 | 3 | 21 | 0,3 | 8 | 0,5 |
| $17 \leq h \leq 49$ | $\{2{,}27 \times (17/h)\} - 0{,}27$ | $21 \leq h \leq 45$ | 0,2 | $10 \leq h \leq 50$ | $\{0{,}25 \times (10/h)\} + 0{,}25$ |

[a] The levels given for odd harmonics that are multiples of 3 apply to zero sequence harmonics. Also on a three-phase network without a neutral conductor or without load connected between phase and earth, the actual values of the third and ninth harmonics might be much lower than the compatibility levels, depending on the voltage unbalance of the system.

#### 4.2.5.2.2 Compatibility levels – HV and EHV networks

The compatibility levels for individual harmonics on HV and EHV networks are given in table 6.

The THD of the supply voltage, including all harmonics up to the order 40, shall not exceed 4 %.

NOTE It is intended that customers supplied at HV and EHV will have specifically agreed upon harmonic limits written into contracts; these will generally be equal to or lower than those in table 6, and equal to, or higher than, the licensee's planning levels for HV networks. Recommended planning levels for HV networks are given in NRS 048-4.

**Table 6 — Compatibility levels for harmonic voltages for HV and EHV networks (Expressed as a percentage of the reference voltage)**

| 1 | 2 |
|---|---|
| **Harmonic order** *h* | **HV and EHV harmonic voltage** % |
| 3 | 2,5 |
| 5 | 3,0 |
| 7 | 2,5 |
| 11 | 1,7 |
| 13 | 1,7 |
| 17 | 1,2 |
| 19 | 1,2 |
| 23 | 0,8 |
| 25 | 0,8 |

NOTE The compatibility levels are those recommended by Cigré TB261, which contains recommendations derived from international data collected. Data for even harmonics and higher-order harmonics was not available, and has therefore not been included. Reference values for these harmonic orders may be based on the planning levels given in NRS 048-4.

**4.2.5.2.3 Limits**

Limits for voltage harmonics have not been specified.

**4.2.5.2.4 Assessment method – Long-term effects**

**4.2.5.2.4.1 Reference voltage for measurements**

The reference voltage shall be the measured fundamental (50 Hz) voltage.

**4.2.5.2.4.2 Assessment period**

The requirements of 4.2.1.3 shall apply for individual harmonics and THD.

**4.2.5.2.4.3 Retained values, single-phase systems**

The requirements of 4.2.1.4 shall apply for individual harmonics and THD.

**4.2.5.2.4.4 Retained values, multi-phase systems**

The requirements of 4.2.1.5 shall apply for individual harmonics and THD.

**4.2.5.2.4.5 Exclusion of flagged and missing data**

The requirements of 4.2.1.6 shall apply for individual harmonics and THD.

**4.2.5.2.5 Compliance criteria**

The highest of the assessed 95 % weekly values over the full measurement period shall be compared with the compatibility levels in 4.2.5.2.1.

**4.2.5.3 Short-term effects**

**4.2.5.3.1 Compatibility levels – LV and MV networks**

The compatibility levels for individual harmonic components of the voltage are based on the levels given in table 5 multiplied by a factor $k$ given by (1).

$$k = 1{,}3 + \{(0{,}7/45) \times (h - 5)\} \qquad (1)$$

where

$h$ is the harmonic order.

The corresponding compatibility level for THD is 11 %.

**4.2.5.3.2 Assessment method — Short-term effects**

**4.2.5.3.2.1 Reference voltage for measurements**

The reference voltage shall be the measured fundamental (50 Hz) voltage.

**4.2.5.3.2.2 Assessment period**

The assessment period shall be at least one day.

#### 4.2.5.3.2.3 Retained values

For each harmonic and for the THD measured on all phases of the supply voltage over 99 % of one day, the 150 cycle (nominally 3 s) mean of harmonic voltages shall be retained.

#### 4.2.5.3.2.4 Exclusion of flagged and missing data

Each harmonic and the THD shall comply with the requirements of 4.2.1.6

#### 4.2.5.3.3 Compliance criteria

The highest (of all phases) of the assessed 99 % daily values over the full measurement period shall be compared with the compatibility levels in 4.2.5.3.1.

#### 4.2.5.4 Interharmonic voltages

See annex B for information about interharmonic voltages.

### 4.2.6 Mains signalling

#### 4.2.6.1 Compatibility levels

The compatibility levels for signalling voltages used on power systems shall be those given in 4.2.5.3.1 (for short-term effects of harmonics).

#### 4.2.6.2 Limits

Signalling voltages above the compatibility levels may be exceeded for short-term bursts of signalling but shall not exceed the levels given in figure 2.

NOTE Power line carrier signalling with frequencies in the range from 95 kHz to 148,5 kHz may be used in customers' installations. Though the use of the public system for the transmission of signals between customers is not allowed, voltages of these frequencies up to 1,4 V r.m.s. in the public LV distribution system should be taken into account. Because of the possibility of mutual influences of neighbouring signalling installations, the customer might need to apply protection or appropriate immunity for his signalling installation against this influence.

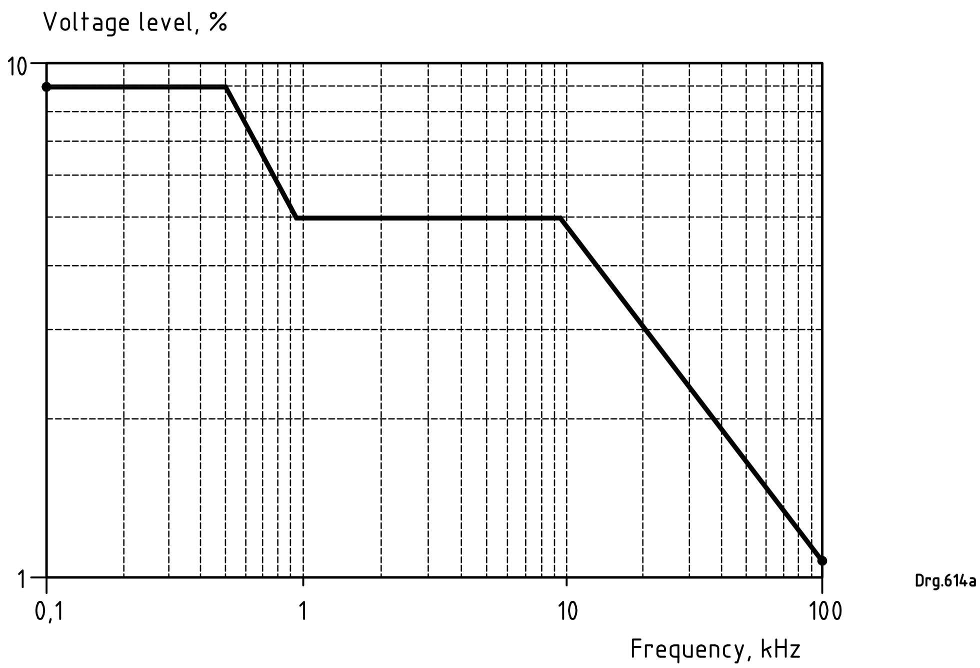


**Figure 2 — Voltage levels of signal frequencies, in % of $U_n$, used in public LV distribution systems**

#### 4.2.6.3 Assessment method

##### 4.2.6.3.1 Reference voltage for measurements

The requirements of 4.2.1.2 shall apply.

##### 4.2.6.3.2 Assessment period

The assessment period shall be at least 24 h. Over 99 % of a 24 h period, the 150 cycle (nominally 3 s) mean of signalling voltages shall be retained.

##### 4.2.6.3.3 Retained values, single-phase systems

Determine the highest 3 s r.m.s. value which is not exceeded for more than 95 % of the 24 h period, and retain the value for comparison with the compatibility levels.

Determine the highest 3 s r.m.s. value(s) of the 24 h period and retain the value(s) for comparison with the limit(s).

##### 4.2.6.3.4 Retained values, multi-phase systems

For each phase, determine the highest 3 s r.m.s. value which is not exceeded for more than 95 % of the 24 h period. The most extreme value(s) is retained for comparison with the compatibility level(s).

For each phase, determine the highest 3 s r.m.s. value(s) of the 24 h period. The most extreme value(s) is retained for comparison with the limit(s).

##### 4.2.6.3.5 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

#### 4.2.6.4 Compliance criteria

The highest of the assessed 99 % daily values over the full measurement period shall be compared with the compatibility levels in 4.2.6.1.

The highest of the assessed daily maximum values over the full measurement period shall be compared with the limits in 4.2.6.2.

### 4.2.7 Voltage flicker

#### 4.2.7.1 Compatibility level

For LV and MV networks, the compatibility level for long-term flicker severity ($P_{lt}$) shall be 1,0.

No flicker compatibility levels are defined for HV and EHV networks.

NOTE Flicker compatibility levels are based on the visual perception of the effects of voltage fluctuations on lighting equipment, as measured in accordance with IEC 61000-4-15. These voltage fluctuation levels are significantly lower than levels that would affect other equipment.

#### 4.2.7.2 Assessment method

##### 4.2.7.2.1 Reference voltage for measurements

The requirements in 4.2.1.2 shall apply.

#### 4.2.7.2.2 Assessment period

The requirements of 4.2.1.3 shall apply.

#### 4.2.7.2.3 Retained values

Short-term flicker severity ($P_{st}$) shall be measured over a 10 min period, as specified in IEC 61000-4-15, and long-term flicker severity ($P_{lt}$) shall be calculated over a 2 h period, as shown in (2):

$$P_{lt} = 3\sqrt{\frac{\sum_{k=1}^{12} P_{st,k}^3}{12}} \qquad (2)$$

where

$P_{st,k}$ is the general term for a consecutive 10 min short-term flicker severity value.

The highest 95 % values of the $P_{lt}$ phase values for each weekly period shall be retained.

NOTE Where investigation of complaints that are restricted to specific times of the day (typically evening) are undertaken, it might be necessary to restrict the values used in the assessment to values measured during those specific times.

#### 4.2.7.2.4 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

#### 4.2.7.3 Compliance criteria

The highest of the assessed 95 % weekly $P_{lt}$ values over the full measurement period shall be compared with the compatibility level in 4.2.7.1.

### 4.2.8 Rapid voltage changes

For information about rapid voltage changes, see annex A.

NOTE Indicative emission limits for rapid voltage changes for individual customers at the point of common coupling (PCC) are given in NRS 048-4.

### 4.2.9 Voltage dips

#### 4.2.9.1 General

**4.2.9.1.1** The environment has a significant impact on the frequency of faults that give rise to voltage dips, particularly in the case of overhead lines. The network topology in the vicinity of any customer's plant has a significant effect on the number of voltage dips, as well as on the magnitude and duration of these dips. It is therefore impossible to set national compatibility levels that are acceptable to both licensees and customers. It is anticipated that voltage dip performance will be contracted for, or managed, in terms of the *NERSA Directive on power quality*.

The role of this part of NRS 048 is to provide a uniform approach to the characterization of voltage dip performance (see table 7), and to provide a characteristic historical dip performance in accordance with this approach. While this characterization method addresses the most common effects of dips on customers' plant, it does not address complex dip parameters such as phase jump at the onset of a dip, phase shift during a dip, pre-dip and post-dip voltages, and distortion superimposed on the voltage during a dip. Where the latter causes problems with customers' plant, a licensee is still required to address the problem in terms of the incident reporting procedure outlined in the *NERSA Directive on power quality*.

NOTE The definitions of the dip categories (S, T, X, Y, Z) are based on a combination of network protection characteristics and customer load compatibility. Table 8 summarizes the basis for these definitions.

**4.2.9.1.2** The dip categorization is based on the philosophy that

a) licensees should manage protection performance times (for example, the number of X-type dips allowed is more than the number of S-type dips);

b) licensees should place particular emphasis on managing the number of faults that occur close to a particular customer (for example the sum of the number of T-type dips is less than the sum of the number of X-type and S-type dips); and

c) customers should specify the dip sensitivity of their process equipment to enable appropriate mitigation measures to be considered, so as to limit the number of licensee fault events that actually affect the plant.

**Table 7 — Characterization of voltage dips according to depth and duration**

<table>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td rowspan="2">Range of dip depth<br>$\Delta U$<br>(expressed as a percentage of declared voltage $U_d$)</td><td rowspan="2">Range of residual voltage<br>$U_r$<br>(expressed as a percentage of declared voltage $U_d$)</td><td colspan="3">Duration<br>t</td></tr>
<tr><td>20 < t ≤ 150 ms</td><td>150 < t ≤ 600 ms</td><td>0,6 < t ≤ 3 s</td></tr>
<tr><td>$10 < \Delta U \leq 15$</td><td>$90 > U_r \geq 85$</td><td rowspan="3"></td><td rowspan="2">Y</td><td></td></tr>
<tr><td>$15 < \Delta U \leq 20$</td><td>$85 > U_r \geq 80$</td><td rowspan="2">Z1</td></tr>
<tr><td>$20 < \Delta U \leq 30$</td><td>$80 > U_r \geq 70$</td><td rowspan="3">S</td></tr>
<tr><td>$30 < \Delta U \leq 40$</td><td>$70 > U_r \geq 60$</td><td>X1[a]</td><td rowspan="3">Z2</td></tr>
<tr><td>$40 < \Delta U \leq 60$</td><td>$60 > U_r \geq 40$</td><td>X2</td></tr>
<tr><td>$60 < \Delta U \leq 100$</td><td>$40 > U_r \geq 0$</td><td colspan="2">T</td></tr>
<tr><td colspan="5">NOTE In the case of measurements on LV systems, it is acceptable to set the dip threshold at 0,85 pu.</td></tr>
<tr><td colspan="5">[a] A relatively large number of events fall into the X1 category. However, it is recognized that dips with complex characteristics (such as phase jump, UB, and multiple phases) might have a significant effect on customers' plant, even though these might be small in magnitude. Customers might not have the means to mitigate the effects of such dips on their plant.</td></tr>
</table>

**4.2.9.1.3** The dip categories provide for

a) a greater emphasis on customer plant dip immunity in the case of small, short duration dips (being the most common type of dip in the case of licensee of HV and EHV networks);

b) two specific types of dip category where licensees will have to specifically limit the number of dips (in T-type close-up faults, and Z2-type long duration events); and

c) four dip categories that define the area in which combined management of dip performance and dip immunity is necessary (S, X1, X2, and Z1). The Y area is relatively larger for shorter duration dips and relatively smaller for long duration dips, and this is an important aspect for future regulatory purposes. For example, where such events are imported by a local distributor, having originated in another distributor many kilometres away, the cost of reducing these is, in the majority of cases, not warranted.

**Table 8 — Basis for the voltage dip categories defined in table 7**

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Dip category** | **Values of duration and depth** | | **Basis for definition** |
| Y | Duration | > 20 ms to 3 s | Dip definition (20 ms to 3 s) |
| | Depth | 30 %, 20 %, 15 % | Minimum plant compatibility requirement (this covers a significant number of short duration dips) |
| X1 | Duration | > 20 ms to 150 ms | Typical zone 1 clearance (no pilot wire) |
| | Depth | 30 % to 40 % | Desired plant immunity – as this spans many dips caused by remote faults on the licensee network |
| X2 | Duration | > 20 ms to 150 ms | Typical zone 1 clearance (no pilot wire) |
| | Depth | 40 % to 60 % | Dips potentially causing drives to trip, caused by remote faults on the licensee network |
| S | Duration | > 150 ms to 600 ms | Typical zone 2 and accelerated clearance<br>Also some distribution faults |
| | Depth | 20 % to 60 % | Plant compatibility (drives trip > 20 %)<br>caused by remote faults on the licensee network |
| T | Duration | > 20 ms to 600 ms | Zone 1 and zone 2 clearance times |
| | Depth | 60 % to 100 % | Plant compatibility (contactors trip > 60 %)<br>caused by close-up faults on the licensee network |
| Z1 | Duration | > 600 ms to 3 s | Back-up and thermal protection clearance or long recovery times (transient voltage stability), or both |
| | Depth | 15 % to 30 % | Remote faults<br>Post-dip motor recovery without stalling |
| Z2 | Duration | > 600 ms to 3 s | Back-up and thermal protection clearance |
| | Depth | 30 % to 100 % | Closer faults<br>Potential motor stalling |

#### 4.2.9.2 Characteristic values

The characteristic values for voltage dips are given in the form of the number of dip events in each dip category (X1, X2, Z1, etc.) which have historically not been exceeded at 95 % and 50 % of the monitored sites in South Africa (see tables 9 and 10). Statistics are provided for each network voltage. This network voltage is defined as the nominal voltage of the licensee network that supplies a particular measurement site. When the performance of a particular site is compared with these figures, it should be noted that the network voltage is not necessarily the voltage at which the customer takes supply. For example, in the case where a single customer is supplied at 22 kV from a 132 kV/22 kV transformer, the applicable network voltage shall be 132 kV. The set of S, T, X, Y and Z values applicable to a customer shall be evaluated in each case, taking account of the network configuration supplying that customer.

NOTE 1 For a network voltage range of 6,6 kV to 44 kV, the values are based on limited monitoring sites, within very divergent networks, earthing arrangements, monitoring practices and environmental characteristics. Hence they should only be regarded as indicative values. In future, additional data could be expected to be available, that could provide some measure of statistical validity. Based on the data used, a differentiation has been made between networks with large exposure (i.e. extended overhead feeders) and those with less exposure (i.e. shorter overhead or underground feeders).

NOTE 2 The numbers of voltage dips in tables 9 and 10 are derived from data collected up to mid 2002. Consideration is being given to making updated national dip data available on a regular basis (for example on a website). Such data would supersede the data in tables 9 and 10.

**Table 9 — Characteristic values for the number of voltage dips per year for each category of dip window (95 % of sites)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| **Network voltage range (nominal voltages)** | **Number of voltage dips per year** | | | | | |
| | **Dip window category** | | | | | |
| | **X1** | **X2** | **T** | **S** | **Z1** | **Z2** |
| 6,6 kV to ≤ 44 kV extended overhead | 85 | 210 | 115 | 400 | 450 | 450 |
| 6,6 kV to ≤ 44 kV | 20 | 30 | 110 | 30 | 20 | 45 |
| > 44 kV to ≤ 220 kV | 35 | 35 | 25 | 40 | 40 | 10 |
| 220 kV to ≤ 765 kV | 30 | 30 | 20 | 20 | 10 | 5 |

**Table 10 — Characteristic values for the number of voltage dips per year for each category of dip window (50 % of sites)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| **Network voltage range (nominal voltages)** | **Number of voltage dips per year** | | | | | |
| | **Dip window category** | | | | | |
| | **X1** | **X2** | **T** | **S** | **Z1** | **Z2** |
| 6,6 kV to ≤ 44 kV extended overhead | 13 | 12 | 10 | 13 | 11 | 10 |
| 6,6 kV to ≤ 44 kV | 7 | 7 | 7 | 6 | 3 | 4 |
| > 44 kV to ≤ 220 kV | 13 | 10 | 5 | 7 | 4 | 2 |
| 220 kV to ≤ 765 kV | 8 | 9 | 3 | 2 | 1 | 1 |

### 4.2.9.3 Assessment method

All phases of the supply voltage shall be monitored. In the case of systems with solidly earthed transformer neutrals, the phase-to-neutral voltages shall be measured. In the case of delta-connected systems or systems with impedance earthing or that are unearthed, the phase-to-phase voltages shall be monitored. Metering class 0,1, 0,2, 0,5 and 1,0 voltage transformers can be used for the measurement.

The number of dip events for each monitored site shall be classified according to the dip categories defined in table 8.

When considering the performance of a licensee, the assessed number for the monitored sites in each network voltage range shall be the number for which 95 % of the records are below the assessed number.

NOTE 1 Dips of the same magnitude and duration can have different effects on a customer or groups of customers, depending on the particular conditions of the network and load at the time of the dip.

NOTE 2 See SANS 61000-4-30 for measurement definitions.

NOTE 3 In the case when the voltages on all three phases recover for less than 30 ms, the dip is recorded as one dip incident with the reported duration being the total duration including subsequent dips (from beginning of the first dip to recovery of the last dip). The magnitude of the dip will be the largest magnitude over the full period.

NOTE 4 Some international licensees adopt only phase-to-phase dip measurements. This has the effect of reducing the perceived severity of a single phase-to-earth fault (the majority of faults), and should be taken into consideration if international performance comparisons are undertaken.

NOTE 5 Time aggregation refers to the characterization of several dips in short succession as a single dip event. Time aggregation is not applied in the assessment method defined in this part of NRS 048 since such value will be related to how a specific customer plant is affected by multiple dips. Such techniques may however be applied through common agreement in interactions between utilities and customers. In such cases, the method of assessment should be mutually agreed upon and clearly defined. It should clearly be identified as NOT complying with the assessment requirements of this part of NRS 048, but may be referred to as a modification of the specified dip assessment requirements.

#### 4.2.9.4 Compliance criteria

No compliance criteria are defined for voltage dips. In the absence of specific contractual clauses, voltage dip performance shall be managed in terms of the *NERSA Directive on power quality*.

### 4.2.10 Voltage swells

#### 4.2.10.1 General

Voltage swells experienced on South African networks are generally caused by events such as the sudden tripping of large loads or of sections of supply network. Problems with voltage control devices such as regulators, tap changers, or capacitors, and the loss of a neutral on LV systems can result in overvoltages as well as voltage swells at the point of supply.

NOTE The sudden tripping of large loads or sections of the network can also result in smaller rapid voltage changes. These are addressed in annex A.

#### 4.2.10.2 Assessment method

A swell shall be measured in accordance with SANS 61000-4-30 and shall be defined as having a duration from 20 ms to 10 min.

The voltage threshold for the purpose of measuring a swell in accordance with SANS 61000-4-30 shall be set at +15 % of the standard voltage in the case of networks with voltages less than 500 V, and +10 % of declared voltage in the case of networks with voltages greater than or equal to 500 V.

All phases of the supply voltage shall be monitored. In the case of systems with solidly earthed transformer neutrals, the phase-to-neutral voltages shall be measured. In the case of delta-connected systems, or systems with impedance earthing, or systems that are unearthed, the phase-to-phase voltages shall be monitored.

#### 4.2.10.3 Compliance criteria

No compliance criteria are defined at this stage for voltage swells.

NOTE Compatibility levels and limits for voltage magnitude are specified in 4.2.2.2 and 4.2.2.3.

### 4.2.11 Voltage transients and surges

#### 4.2.11.1 General

Voltage transients are caused by switching events or arcing. Voltage surges are caused by lightning.

#### 4.2.11.2 Compliance criteria

No compliance criteria are defined for voltage transients and surges.

## 4.3 Interruption performance

### 4.3.1 Categorization of events

#### 4.3.1.1 General

The categorization and classification of interruptions and customer load reduction events in this part of NRS 048 are intended to be applied when the effects of such events on a specific customer's point of supply are evaluated. The definition of interruption indices (for the purposes of statistical system performance reporting) is addressed in NRS 048-6.

There are several types of event that could be perceived by customers as interruptions. Such events can be recorded in the following four main categories:

a) unplanned interruptions (see 4.3.1.2);

b) voluntary customer load reduction events(see 4.3.1.3);

c) planned interruptions (see 4.3.1.4); and

d) involuntary customer load reductions (see 4.3.1.5).

Interruptions are further classified as either momentary or sustained interruptions (see 4.3.2).

#### 4.3.1.2 Unplanned interruptions

An unplanned event that results in the disconnection of one or more phases of the network that supply the customer for a period of more than 3 s, shall be categorized as an unplanned interruption (see NOTE 1 below). Where not all phases are disconnected from the supply, such cases usually result in under-voltage events on the phase(s) that remain connected at the point of supply.

Unplanned disconnection events typically occur when the only remaining circuit (see NOTE 2 below) to a specific point of supply is disconnected in the event of

a) the failure of a component (such a component includes a jumper, a joint, a conductor, a circuit-breaker and a transformer),

b) a fuse or circuit-breaker operation,

c) a fault that does not result in reconnection of the circuit on all phases to the customer within 3 s,

d) a trip on one or more phases due to events such as an operator error or protection operation (for example overload protection), or

e) a trip on one or more phases due to emergency action by the licensee.

NOTE 1 Such a disconnection is not necessarily limited to the circuits that directly supply the customer, but could have occurred further back in the network.

NOTE 2 The term "only remaining circuit" is used to cover cases where customers are served by more than one supply circuit, and all but one of the circuits have been disconnected before the unplanned interruption event.

NOTE 3 An interruption is not defined in terms of voltage measurements, but rather in terms of the disconnection of the supply point. Voltage measuring instruments can in some cases provide erroneous indications of whether an interruption occurred or not. Instruments specified in accordance with SANS 61000-4-30 may, however, be used to assist in interruption assessment. In such cases a voltage interruption threshold of 10 % of declared voltage, and a duration threshold of 3 s are recommended. These measurements should be interpreted in accordance with 4.3.1.2.

#### 4.3.1.3 Voluntary customer load reduction events

Customer load reduction events are characterized by the curtailment, partial curtailment, or reduction of customer load. Where both the following provisions are met, these events shall be categorized as **voluntary** customer load reduction events.

a) Actions to reduce load are required by the licensee specifically to protect the security of the supply system to its general customer base.

b) The customer has agreed to such reduction before the event, and has been able to define the load to be interrupted or the load magnitude to be reduced (or both). (This agreement could be in terms of a contract, and could be executed by automatic relays designed to trip the load as agreed to by the customer in such a contract). This includes voluntary under-frequency load shedding.

Voluntary under-frequency load shedding of several customers shall be classified as a single event and as a voluntary customer load reduction event. Voluntary customer load reduction events shall neither be categorized as unplanned nor as planned interruptions, but shall be assessed separately.

#### 4.3.1.4 Planned interruptions

An interruption to a customer shall be classified as a planned interruption if the conditions for notification or negotiation of the interruption, as specified in NRS 047-1, are met.

NOTE NRS 047-1 sets out requirements that customers be given notice before interruption takes place. If this requirement is met, the interruption can be considered a planned interruption.

#### 4.3.1.5 Involuntary customer load reductions

Where a customer load reduction event is not classified as a voluntary load reduction event (see 4.3.1.3), it shall be classified as an involuntary load reduction event. Such events include liaison with a customer, by the licensee, just before requiring that the customer reduce load.

Mandatory under-frequency load shedding of several customers shall be classified as a single and an involuntary load reduction event. Mandatory customer load reduction events shall neither be categorized as unplanned nor planned interruptions, but shall be assessed separately.

### 4.3.2 Classification of unplanned interruptions

NOTE If required, this classification can be applied to involuntary load reductions.

#### 4.3.2.1 HV and EHV networks

**4.3.2.1.1 Momentary interruptions:** Unplanned interruptions of HV and EHV circuits that are longer than 3 s but less than or equal to 1 min shall be classified as momentary interruptions.

**4.3.2.1.2 Sustained interruptions:** Unplanned interruptions of HV and EHV circuits longer than 1 min shall be classified as sustained interruptions.

NOTE 1 In general a one-minute limit differentiates all automatic reclose events from events that involve operator intervention. A one-minute classification is commonly used internationally by transmission utilities.

NOTE 2 In some cases, transmission licensees may use a subclassification of momentary interruptions with an upper limit of 10 s to cover three-phase auto-reclose events not related to generation supply points (the latter may have dead times of 20 s to 30 s and restoration times of up to 45 s).

#### 4.3.2.2 LV and MV networks

**4.3.2.2.1 Momentary interruption events:** Unplanned interruptions of LV and MV circuits that are longer than 3 s but less than or equal to 5 min shall be classified as momentary interruptions.

**4.3.2.2.2 Momentary interruption events:** Where an interrupting device on an LV or MV circuit has a sequence of operations, for example if a recloser or breaker operates two, three or four times and then holds, those momentary interruptions shall be classified as one momentary interruption event. Such a sequence of operations shall be completed in a specified time not exceeding 5 min.

**4.3.2.2.3 Sustained interruptions:** Unplanned interruptions of LV and MV circuits longer than 5 min shall be classified as sustained interruptions.

### 4.3.3 Characteristic values

#### 4.3.3.1 Characteristic values of LV and MV momentary interruptions (> 3 s, ≤ 5 min)

Under normal operating conditions the annual occurrence of momentary interruptions of the supply voltage ranges from a few tens up to over a hundred per annum in the case of overhead networks.

#### 4.3.3.2 Characteristic values of LV and MV sustained interruptions (> 5 min)

Levels of interruption performance for both planned and unplanned interruptions differ substantially from network to network (see NOTE 1).

For the purpose of providing characteristic interruption performance, network categories are based on the network characteristics defined in table 11 (see NOTE 2). Characteristic performance levels, based on historical performance data for South African networks, are provided in tables 12 and 13 for three network categories.

NOTE 1 Such performance levels depend on aspects such as the exposure of the network to the environment (for example, line lengths, terrain, customer density, environmental elements such as lightning, bush fires etc.), the characteristics of the network (for example, the ability to sectionalize networks, the availability of alternative supplies) and human factors (operator error, vandalism, accidents, overload caused by illegal connections, contractors digging up cables).

NOTE 2 Characteristic interruption performance values cannot be provided for specific customer categories (e.g. agricultural, commercial, residential, industrial), as this level of segregation in available performance data is not present at this time in South Africa (the latter will be addressed in NRS 048-6). It should also be noted that different types of customers may be connected to any given network (i.e. networks are not specifically designed to serve specific types of customers). Classification of characteristic values has not been based on definitions such as “rural’ or “urban”, as what may be considered as an “urban” area may in fact be supplied by a very long radial overhead MV feeder (often considered a “rural” feeder). For this reason network categories are defined based on technical criteria that attempt to provide a more specific definition of the characteristics of the network. The large variability in the data in tables 12 and 13 is impacted by a combination of factors listed in NOTE 1.

NOTE 3 Interruptions caused by LV faults are presently not logged accurately for the purposes of statistical analysis by some licensees. Suitable statistical data is therefore currently not available for the purpose of defining characteristic performance levels.

NOTE 4 The statistics provided for network category B in tables 12 and 13 are based on data for feeders of length exceeding 1 km.

NOTE 5 The characteristic values provided will be reviewed in future editions of this part of NRS 048. NERSA is currently implementing reliability improvement incentive programs with some licensees. It is likely that this will result in a reduction of interruptions reflected in the above figures for class B networks by 2009. The quality of available interruption data is also improving nationally.

The numbers in table 12 reflect the interruption performance currently experienced by customers in South Africa.

**Table 11 — Network categories (MV criteria)**

| 1 | 2 |
|---|---|
| **Network category** | **Feeder type** |
| A | > 80 % underground or aerial cable |
| B | > 80 % overhead line ( > 1 km line length) |
| C | Networks that do not comply with the criteria in A and B |
| NOTE The criteria relate to the characteristics of the MV networks that supply the customer, since MV networks traditionally have the largest impact on interruption performance. | |

#### 4.3.3.3 Characteristic values of HV and EHV sustained interruptions (> 1 min)

No characteristic values have been specified.

NOTE It is expected that NERSA will put into effect measures that will require licensees to manage interruptions (see 4.3.5.)

### 4.3.4 Assessment method

#### 4.3.4.1 Unplanned interruption parameters

Interruption performance as experienced by a customer shall be assessed by recording the date, start time, and duration of each individual unplanned interruption event.

It is not practicable for licensees to continuously monitor all individual customer interruptions on LV and MV networks. However, a licensee shall keep records of circuit interruption events for analysis in the event that an assessment of interruptions at a specific customer's point of supply is required.

#### 4.3.4.2 Unplanned interruption duration

The start time of the interruption shall be the time that one or more of the supply phases are disconnected. Where information to establish this time is not available, the start time of an interruption shall be deemed to be the time when the first customer notifies the licensee of the interruption.

**Table 12 — Characteristic values for the number of sustained interruptions per annum experienced by up to 50 % (and up to 95 %) of LV and MV customers in South Africa**

| 1 | 2 | 3 |
|---|---|---|
| **Network category** | **Unplanned interruptions, number** | **Planned interruptions, number** |
| A | 3 (6) | < 1 (3) |
| B | 18 (75) | 4 (11) |
| NOTE 1 The values for 50 % of customers reflect the number of events per annum that are generally not exceeded in the case of 50 % of customers in South Africa.<br><br>NOTE 2 The values for 95 % of customers reflect the number of events per annum that are generally not exceeded in the case of 95 % of customers in South Africa.<br><br>NOTE 3 Characteristic values for category C networks will generally be between those of category A and category B networks. | | |

**Table 13 — Characteristic values for the duration of individual sustained interruptions for up to 50 % (and up to 95 %) of interruptions experienced by LV and MV customers in South Africa**

| 1 | 2 | 3 |
|---|---|---|
| **Network category** | **Unplanned interruptions, duration**<br>h | **Planned interruptions, duration**<br>h |
| A | 3,5 (18) | 4 (9) |
| B | 2,5 (12) | 3 (14) |

NOTE 1 The values for 50 % of interruptions reflect the duration of interruptions that are expected not to be exceeded in the case of 50 % of interruptions experienced by customers in South Africa.

NOTE 2 The values for 95 % of interruptions reflect the duration of interruptions that are expected not to be exceeded in the case of 95 % of interruptions experienced by customers in South Africa.

NOTE 3 Characteristic values for category C networks will generally be between those of category A and category B networks.

The duration of an interruption shall be measured from the start time of the interruption until the ability to supply the load has been restored by the licensee.

Under emergency conditions, a licensee may restore supply to the customer, but might not be in a position to comply with the levels of quality defined in this part of NRS 048 for the duration of this emergency condition. For this reason, the "ability to supply" shall be assessed as a condition where the individual 10 min r.m.s. voltage magnitude values do not exceed the limits defined in 4.2.2.3. Under such conditions, other voltage magnitude compliance criteria in 4.2.2.5 shall not apply.

#### 4.3.4.3 Specific assessment criteria

The following criteria shall apply in the case of the assessment of unplanned interruptions:

a) in the case of LV customers connected to the MV network by Dy-connected transformers or single-phase transformers, a single-phase fuse operation on the MV network shall be classified as a unplanned interruption;

b) in the case of SWER customers (tapped off the MV system by a line-to-line transformer connection), a single-phase fuse operation on one of the phases to which the SWER system is connected shall be assessed as an unplanned interruption on the LV side;

c) where the supply point to a customer is interrupted but the customer load is supplied from another supply point by circuits that do not belong to the licensee (whether by those of another licensee, or by internal generation), the event shall be classified as a unplanned interruption;

d) where a customer has specifically contracted for diversity (i.e. the ability to swing all or part of the load to another supply point in the event of an interruption), the disconnection of one or more phases of the supply to the supply point shall be classified as an unplanned interruption, and the manner in which such an unplanned interruption is handled shall be in accordance with the contract between the customer and the licensee;

e) where an interruption occurs when a customer has been warned that there is a risk of tripping the supply, such an event shall be assessed as a unplanned interruption;

f) where a voluntary customer load reduction event (see 4.3.1.3) precedes an unplanned interruption, both events shall be logged and reported independently;

g) where an unplanned interruption to a customer is caused by a fault in that customer's plant, such an event shall not be regarded as an unplanned interruption if generally accepted protection practices have been implemented and operated successfully; where the severity of the inter-ruption is impacted by protection operation outside of normally expected practices, and such operations were not able to contain the extent of the interruption, such an interruption shall be assessed as an unplanned interruption; and

h) where a fault in a customer's plant causes interruption of supply to other customers, the licensee shall record the interruption as a unplanned interruption.

### 4.3.5 Compliance criteria

No compliance criteria are defined for unplanned interruptions or involuntary customer load reduction events. In the absence of specific contractual clauses, such interruptions and events shall be managed in terms of the requirements of the *NERSA Directive on power quality*, as specified in NRS 048-4.

NOTE It is expected that NERSA will define regulatory interruption reporting mechanisms, standards and incentives. Such standards and incentives may be linked to rate adjustments in future.

# Annex A
(informative)

# Rapid voltage changes

## A.1 Characteristic levels

Switching events on the licensee's network or within customers' plant generally give rise to rapid voltage changes of less than 15 % on LV networks and less than 10 % on MV networks. The frequency of such rapid voltage changes (RVCs) will have an impact on the flicker levels and as such are addressed by the flicker compatibility levels.

## A.2 Assessment method

The relative voltage change can be approximated in the cases of single-phase and symmetrical three-phase loads by the equations A.2.1, A.2.2 and A.2.3. See figure A.1.

$$\Delta U \approx \Delta I_{\mathrm{p}} \cdot R_{\mathrm{L}} + \Delta I_{\mathrm{q}} \cdot X_{\mathrm{L}} \qquad \text{(A.2.1)}$$

$$I = I_{\mathrm{p}} - \mathrm{j} I_{\mathrm{q}} \qquad \text{(A.2.2)}$$

$$Z_{\mathrm{L}} = R_{\mathrm{L}} + \mathrm{j} X_{\mathrm{L}} \qquad \text{(A.2.3)}$$

where

$\Delta U$ is the change in voltage $U$, in volts;

$I_p$ and $I_q$ are the active and reactive components of the current $I$ respectively, in amperes;

$R_L$ and $X_L$ are the resistive and reactive components of the power line's complex impedance, $Z_L$, in ohms, of the power line that serves the load;

j is the "j operator" [$j^2 = -1$].

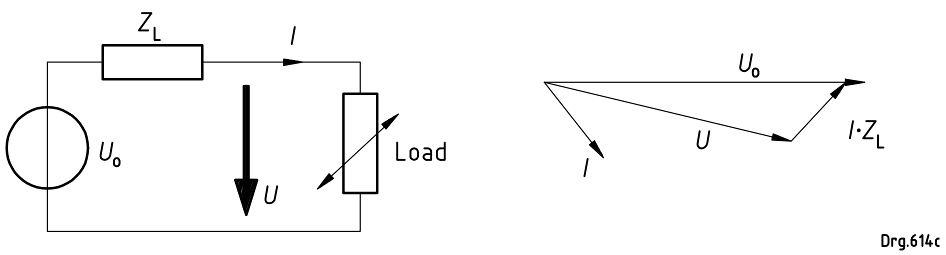


**Figure A.1 — Equivalent circuit and vector diagram for simple assessment**

## A.3 Examples of rapid voltage changes

Figures A.2 and A.3 illustrate examples of rapid voltage changes.

**Annex A**
*(concluded)*

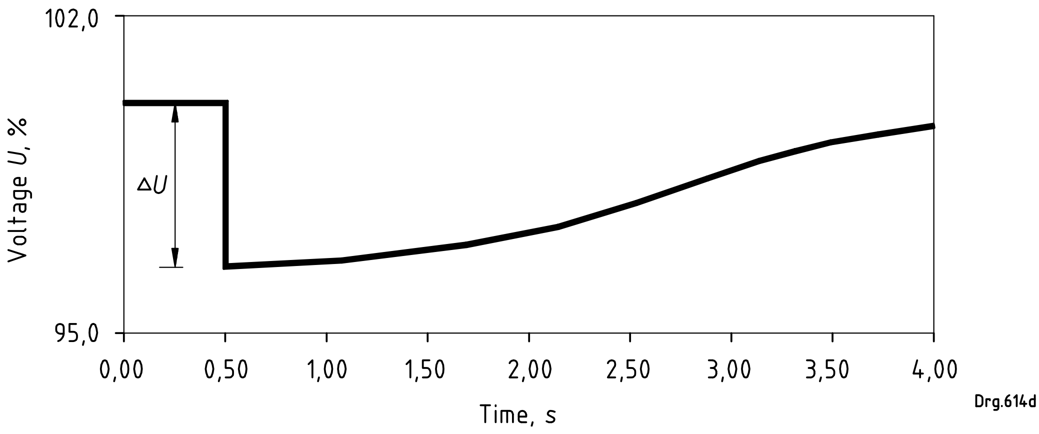


**Figure A.2 — Example of a rapid voltage change associated with motor starting**

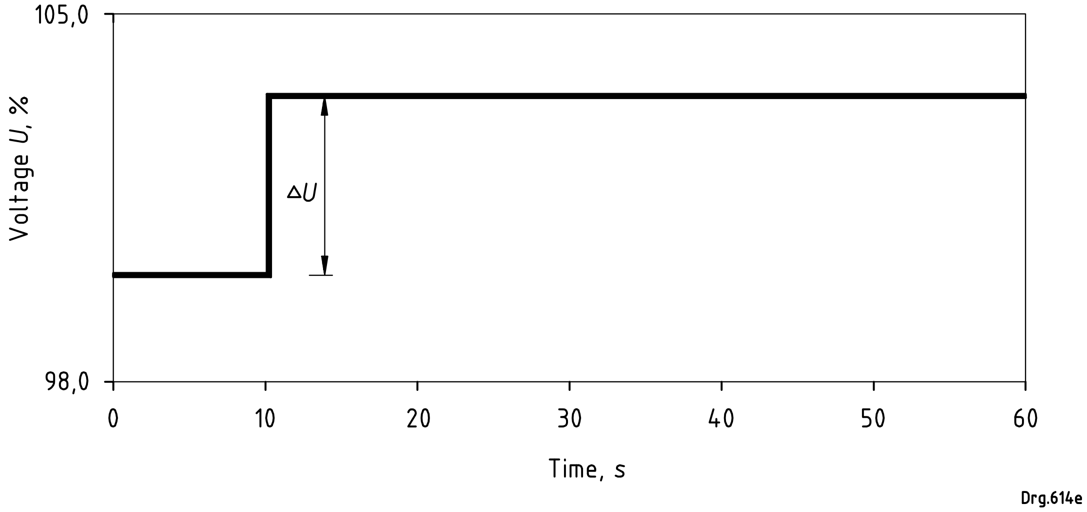


**Figure A.3 — Example of a rapid voltage change associated with capacitor switching**

# Annex B
(informative)

## Interharmonic voltages on LV networks

No compatibility levels or limits are specified for interharmonic voltages, since knowledge of electromagnetic disturbances that result from interharmonic voltages is still developing.

The effects of interharmonic voltages at frequencies close to fundamental frequency result in amplitude modulation of the supply voltage, which give rise to flicker.

In the case of interharmonic voltages on LV networks, some characteristic values derived from the interharmonic voltages associated with flicker have been published in SANS 61000-2-2 (see table B.1.)

**Table B.1 — Characteristic values of interharmonic voltages on LV networks corresponding to the compatibility level with respect to flicker effect (expressed as a percentage of the fundamental power-frequency voltage)**

| 1 | 2 | 3 |
|---|---|---|
| **Order**<br>$m$[a] | **Interharmonic frequency**<br>$f_m$<br>Hz | **Interharmonic voltage**<br>% |
| 0,2< $m \leq$ 0,6 | 10 < $f_m \leq$ 30 | 0,51 |
| 0,60< $m \leq$ 0,64 | 30 < $f_m \leq$ 32 | 0,43 |
| 0,64< $m \leq$ 0,68 | 32 < $f_m \leq$ 34 | 0,35 |
| 0,68< $m \leq$ 0,72 | 34 < $f_m \leq$ 36 | 0,28 |
| 0,72< $m \leq$ 0,76 | 36 < $f_m \leq$ 38 | 0,23 |
| 0,76< $m \leq$ 0,84 | 38 < $f_m \leq$ 42 | 0,18 |
| 0,84< $m \leq$ 0,88 | 42 < $f_m \leq$ 44 | 0,18 |
| 0,88< $m \leq$ 0,92 | 44 < $f_m \leq$ 46 | 0,24 |
| 0,92< $m \leq$ 0,96 | 46 < $f_m \leq$ 48 | 0,36 |
| 0,96< $m \leq$ 1,04 | 48 < $f_m \leq$ 52 | 0,64 |
| 1,04< $m \leq$ 1,08 | 52 < $f_m \leq$ 54 | 0,36 |
| 1,08< $m \leq$ 1,12 | 54 < $f_m \leq$ 56 | 0,24 |
| 1,12< $m \leq$ 1,16 | 56 < $f_m \leq$ 58 | 0,18 |
| 1,16< $m \leq$ 1,24 | 58 < $f_m \leq$ 62 | 0,18 |
| 1,24< $m \leq$ 1,28 | 62 < $f_m \leq$ 64 | 0,23 |
| 1,28< $m \leq$ 1,32 | 64 < $f_m \leq$ 66 | 0,28 |
| 1,32< $m \leq$ 1,36 | 66 < $f_m \leq$ 68 | 0,35 |
| 1,36< $m \leq$ 1,40 | 68 < $f_m \leq$ 70 | 0,43 |
| 1,4< $m \leq$ 1,8 | 70 < $f_m \leq$ 90 | 0,51 |

[a] $m$ is a non-integer, sub-multiple or multiple of the fundamental power frequency.

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