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# NRS 048-2:2003

Second edition

Rationalized User Specification

# ELECTRICITY SUPPLY — QUALITY OF SUPPLY

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

N R S

This Rationalized User Specification is
issued by the Technology Standardization Department (TSD), 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).

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# Contents

## Foreword

This second edition of 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). It is based on a review by this working group of a discussion document commissioned by the National Electricity Regulator (NER). The working group membership included customer representation, inter alia formal representation of the Energy Intensive User Group (EIUG).

The working group, while recognizing that no such standards have been prepared elsewhere for developing networks in developing countries, was guided by recommendations in international (IEC), European (CENELEC), and North American (IEEE) standards and reports, and reports and data available locally. This second edition was prepared to take into account, where appropriate, developments in IEC and other standards since the publication of the first edition of this part of NRS 048. This second edition was also prepared to take into account the measurement of quality of supply (QOS) parameters on South African power networks recorded since the publication of the first edition of this part of NRS 048.

This second edition of this part of NRS 048 specifies QOS parameters more comprehensively than was the case in the first edition. Compatibility levels, limits, and voltage characteristics are specified, which can be used by utilities, their customers, and the NER in managing power quality issues. The *NER directive on power quality* sets out the basis for managing power quality, and should be referred to when applying the levels and limits specified in this part of NRS 048.

Where specified, compatibility levels or limits (or both) might be declared by the NER as minimum standards for licensing requirements.

This part of NRS 048 was prepared by a working group comprising the following members:

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

Part 1: *Overview of implementation of standards and procedures.* (Under review.)

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

Part 3: *Procedures for measurement and reporting.*

Part 4: *Application guidelines for utilities*.

Part 5: *Instrumentation and transducers for voltage quality monitoring and recording*.

Annexes A, B, C and D are for information only.

Recommendations for corrections, additions or deletions should be addressed to the NRS Projects Manager, Technology Standardization Department (TSD), Eskom, PO Box 1091, Johannesburg, 2000.

## 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. 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.

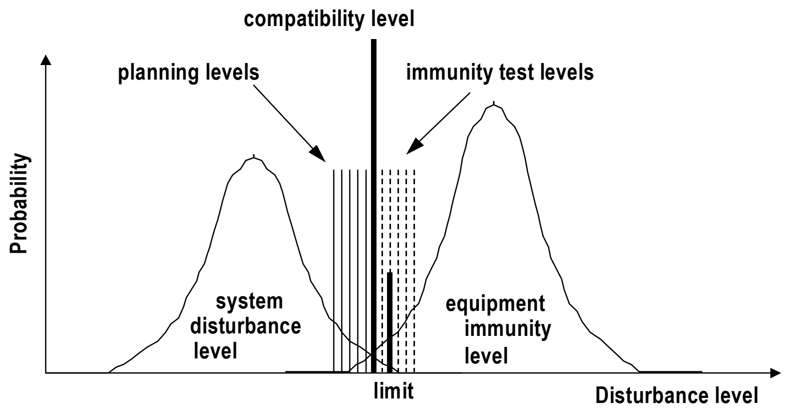


**Figure 1 — Illustration of the concept of compatibility levels**

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. 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. 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 the compatibility level. 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. 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. However, a licensee may choose not to meet 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 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 NRS 048, accepting that the levels for QOS parameters at inter-licensee interfaces might be different from the levels for end customers specified in NRS 048. NRS 048-4 gives guidance on the factors to be considered in setting QOS parameters in inter-licensee contracts, and provides planning levels for some parameters.

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 cognisance of the fact that existing installations might have been designed for, and might be operated at, lower levels. 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 must have immunity.

Where there are applicable international standards, these have been referenced in compiling this edition of this part of NRS 048. Where applicable, for specifying assessment methods, the weekly assessment criterion as used in [European standard] 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.

Certain QOS parameters are the subject of regulations of the Electricity Act, 1987 (Act No. 41 of 1987). It is expected that the NER would apply for these regulations to be revised to make reference to this part of NRS 048.

## Keywords

Quality of supply; Power quality; Compatibility levels; Assessment methods; Quality of supply parameters; Voltage quality; Reliability of supply.

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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. It is intended to provide

a) the National Electricity Regulator (NER) with a means of evaluating and regulating the quality of supply (QOS) provided by licensees (see note 1);

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

c) licensees with QOS 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 The annual reporting requirements and system performance criteria for licensees will be specified separately by the NER. 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.

NOTE 2 It is intended that licensees meet the appropriate compatibility levels and limits specified in this part of NRS 048 for each customer.

### 1.2 Applicability to licensees

Unless otherwise specifically agreed in a supply contract, it is intended that licensees ensure that all QOS parameters to a specific customer, when assessed as specified in this part of NRS 048, 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 utility.

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 for which the network was designed to operate under, 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 for which the network was designed to operate under; 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 third parties 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 Occurrences attributable to staff or contractors of the licensee are NOT considered as unavoidable events.

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

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

Normal network operating conditions include the following:

a) all reactive compensation states when the above exclusions are not in affect; and

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

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 meet the requirements. Appropriate measures may include a specific plan that may take several weeks or months to implement. Appropriate measures may also mean that a rare exceedance of the requirements is not specifically rectified if this can only be achieved by costly interventions. 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 *NER 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 operates 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 may 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 that compatibility levels and limits are exceeded.

## 2 Normative references

The following documents contain provisions which, through reference in this text, constitute provisions of this specification. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and parties to agreements based on this specification are encouraged to investigate the possibility of applying the most recent editions of the documents listed below. Information on currently valid national and international standards and specifications can be obtained from Standards South Africa.

IEC 61000-4-15:1997, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 15: Flickermeter – Functional and design specifications.*

SANS 61000-4-30:2003, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*.

*NER directive on power quality*, March 2002. (Available from the National Electricity Regulator.)

NRS 047-1:2002, *Electricity supply – Quality of service – Part 1: Minimum standards.*

NRS 048-1:1996, *Electricity supply – Quality of supply – Part 1: Overview of implementation of standards and procedures*. (See note 1.)

NRS 048-3:2002, *Electricity supply – Quality of supply – Part 3: Procedures for measurement and reporting.*

NRS 048-5:1998, *Electricity supply – Quality of supply – Part 5: Instrumentation and transducers for voltage quality monitoring and recording.* (See note 2.)

NOTE 1 NRS 048-1 is under review. It is referenced only for the glossary of terms, definitions and abbreviated terms therein. The implementation of standards and procedures are superseded by the requirements of the NER, set out in the *NER directive on power quality*.

NOTE 2 SANS 1816, which is intended to cover the requirements for power quality measuring instruments, and which might replace NRS 048-5, is in course of preparation.

## 3 Terms, definitions and abbreviated terms

For the purposes of this part of NRS 048, the terms, definitions and abbreviated terms given in NRS 048-1 apply.

## 4 Requirements

### 4.1 Instrumentation

Instruments that are intended to measure voltage parameters specified in this part of NRS 048 shall comply with the requirements of either SANS 61000-4-30 (for class A measurements), or, in the case of class B measurements, NRS 048-5 or the national standard which has replaced it.

NOTE 1 Measurement methods are not considered in this part of NRS 048. Instrument and transducer accuracies are covered in NRS 048-5, which is expected to be replaced by SANS 1816, and which will in addition cover the measurement methods for each parameter.

NOTE 2 Class A measurement requirements will be proposed for the purpose of comparing measured performance with standards in the case of dispute on the accuracy of the measurements.

The less stringent class B measurement requirements will be proposed for surveys and monitoring for general compliance with standards.

NOTE 3 The adoption of the above measurement methods poses a change to some of the measurement methods specified in the first edition of NRS 048-2. The changes will be applicable only in respect of class A measurements. Important changes are:

a) The “flagging” of measured data where dips, swells, or interruptions occurred.

b) For class A measurements, continuous 3 s measurements are required (as opposed to the present edition requirement of one 200 ms sample every 3 s).

Nevertheless, it is intended to embrace the current NRS 048-5 requirements within the class B of instruments, thus allowing the continued use of the installed base of instruments that comply with NRS 048-5.

NOTE 4 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 frequency 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”.

The flagging of data is applicable for class A measurement performance during measurement of power frequency, voltage magnitude, flicker, voltage UB, 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 shall include the flagged data and shall itself be flagged. Flagged values used in the assessment methods as specified in this part of NRS 048-2 shall be ignored in the assessment. However, frequency measurements need to be specifically analyzed.

## 4.2 Quality of supply parameters

### 4.2.1 Assessment requirements

#### 4.2.1.1 General

Where specifically referenced for particular parameters, the assessment requirements in 4.2.1.2 to 4.2.1.6 shall apply. For other 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 a deviation from a fixed reference voltage.

In the case of LV networks, the reference voltage shall be standard voltage (230 V/400 V) as defined in the Regulations of the Electricity Act, 1987 (Act No. 41 of 1987).

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 utility, which may be greater or smaller than nominal voltage). It is recommended that the declared voltage be within 5 % of nominal voltage.

All phases of the supply voltage shall be monitored. In the case of systems with solidly earthed transformer neutrals, the phase-to-earth voltages shall be measured. In the case of delta-connected systems or systems with impedance earthing or which are unearthed, 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-minute r.m.s. value(s) which is 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-minute 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-minute 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-minute 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 remaining after excluding flagged and missing data, provided that no more than 10 % of the 10-minute values have been excluded.

For specific investigation of a customer complaint, the assessed values shall be based on the data remaining after excluding flagged and missing data, provided that no more than 2 % of the 10-minute 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 400 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 in a supply contract, the compatibility levels for the magnitude of supply voltage shall be as specified in table 1. In the case of nominal system voltages above 500 V, in the absence of any agreement to the contrary, the supply voltage shall not deviate from the declared or agreed voltage by more than 5 % for any period longer than 10 consecutive minutes.

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

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

#### 4.2.2.3 Limits

For supplies direct to customers at voltages less than 500 V, the maximum voltage deviation shall not be greater than specified in table 2. For supplies direct to customers at or above 500 V, the maximum voltage deviation shall not be greater than specified in table 2, and in all cases the voltage shall not be greater than the relevant maximum voltage specified in table 3.

NOTE In the case of a single-phase MV fuse failure, the voltage supplied on LV networks may be significantly outside the limits until the problem has been rectified. Customers should protect plant against such extreme events. In terms of this part of NRS 048, such events are considered as interruptions and will, as specified in SANS 61000-4-30 be flagged as potentially erroneous voltage magnitude events.

**Table 2 — Maximum deviation from standard or declared voltages**

| 1 | 2 |
|---|---|
| **Voltage level**<br>V | **Limit**<br>% |
| < 500 | ± 15 |
| ≥ 500 | ± 10 |

**Table 3 — Maximum voltages for supplies to customers above 500 V**

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

#### 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, retain number of times that more than two consecutive 10-minute values have been outside the higher or lower compatibility level (see note 2 of 4.2.2.5).

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

The requirements of 4.2.1.5 shall apply. In addition, retain number of times that more than two consecutive 10-minute values have been outside the higher or lower compatibility level (see note 2 of 4.2.2.5).

#### 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

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 as otherwise contracted (see note 1); and

b) not more than two consecutive 10-minute values shall exceed the higher applicable compatibility level given in table 1, and not more than two consecutive 10-minute values shall be less than the lower applicable compatibility level given in table 1, or as otherwise contracted. (See note 2.)

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

NOTE 2 Consecutive requirements are introduced to ensure that exceedances of equipment design standards are avoided for long periods in the week.

The criteria for compliance with the limits given in tables 2 and 3 shall be as follows:

a) the maximum deviation of the 10-minute values from declared voltage over the full measurement period shall not exceed the limits given in table 2; and

b) the highest of the assessed weekly maximum values of the 10-minute values over the full measurement period shall not exceed the limits given in table 3.

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

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

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

## 4.2.3 Frequency

### 4.2.3.1 Standard frequency

The standard frequency shall be 50 Hz.

### 4.2.3.2 Compatibility levels

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

**Table 4 — Deviation from standard frequency**

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

#### 4.2.3.3 Limits

The limits for the frequency of the supply voltage shall be as specified in table 5.

**Table 5 — Maximum deviation from standard frequency**

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

#### 4.2.3.4 Assessment method

##### 4.2.3.4.1 Assessment period

All values, over a period of one year shall be recorded.

##### 4.2.3.4.2 Retained values

NOTE Measurement of frequency has particular requirements, in accordance with instrumentation 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.

##### 4.2.3.4.3 Exclusion of flagged and missing data

The requirements of 4.2.1.6 shall apply.

#### 4.2.3.5 Compliance criteria

The assessed levels, to be compared with the compatibility levels and limits given in tables 4 and 5 respectively, shall be the individual measured values of frequency.

### 4.2.4 Voltage unbalance

#### 4.2.4.1 General

UB can be described in terms of the contribution of zero sequence voltages and the contribution of negative sequence voltages. In this part of NRS 048 only the contribution of the negative sequence voltages are given because this is the relevant component when considering the impact on equipment connected to the system. (see the definition of voltage UB in NRS 048-1 for further explanation).

#### 4.2.4.2 Compatibility level

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

On networks where there is a predominance of single-phase or two-phase customers, a compatibility level of 3 % may be applied.

NOTE The relaxation of the compatibility level to 3% might apply in the case of unusual network or load configurations, that mitigate against limiting UB to 2 %. It is anticipated that utilities would inform affected customers when being connected, that the higher UB level might be experienced.

#### 4.2.4.3 Limits

Limits for UB have not been specified.

NOTE 1 A limit for UB 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 voltage UB 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 forced interruptions (see 4.3.1.2) and will, be flagged as potentially erroneous UB 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 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 very short-term effects.

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

Very short effects relate mainly to disturbing effects on electronic devices that may be susceptible to harmonic distortion. The effects of transients are excluded (see annex D).

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

#### 4.2.5.2.1 Compatibility levels

The compatibility levels for harmonics on LV and MV networks are given in table 6.

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

NOTE 1 It is intended that customers supplied at HV and EHV will have specifically agreed harmonic limits written into contracts, these will generally be equal to or higher than the planning levels in NRS 048-4. These recommended planning levels are provided in annex A.

NOTE 2 Limits for levels of harmonic voltages are not specified. Limits for each harmonic of order h 1,5 to 2,5 multiplied by the magnitudes given in table 6 are under consideration, to be applied to 10 min values.

**Table 6 — Compatibility levels for harmonic voltages**
**(Expressed as a percentage of the fundamental voltage of LV and MV power systems)**

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **Odd harmonics** | | | | **Even harmonics** | |
| **Not multiples of 3** | | **Multiples of 3** (See note) | | | |
| **Order** *h* | **magnitude** % | **Order** *h* | **magnitude** % | **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 | $10 \leq h \leq 50$ | $\{0{,}25 \times (10/h)\} + 0{,}25$ |
| NOTE 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 UB of the system. | | | | | |

#### 4.2.5.2.2 Assessment method

#### 4.2.5.2.2.1 Reference voltage for measurements

Each harmonic and the THD shall comply with the requirements of 4.2.1.2.

#### 4.2.5.2.2.2 Assessment period

Each harmonic and the THD shall comply with the requirements of 4.2.1.3.

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

Each harmonic and the THD shall comply with the requirements of 4.2.1.4.

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

Each harmonic and the THD shall comply with the requirements of 4.2.1.5.

#### 4.2.5.2.2.5 Exclusion of flagged and missing data

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

#### 4.2.5.2.3 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)

The compatibility levels for individual harmonic components of the voltage are based on the levels given in table 6 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

Each harmonic and the THD shall comply with the requirements of 4.2.1.2.

#### 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 (as 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 have to be taken into account. Because of the possibility of mutual influences of neighbouring signalling installations the customer may need to apply protection or appropriate immunity for his signalling installation against this influence.

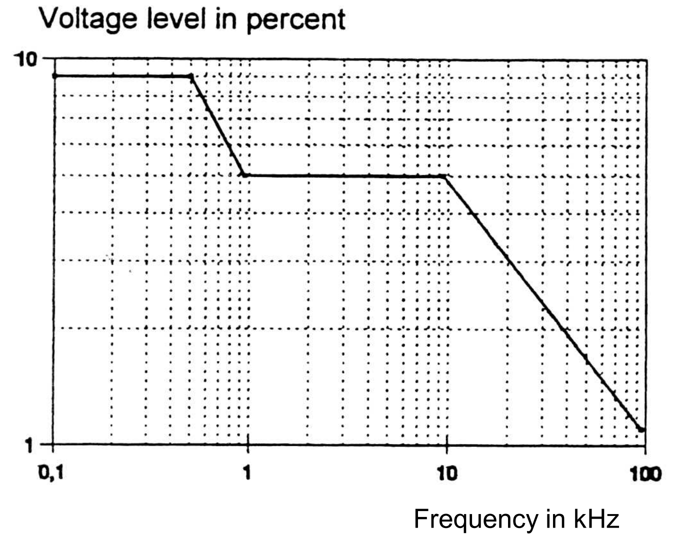



**Figure 2 — Voltage levels of signal frequencies in percent of $U_n$ used in public LV distribution systems**

#### 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-hour period the 150 cycle (nominally 3 s) mean of signal 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-hour period, and retain the value for comparison with the compatibility levels.

Determine the highest 3 s r.m.s. value(s) of the 24-hour 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-second r.m.s. value which is not exceeded for more than 95 % of the 24-hour period. The most extreme value(s) is retained for comparison with the compatibility level(s).

For each phase, determine the highest 3-second r.m.s. value(s) of the 24-hour 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 ($P_{\mathrm{lt}}$) shall be 1,0.

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

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

where

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

The highest 95 % values of the $P_{\mathrm{lt}}$ 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 $P_{\mathrm{lt}}$ 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 C.

NOTE Indicative emission limits for rapid voltage changes for individual customers at the PCC are given in NRS 048-4.

### 4.2.9 Voltage dips

#### 4.2.9.1 General

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 *NER directive on power quality*.

The role of this part of NRS 048 is to provide a uniform approach for the characterization of voltage dip performance (see table 7), and to provide characteristic historical dip performance in accordance with this approach. While this characterization method addresses the most common affects of dips on customer plants, 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 cause problems with customer plant, a licensee is still required to address the problem in terms of the incident reporting procedure outlined in the *NER directive on power quality*.

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

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

<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 % of $U_d$)</td><td rowspan="2">Range of residual voltage<br>$U_r$<br>(expressed as a % of $U_d$)</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 colspan="3">Y</td></tr>
<tr><td>$15 < \Delta U \leq 20$</td><td>$85 > U_r \geq 80$</td><td colspan="2">Y</td><td rowspan="2">Z1</td></tr>
<tr><td>$20 < \Delta U \leq 30$</td><td>$80 > U_r \geq 70$</td><td>Y</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 against the effects of such dips on their plant.</td></tr>
</table>

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 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.

The dip categories provide for:

a) a greater emphasis on customer plant dip immunity for small short duration dips (the most common on licensee EHV and HV networks);

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

c) four dip categories that define the area in which combined management of dip performance and dip immunity is necessary (X1, X2, S, and Z1). The changes to the Y and X areas are important for future regulatory purposes where these events may be imported by a local distributor, and may occur in another distributor many kilometres away. From a licensee point of view, the cost of reducing these is in the majority of cases not warranted. Note that the Y area has been increased for shorter duration dips, but reduced for longer dips.

**Table 8 — Basis for categorization of voltage dips**

| 1 | 2 | | 3 |
|---|---|---|---|
| **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 comparing the performance of a particular site 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.

NOTE 1 A network voltage is not necessarily the voltage at which the customer takes supply. It may be the voltage of the network that feeds the PCC. Therefore, the set of Z, T, S, X and Y values applicable to a customer should be evaluated in each case, taking account of the network configuration supplying that customer.

NOTE 2 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.

NOTE 3 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 rural | 85 | 210 | 115 | 400 | 450 | 450 |
| 6,6 kV to ≤ 44 kV | 20 | 30 | 110 | 30 | 20 | 45 |
| > 44 kV to ≤ 132 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 rural | 13 | 12 | 10 | 13 | 11 | 10 |
| 6,6 kV to ≤ 44 kV | 7 | 7 | 7 | 6 | 3 | 4 |
| > 44 kV to ≤ 132 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 which 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 window categories in table 8.

When considering the performance of a utility, 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 Refer to SANS 61000-4-30 for measurement definitions.

NOTE 3 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.

#### 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 *NER directive on power quality*.

### 4.2.10 Voltage swells and transient overvoltages

For information about voltage swells and transient overvoltages on LV networks, see annex D.

## 4.3 Reliability of supply

### 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 in evaluating the effects of such events on a specific customer's point of supply. The definition of interruption indices for the purposes of statistical system performance reporting will be defined separately by the NER.

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

a) forced interruptions (see 4.3.1.2);

b) voluntary customer load reductions (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 shall be further classified as either momentary interruptions or sustained interruptions.

#### 4.3.1.2 Forced interruptions

An unplanned event that results in the disconnection of one or more phases of the network that supplies the customer for a period of more than 3 s, shall be categorized as a forced interruption (see note 1 below). Such cases usually result in under-voltage events on the phase(s) that remain connected at the point of supply. These under-voltage events shall be assessed separately (see 4.2.2.6).

Forced 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 either

a) a failure of a component (such components include jumpers, joints, conductors, circuit-breakers and transformers),

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 limited to the circuits directly supplying the customer.

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 forced 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 may 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 terms of 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, such 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 voluntarily 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 may be in terms of a contract, and may be executed by automatic relays designed to trip the load as agreed 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 classified as a voluntary load reduction event. Voluntary customer load reduction events shall neither be categorized as forced nor planned interruptions, but shall be assessed separately.

#### 4.3.1.4 Planned interruptions

Planned interruptions, as specified in NRS 047-1, shall be classified as quality of service interruption events.

NOTE 4.5.5 of NRS 047-1 sets out requirements for customers to be given prior notice, for an interruption to be considered as a planned interruption.

#### 4.3.1.5 Involuntary 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 prior to requiring that the customer reduces 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 forced nor planned interruptions, but shall be assessed separately.

### 4.3.2 Classification of forced interruptions

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

#### 4.3.2.1 EHV and HV networks

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

**Sustained interruptions (EHV/HV):** Forced interruptions of EHV and HV 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 involving operator intervention. A one-minute classification is commonly used internationally by transmission utilities.

NOTE 2 In some cases, transmission licensees may use a sub-classification 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 MV and LV networks

**Momentary interruptions (MV/LV):** Forced interruptions of MV and LV circuits longer than 3 s and less than or equal to 5 minutes shall be classified as momentary interruptions.

**Momentary interruption events (MV/LV):** Where an interrupting device on an MV or LV 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 shall be completed in a specified time not to exceed 5 min.

**Sustained interruptions (MV/LV):** Forced interruptions of MV and LV circuits longer than 5 min shall be classified as sustained interruptions.

### 4.3.3 Characteristic values

#### 4.3.3.1 Characteristic values of MV and LV 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 several hundreds in the case of overhead networks.

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

No characteristic values have been specified.

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

No characteristic values have been specified.

NOTE It is expected that the NER will put in effect measures requiring licensees to manage interruptions. (See 4.3.5.)

### 4.3.4 Assessment method

#### 4.3.4.1 Forced interruption parameters

Interruption performance to a customer shall be assessed by recording the date, start time, and duration of each individual forced 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 Forced 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.

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, as specified in NRS 048-3. Requirements for the restoration of supply after a forced interruption are given in NRS 047-1.

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-minute 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 to the assessment of forced 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 forced 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 a forced 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 not belonging to the licensee (whether by those of another licensee, or by internal generation), the event shall be classified as a forced 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 a forced interruption, and the manner in which such a forced interruption is handled shall be in terms of 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 forced interruption;

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

g) where a forced interruption to a customer is caused by a fault in that customer's plant, such an event shall not be regarded as a forced interruption if generally accepted protection practices have been implemented and these operated successfully; where the severity of the interruption 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 a forced 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 forced interruption.

### 4.3.5 Compliance criteria

No compliance criteria are defined for forced 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 *NER directive on power quality*.

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

# Annex A
(informative)

## Recommended planning levels for harmonic voltage on HV and EHV systems

**Table A.1 — Recommended planning levels for harmonic voltage (expressed as a percentage of the rated voltage of HV and EHV power systems)**

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **Odd harmonics non-multiple of 3** | | **Odd harmonics multiple of 3** | | **Even harmonics** | |
| **Order**<br>*h* | **Harmonic voltage HV and EHV**<br>% | **Order**<br>*h* | **Harmonic voltage HV and EHV**<br>% | **Order**<br>*h* | **Harmonic voltage HV and EHV**<br>% |
| 5 | 2 | 3 | 2 | 2 | 1,5 |
| 7 | 2 | 9 | 1 | 4 | 1 |
| 11 | 1,5 | 15 | 0,3 | 6 | 0,5 |
| 13 | 1,5 | 21 | 0,2 | 8 | 0,4 |
| 17 | 1 | > 21 | 0,2 | 10 | 0,4 |
| 19 | 1 | | | 12 | 0,2 |
| 23 | 0,7 | | | > 12 | 0,2 |
| 25 | 0,7 | | | | |
| > 25 | $0,5 + 0,5 \times 25/h$ | | | | |
| **THD in HV networks**<br>% | | | | | |
| ≤ 3 | | | | | |

# Annex B
(informative)

## Interharmonic voltages on LV networks

No compatibility levels or limits are specified for interharmonic voltages, as knowledge of the electromagnetic disturbances resulting 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.

For interharmonic voltages on LV networks, some characteristic values, derived from the interharmonic voltages associated with flicker, have been published in IEC 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**

| 1 | 2 | 3 |
|---|---|---|
| **Order**<br>$m$ | **Interharmonic frequency**<br>$f_m$ Hz | **Interharmonic voltage as a percentage of $U_n$**<br>$U_m$ % |
| $0,2 < m \leq 0,6$ | $10 < f_m \leq 30$ | 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 |

# Annex C
(informative)

# Rapid voltage changes

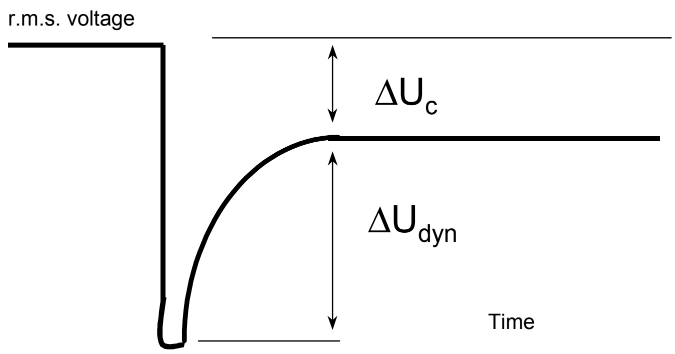
## C.1 Characteristic levels

Switching events on the utility's network or within customers' plant generally give rise to rapid voltage changes of less than 10 % on MV networks and less than 15 % on LV 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.

## C.2 Assessment method

The r.m.s. voltages are calculated using a 20 ms window and sliding this 20 ms window at 10 ms intervals.

Figure C.1 illustrates an RVC.




NOTE 1 $\Delta U_c$ is the steady state r.m.s. voltage change, and $\Delta U_{dyn}$ is the dynamic r.m.s. voltage change.

NOTE 2 A decrease in voltage is illustrated. The voltage could, however, also increase as a result of a rapid voltage change.

**Figure C.1 — Illustration of an RVC**

# Annex D
(informative)

# Voltage swells and transient overvoltages

## D.1 Voltage swells

Voltage swells experienced on the South African networks are generally due to events such as switching out large loads or sections of network, or problems with voltage control devices such as regulators, tap changes, or capacitors.

NOTE 1 Phase-to-phase voltages swells usually do not exceed 1,15 of the declared voltage.

NOTE 2 On LV systems, the loss of neutral may result in significant overvoltages at the point of supply, particularly during a fault. Such events might also cause several QOS parameters to be outside the limits specified in this part of NRS 048, and will require special or emergency action on the part of the licensee and customers.

## D.2 Transient overvoltages on LV networks

Transient overvoltages are complex phenomena that occur on networks due to lightning switching, etc. Specific instances will be dealt with in terms of the *NER directive on power quality.*

NOTE SANS 10142-1 contains guidelines regarding the provision of surge arrestors by the customer at his point of supply.

# Bibliography

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