Zambian Standard

ELECTRICITY SUPPLY – POWER QUALITY AND RELIABILITY

Part 1: Overview of Implementation and Minimum Standards
DATE OF PUBLICATION

This Zambian Standard has been published under the authority of the Standards Council of the Zambia Bureau of Standards on ……………….

ZAMBIA BUREAU OF STANDARDS


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A Zambian standard does not purport to include all the necessary provisions of a contract. Users of Zambian standards are responsible for their correct application.

TECHNICAL COMMITTEE RESPONSIBLE

This Zambian standard was prepared by the Technical Committee – Electricity Supply (ETD TC 5/8) upon which the following organisations were represented:

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Energy Regulation Board
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CONTENTS

FOREWORD .......................................................................................................................... iii
ACKNOWLEDGEMENT ......................................................................................................... iii
KEY WORDS ......................................................................................................................... iii
0. INTRODUCTION ............................................................................................................... 1
1. SCOPE ............................................................................................................................. 2
2. NORMATIVE REFERENCES ............................................................................................. 2
3. DEFINITIONS AND ABBREVIATIONS ............................................................................. 3
  3.1 DEFINITIONS ............................................................................................................. 3
  3.2 ABBREVIATIONS ...................................................................................................... 7
4. OVERVIEW OF THE IMPLEMENTATION OF QUALITY AND RELIABILITY OF
   ELECTRICITY STANDARDS AND PROCEDURES ...................................................... 8
  4.1 RELATIONSHIP BETWEEN COMPATIBILITY LEVELS AND ASSESSED LEVELS .... 8
  4.2 APPLICABILITY OF MINIMUM STANDARDS .......................................................... 9
  4.3 MEASUREMENT AND REPORTING ....................................................................... 9
  4.4 CONSUMER COMPLAINTS ................................................................................... 9
  4.5 CIRCUMSTANCES UNDER WHICH THE MINIMUM STANDARDS MIGHT NOT APPLY. 9
  4.6 RESPONSIBILITY FOR COSTS OF PQR INVESTIGATIONS ....................................... 9
  4.7 COUNTER-MEASURES INSTALLED ON CONSUMERS’ NETWORKS ....................... 10
5. MINIMUM STANDARDS .................................................................................................... 10
  5.1 VOLTAGE HARMONICS AND INTER-HARMONICS ............................................. 10
  5.2 VOLTAGE FLICKER ............................................................................................. 12
  5.3 VOLTAGE UNBALANCE ..................................................................................... 13
  5.4 VOLTAGE DIPS .................................................................................................... 13
  5.5 VOLTAGE SWELLS ............................................................................................. 15
  5.6 VOLTAGE TRANSIENTS AND SURGES ............................................................. 16
  5.7 INTERRUPTIONS ...................................................................................................... 17
  5.8 VOLTAGE REGULATION .................................................................................... 20
  5.9 FREQUENCY .......................................................................................................... 20
ANNEX A ............................................................................................................................ 22
  A.1 STANDARDS ........................................................................................................ 22
ANNEX B ............................................................................................................................ 23
RECOMMENDED PLANNING LEVELS FOR HARMONIC VOLTAGE ON HV AND EHV SYSTEMS
............................................................................................................................................... 23
ANNEX C ............................................................................................................................ 24
INDICATIVES NUMBER OF VOLTAGE DIPS PER YEAR FOR EACH CATEGORY OF DIP WINDOW
............................................................................................................................................... 24
ANNEX D ............................................................................................................................ 25
NUMBER AND DURATION OF PLANNED AND FORCED INTERRUPTIONS PER YEAR .......... 25
FOREWORD

This Zambian Standard has been prepared by the Technical Committee – Electricity Supply (ETD TC 5/8), in accordance with the procedures of the Zambia Bureau of Standards (ZABS).

The technical committee was guided by recommendations from the International Electro-technical Commission (IEC), Zambia Bureau of Standards (ZABS), Institution of Electrical Engineers (IEE), Institute of Electrical and Electronics Engineers (IEEE), British Standards Institute (BSI), and NRS of South Africa, and in reports and data available locally.

ZS 387 consists of the following parts under the general title Electricity Supply – Power Quality and Reliability:

Part 1: Overview of Implementation of Standards and Procedures
Part 2: Minimum Standards
Part 3: Measurement and Reporting Procedures
Part 4: Application Guidelines for Enterprises
Part 5: Instrumentation and Transducers for Voltage Quality Monitoring and Recording

Reference has been made to the following publication in the preparation of this standard:

ZS 387-1: 2000 Electricity Supply – Power Quality and Reliability – Code of Practice
Part 1: Overview of Implementation of Standards and Procedures

Part 2: Minimum Standards

NRS 047-1:2005 Electricity Supply Quality of Service
Part 1: Minimum standards

NRS 048-2:2007 Electricity Supply — Quality of Supply
Part 2: Voltage characteristics, compatibility levels, limits and assessment methods

ACKNOWLEDGEMENT

The Zambia Bureau of Standards would like to acknowledge the invaluable material and financial support of the Energy Regulation Board and all the institutions and stakeholders that contributed towards developing this Standard.

KEY WORDS

Power Quality and Reliability; Implementation; Standards; Procedures; Minimum standards.

COMPLIANCE WITH A ZAMBIAN STANDARD DOES NOT OF ITSELF CONFER IMMUNITY FROM LEGAL OBLIGATIONS
0. INTRODUCTION

This Standard which comprises four (4) parts provides the Zambian Electricity Supply Industry with a basis for evaluating the Power Quality and Reliability delivered to consumers by the industry, and with a means of determining whether enterprises meet the minimum standards required by the ERB. The underlying principle is that, quality, safe and reliable electricity is delivered to consumers.

It is a particular feature of electricity that, in respect of certain characteristics such as harmonics, its quality is affected by the users (as a result of the nature of the loads connected, such as electric arc furnaces, power electronic drives e.t.c) rather than only by the producers or suppliers. The supply voltage is variable because each consumer’s load varies constantly, and there is a further variation in the degree of coincidence between the demands of several consumers. For this reason, this standard deals with the voltage characteristics in statistical or probabilistic terms. It is in the economic interests of the consumer that the reference standards of supply relate to normally expected conditions rather than to abnormal or extreme contingencies, such as an unusual degree of coincidence between the demands of several large consumers or regions of supply.

This part of ZS 387 provides an overview of standards and procedures for the management of the Power Quality and Reliability in the electricity supply industry, with particular reference to the application of minimum standards to meet the requirements of the ERB. The minimum standards cover voltage quality parameters which affect the normal operation of the electricity dependent processes of consumers. Each of the voltage quality parameters is described and the minimum standards for each parameter are specified.

The minimum standards in this part of ZS 387 are intended to be applied as measures of power quality and reliability at the point of supply to end consumers of electricity enterprises.

Certain Power Quality and Reliability (PQR) parameters have been the subject of regulations of the Electricity Act, 1995 (Cap 433 of the Laws of Zambia). ZS 387 will be harmonised with the Regulations. Enterprises responsible for generation, transmission, distribution and Supply of Electricity have to co-ordinate their contractual relationships with one another, based on the requirements of ZS 387. In general, inter-enterprise agreements will have to provide for measurements in accordance with the principles set out in ZS 387, accepting that the levels for PQR parameters at inter-enterprise interfaces might be different from the levels for end consumers specified in ZS 387. Reporting on Power Quality and Reliability measurements at inter-enterprise interfaces could be required, where prescribed by the ERB. ZS 387 part 3 gives guidance on the factors to be considered in setting PQR parameters in inter-enterprise contracts, and provides planning levels for some parameters.
ZS 387 does not cover network design or equipment performance. This edition of ZS 387-part 1 does not give compatibility levels for voltage surges.

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 topography, etc., many consumers will experience considerably smaller variations of the voltage characteristics than the minimum standards given in this part of ZS 387.

Not all equipment and systems have been designed to operate optimally to the minimum standards given in this part of ZS 387, and enterprises 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 in excess of these minimum standards, countermeasures might be required at the consumer’s plant, in order to ensure acceptable performance.

Since the development of ZS 387 in 2000, some progress has been made in the gathering of data for monitoring power quality parameters in the country. The gathering of data and records which will be used to measure and report on performance, and formulate revisions of the Power Quality and Reliability standards, will continue, and ZS 387 is therefore to be regarded as an evolving specification.

The minimum standards in this part of ZS 387 could be superseded in total or in part by the terms of a contract between an individual consumer and an enterprise provided that this does not affect the third party.

1. **SCOPE**

This part of ZS 387 provides an overview of the implementation of standards and procedures for the management of Power Quality and Reliability in the electricity supply industry, with particular reference to the application of minimum standards to meet the requirements of the ERB. This part of ZS 387 also provides a glossary of terms applicable to Power Quality and Reliability.

This part of ZS 387 sets minimum standards for the quality of electricity supplied by Electricity enterprises to end consumers. It is intended to provide the Energy Regulation Board with a means of evaluating and regulating the Power Quality and Reliability provided by enterprises.

2. **NORMATIVE REFERENCES**

The following standards contain provisions which, through reference in this text, constitute provisions of ZS 387-1. All standards are subject to revision and, since any reference to a standard is deemed to be a reference to the latest edition of that standard, parties to agreements based on ZS 387-1 are encouraged to take steps to ensure the use of the most recent editions of the standards indicated below. Information on currently valid national and international standards can be obtained from the Zambia Bureau of Standards.

Electricity Act, 1995 (Cap 433 of the Laws of Zambia)

DEFINITIONS AND ABBREVIATIONS

3. DEFINITIONS

3.1 DEFINITIONS

3.1.1 Assessed level: The 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.

3.1.2 Compatibility level (electromagnetic compatibility level): The specified disturbance level at which an acceptable, high probability of electromagnetic compatibility should exist.

Notes
1. Power Quality and Reliability (PQR) 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.

2. See 4.1 for a further explanation of compatibility in the context of PQR parameters.

3.1.3 Consumer: A person or legal entity that has entered into an electricity supply agreement with an enterprise.

3.1.4 Declared voltage $U_c$: The declared supply voltage $U_c$ is normally the nominal voltage $U_n$ of the system. If by agreement between the supplier and the consumer a voltage different from the nominal voltage is applied to the terminal, then this voltage is the declared supply voltage $U_c$.

3.1.5 Developing network: A network, the construction of which has not yet reached the initially planned configuration, and from which temporary or early supply is made available to consumers by agreement, in order to avoid delayed service availability.
3.1.6 **Distribution voltage**: The set of nominal voltages that are used in power systems for distribution of electricity and whose upper limit is generally accepted to be 66 kV.

3.1.7 **Dwelling**: A place or structure of residence.

3.1.7.1 **Rural**: Clustered or scattered structures, usually of low density, pastoral or agricultural in nature, not served by a well-established infrastructure (roads, telecommunication, etc.). The power is usually supplied radially by overhead lines emanating from one distribution station.

3.1.7.2 **Urban**: Formally or informally built structures, usually of high density, served by a well-established infrastructure (roads, telecommunication, etc.). The power network is usually supplied by more than one distribution station.

3.1.8 **Enterprise (licensee)**: A body, licensed by the ERB for generation, transmission, distribution and supply of electricity.

3.1.9 **Extra high voltage (EHV)**: The set of nominal voltage levels used in power systems in the range \( U_n > 220 \text{kV} \).

3.1.10 **Frequency**: The frequency of alternating voltage generated by power system generators.

3.1.11 **High voltage (HV)**: The set of nominal voltage levels used in power systems in the range \( 33 \text{kV} < U_n \leq 220 \text{kV} \).

3.1.12 **Interruption**: A phenomenon that occurs when one or more phases of a supply to a consumer/group of consumers are disconnected for a period exceeding 3 s.

   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”. [IEC 61000-4-30].

3.1.12.1 **Forced interruption**: An 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.

3.1.12.2 **Planned interruption**: An interruption that occurs when a component is deliberately taken out of service (by the enterprise or its agent) at a selected time, usually for the purposes of construction, preventive maintenance or repair.

3.1.12.3 **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.

3.1.12.4 **Unplanned interruption on EHV and HV networks**:

   a) **momentary interruption**: unplanned interruption in the range \( > 3 \text{s} \) to \( \leq 1 \text{min} \)

   b) **sustained interruption**: unplanned interruption with a duration exceeding 1 minute

   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 \( \leq 10 \text{s} \) 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).

3.1.12.5 **Unplanned interruption on MV and LV networks**:
a) momentary interruption: unplanned interruption in the range $> 3 \text{ s to } \leq 5 \text{ min}$

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 minutes.

c) sustained interruption: unplanned interruption with a duration exceeding 5 minutes

3.1.13 Low voltage (LV): The set of nominal voltage levels that are used for the distribution of electricity and whose upper limit is generally accepted to be an a.c. voltage of 1 000 V (or a d.c. voltage of 1 500 V).

3.1.14 Medium voltage (MV): The set of nominal voltage levels that lie above low voltage and below high voltage in the range $1 \text{ kV} < U_n \leq 33 \text{ kV}$.

Note. The definitions of voltage levels of LV, MV, HV and EHV have been defined without any relationship to distribution and transmission voltage.

3.1.15 Planning level: The level to which an enterprise designs its networks when it evaluates the impact on the supply system of all loads connected to the system. These levels might change from one network to another, depending on network structure and circumstances, and are typically lower than the compatibility level.

3.1.16 Point of common coupling (PCC): That point in a network where more than one consumer is connected or will be connected.

3.1.17 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 utility (undertaker)

3.1.18 Power Quality and Reliability (PQR): Technical parameters to describe the electricity supplied to consumers, and that are used to determine the extent to which the needs of consumers are met in the utilization of electricity.

3.1.19 Site: Physical points in the electricity supply network, which have been categorised for the purpose of monitoring PQR.

3.1.20 Standard nominal voltage: The phase voltage of 230 V measured between a phase conductor and the neutral conductor, or a line voltage of $\sqrt{3} \times 230 \text{ V}$ measured between phase conductors.

3.1.21 Supply voltage dip: A sudden reduction of the supply voltage to a value between 90 % and 1% of the declared voltage $U_c$, followed by a voltage recovery after a short period of time. Conventionally the duration of a voltage dip is between 20 ms and 3 s. The depth of a voltage dip is defined as the difference between the minimum rms voltage during the voltage dip and the declared voltage. Voltage changes which do not reduce the supply voltage to less than 90 % of the declared voltage $U_c$ are not considered dips.

Voltage dips are characterized by the measurement of dip duration below the dip threshold, and by the dip magnitude (see figure 1 and Section 3.1.19 ZS 387-1).
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 utilities and customers.

A role of this specification 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 effects 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 causes problems with customers plant, a utility is still required to address the problem in terms of the incident reporting procedure outlined by the regulator.

3.1.22 Ten (10) minute r.m.s. value: The average (root mean square) value of all the samples taken during a 10-minute period

3.1.23 Transmission voltage: The set of nominal voltages that are used in power systems for bulk transmission of electricity whose range is generally accepted to be above 66 kV.

3.1.24 Voltage flicker: The modulation of the amplitude of the supply voltage, perceived by the observer as a fluctuation of light intensity in electric lighting.

3.1.25 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.

- 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:

$$ THD = \sqrt{\sum_{h=2}^{N} V_h^2} $$

where $V_h$ is the per cent r.m.s value of the $h^{th}$ harmonic or interharmonic voltage component, and $N$ is the highest harmonic considered in the calculation.
3.1.26 **Voltage regulation**: The ability of the steady-state r.m.s. voltage to remain between the upper and lower limits.

3.1.27 **Voltage swells**: A swell is a higher than normal voltage on one or more phases, normally caused by open neutral connections, insulation break down or faults on one phase causing voltage rise on other phases.

3.1.28 **Voltage unbalance**: Voltage unbalance arises in a polyphase system when the magnitudes of the phase voltages or the relative phase displacements of the phases (or both) are not equal. The unbalanced voltages can be represented by the sum of three sets of symmetrical vectors, namely:

a) the positive sequence set, consisting 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, consisting 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, consisting of three vectors, all equal in magnitude and phase.

Voltage unbalance (UB) is usually expressed as a percentage, given by:

\[ UB = \frac{V_n}{V_p} \times 100 \]

where

- \( V_n \) is the negative sequence voltage, in volts; and
- \( V_p \) 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:

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

Where

\[ \beta = \frac{V_{12}^4 + V_{23}^4 + V_{31}^4}{(V_{12}^2 + V_{23}^2 + V_{31}^2)^2} \]

and where, for example,

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

3.2 **ABBREVIATIONS**

3.2.1 **IEC**: International Electrotechnical Commission.

3.2.2 **ERB**: Energy Regulation Board.

3.2.3 **ETD**: Electrotechnical Division
3.2.4 pu: per unit.

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

3.2.6 THD: total harmonic distortion.

3.2.7 UB: unbalance.

3.2.8 UIE: Union Internationale d'Electrothermie

4. OVERVIEW OF THE IMPLEMENTATION OF QUALITY AND RELIABILITY OF ELECTRICITY STANDARDS AND PROCEDURES

4.1 RELATIONSHIP BETWEEN COMPATIBILITY LEVELS AND ASSESSED LEVELS

Figure 2 — Relative values for levels of disturbance

In this standard the concept of determining an assessed level for each PQR parameter from measured values is adopted. This concept is illustrated in figure 1. The assessed level is compared with a compatibility level which is the required minimum standard. Enterprises will generally use planning levels below the compatibility level. Consumers' equipment should, with the provision of mitigation equipment if necessary, have immunity levels higher than 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 enterprise has in the data available for planning and the type of equipment utilised by consumers. The assessment method for each parameter allows for the extreme 5 % of measured values to be discounted when calculating the assessed level.
4.2 APPLICABILITY OF MINIMUM STANDARDS

The minimum standards in this part of ZS 387 are intended to be used by the ERB as the criteria for compliance or non-compliance with acceptable PQR standards, in regulating of electricity enterprises.

The minimum requirements specified apply only at the point of supply to consumers.

Where specific network conditions make it difficult to meet these requirements for declared reasons, for example where the electrical infrastructure is under development, an enterprise may deliver levels of specified PQR parameters below the minimum requirement, with the exception of voltage regulation and frequency provided there is prior agreement with consumers.

4.3 MEASUREMENT AND REPORTING

Enterprises will not be required to demonstrate compliance at each point in their networks. Verification of continued compliance by means of regular reporting of PQR parameters from statistical samples of sites is prescribed in ZS 387-2.

An outline of the measurements and reporting procedure to be followed is given in ZS 387-2.

4.4 CONSUMER COMPLAINTS

It is not intended that the ERB receive all individual PQR complaints direct. Enterprises and their consumers are expected to have attempted to resolve issues of PQR between themselves in the first instance.

In the case of a complaint being received by the ERB, an enterprise will be given a reasonable period of time to demonstrate that it meets the requirements for PQR. This period will be determined by the ERB in conjunction with the complainant and the enterprise. Where, in turn, the enterprise requires a consumer to demonstrate that it meets the requirements for PQR obligation, a reasonable period of time, as determined in conjunction with the ERB, will be allowed.

4.5 CIRCUMSTANCES UNDER WHICH THE MINIMUM STANDARDS MIGHT NOT APPLY

The minimum standards given in this part of ZS 387 might not apply when enterprise networks are exposed to unavoidable circumstances. Examples of such circumstances are given in ZS 387-3.

The minimum requirements will also not apply in the case of a consumer’s non-compliance with his PQR obligations, but only as far as that consumer is concerned.

4.6 RESPONSIBILITY FOR COSTS OF PQR INVESTIGATIONS

The responsibility of the initial investigations will be borne by the enterprise. For details on independent investigations refer to ZS 387-2
4.7 COUNTER-MEASURES INSTALLED ON CONSUMERS’ NETWORKS

Where the reports of measured PQR parameters indicate that the minimum standards have not been achieved at a particular site, or where a sensitive consumer requires an enhanced PQR, counter-measures can be considered. Such counter-measures might include the installation of equipment within the consumer’s network by mutual agreement between the enterprise and the consumer, including the relative allocation of costs where such an installation is found to be more practical or cost effective than an installation on the enterprise’s networks.

The enterprise shall be deemed to have supplied the required PQR, even if the standards are not achieved at the point of common coupling (see 3.1.16), if the counter-measures installed within the consumer’s network have resulted in an acceptable PQR being provided.

Where counter-measures have been implemented, the reporting from the monitored site to the ERB shall be continued, and the appropriate monitored PQR data from the consumer’s plant shall also be provided to the ERB.

5. MINIMUM STANDARDS

5.1 VOLTAGE HARMONICS AND INTER-HARMONICS

5.1.1 COMPATIBILITY LEVELS

The compatibility levels for harmonics on LV and MV networks are given in table 1. The compatibility levels for signalling voltages used on power systems shall be those given in IEC 61000-2-2.

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

Notes:

1. It is intended that consumers supplied at HV will have compatibility levels written into contracts based on the recommended planning levels in ZS 387-3 (See Annex D). As an interim measure, these planning levels are provided for information in Annex A.

2. Recommended Inter-harmonic limits are given in ZS 387-3.
Table 1 — Compatibility levels for harmonic voltages (expressed as a percentage of the declared voltage of LV and MV power systems)

<table>
<thead>
<tr>
<th>Order</th>
<th>Even harmonics</th>
<th>Odd harmonics non-multiple of 3</th>
<th>Harmonic voltage</th>
<th>%</th>
<th>Odd harmonics multiple of 3</th>
<th>Harmonic voltage</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>Order</td>
<td>H</td>
<td>H</td>
<td>Harmonic voltage</td>
<td>%</td>
<td>Order</td>
<td>H</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>1,5</td>
<td>1,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>9</td>
<td>0,3</td>
<td>0,2</td>
<td>0,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>3,5</td>
<td>15</td>
<td>0,2</td>
<td>0,5</td>
<td>0,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>21</td>
<td>0,2</td>
<td>0,5</td>
<td>0,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>2 &gt;21</td>
<td>0,2</td>
<td>0,5</td>
<td>0,5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1,5</td>
<td>10</td>
<td>0,2</td>
<td>0,2</td>
<td>0,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>1,5</td>
<td>12</td>
<td>0,2</td>
<td>0,2</td>
<td>0,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1,5</td>
<td>&gt;12</td>
<td>0,2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;25</td>
<td>0,2 + 1,3 × 25/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total harmonic distortion (THD) ≤ 8 %

NOTE: For each harmonic, the harmonic voltage distortion compatibility level is given as a percentage of the magnitude of the declared (fundamental frequency of 50 ± 1 %) voltage.

5.1.2 ASSESSMENT METHOD

Measurements undertaken to determine compliance shall be carried out in accordance with the requirements for quasi-stationary measurements of IEC 61000-4-7, using an instrument of accuracy class B, as specified in IEC 61000-4-7.

All three phases of a three-phase 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.

The assessment period shall be at least 7 continuous days. The instrument samples and records each harmonic voltage at intervals of 3 s or less. These samples are summed over each 10 minute period, to obtain 10 minute root-mean-square values, \( V_{10,h} \), over each period of 24 h (00:00 to 24:00), as shown in equation 1:

\[
V_{10,h} = \sqrt{\frac{N}{2} \sum_{s=1}^{N} V_{s,h}^2}
\]

where, for the \( h \)th harmonic:

- \( V_{s,h} \) represents the measured r.m.s. values at 3 s intervals during the 10 minute period, in volts;
- \( N \) is the number of r.m.s. values within the measured 10 minute period; and
- \( h \) is the harmonic number.

Where more than one sample is calculated every 3 s, the value \( V_{s,h} \) is calculated as shown in equation 2:
where
\[ V_{o,h} = \sqrt{\frac{\sum_{N} V^2_{o,h}}{N}} \]

Equation 2

For each harmonic and for each 24 h day (00:00 h to 24:00 h), the highest 10 minute root-mean-square values which is not exceeded for 95 % of the time shall be retained as the assessed daily value.

The assessed levels which are to be compared with the compatibility levels are the highest of the assessed daily values over the full assessment period.

5.1.3 ASSESSED LEVELS

Under normal operating conditions, the assessed levels shall be less than the compatibility levels given in table 1. The assessed levels which are to be compared with the compatibility levels are the highest of the retained assessed daily values over the full assessment period.

5.2 VOLTAGE FLICKER

5.2.1 COMPATIBILITY LEVEL

For LV and MV networks, the compatibility level for short-term flicker severity (P<sub>st</sub>) is 1.0, and the compatibility level for long-term flicker (P<sub>lt</sub>) is 0.8.

5.2.2 ASSESSMENT METHOD

Measurements undertaken to determine compliance shall be carried out by measuring 10 minute values of short-term flicker severity (P<sub>st</sub>), using a UIE flickermeter that complies with the requirements of IEC 61000-4-15: 1997.

The assessment period is a minimum of 7 continuous days.

For each 24 h day (00:00 to 24:00), the highest 10 minute P<sub>st</sub> value which is not exceeded for 95 % of the time is recorded for each phase and the highest of these is retained as the daily value.

High P<sub>st</sub> values that are known to have occurred at the time of a voltage dip may be removed from the data.

The assessed levels which are to be compared with the compatibility levels are the highest daily values over the full assessment period.

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.

5.2.3 ASSESSED LEVEL

Short-term flicker severity (P<sub>st</sub>) shall be measured over a 10 minute period, and long-term flicker severity (P<sub>lt</sub>) shall be calculated over a 2 h period, as follows:
where

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

The assessed levels which are to be compared with the compatibility levels are the highest retained daily values over the full assessment period.

5.3 VOLTAGE UNBALANCE

5.3.1 COMPATIBILITY LEVEL

The compatibility level for unbalance on three-phase networks is 2 %. On networks where there is a predominance of single-phase or two-phase consumers, the assessed unbalance may be up to 3 %.

5.3.2 ASSESSMENT METHOD

The assessment period shall be a minimum of 7 continuous days.

For each 24 h day (00:00 to 24:00), the highest 10 minute root-mean-square value of unbalance which is not exceeded for 95 % of the time is retained as the daily value.

The assessed level which is to be compared with the compatibility level is the highest of the daily values over the full assessment period. The maximum 10 minute r.m.s. value (UB\textsubscript{10}) over a period of 24 h (00:00 to 24:00) is calculated as follows:

\[ UB_{10} = \sqrt{\frac{\sum_{t=1}^{N} UB^{2}_{10}}{N}} \]  

Equation 4

5.3.3 ASSESSED LEVEL

The assessed voltage unbalance shall not exceed the compatibility level at any point of supply.

The assessed level which is to be compared with the compatibility level is the highest of the daily values over the full assessment period.

5.4 VOLTAGE DIPS

5.4.1 COMPATIBILITY LEVELS

The compatibility levels for voltage dips are given in the form of a maximum number of dips per year for defined ranges of voltage dip duration and magnitude, designated as dip window categories “S”, “T”, “X”, “Y” and “Z” (see table 2).
5.4.2 THE DIP CATEGORIZATION IS BASED ON THE PHILOSOPHY THAT

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

b) utilities 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 utility fault events that actually affect the plant.

5.4.3 THE DIP CATEGORIES PROVIDE FOR

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

b) two specific types of dip category where utilities will have to specifically limit the number of dips (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 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 2 — Basis for categorization of voltage dips

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

5.5 VOLTAGE SWELLS

5.5.1 GENERAL

Voltage swells experienced on African networks are generally caused by events such as the sudden tripping of large loads or 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 over-voltages 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.

5.5.2 ASSESSMENT METHOD

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

The voltage threshold for the purpose of measuring a swell in accordance with IEC 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.

5.5.3 **COMPLIANCE CRITERIA**

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

5.6 **VOLTAGE TRANSIENTS AND SURGES**

5.6.1 **GENERAL**

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

5.6.2 **COMPLIANCE CRITERIA**

No compliance criteria are defined for voltage transients and surges.

5.6.3 **ASSESSMENT METHOD**

Enterprises shall collect data on voltage dip occurrences as detailed in ZS 387-2, so that target values and standards can be evolved.

All three phases 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 measurement accuracy in the duration of the voltage dip shall be 10 ms. The total accuracy in the minimum dip magnitude shall be ± 2.5 % of the nominal voltage. The accuracy in the logged time of occurrence shall be ± 10 minutes.

Where an individual consumer lodges a complaint that it experiences dips in excess of the annual limits given in table 2, the enterprise shall demonstrate compliance with the 95 % assessment criteria for its area of supply, and the enterprise shall enter into discussion with the consumer to seek an optimal solution to that consumer’s problem. The impact of any proposed solution shall be demonstrated to the ERB.

5.6.4 **ASSESSMENT LEVEL**

For each category of dip in the dip window, 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. These assessed numbers shall be compared with the compatibility levels (the limits for the number of dips) for each dip window category in table 2.
Figure 3 — Voltage dip window

Note – A large proportion of depth less than 20% (window “Y”) are generated in consumers’ plant

Table 3 — Limits for the number of voltage dips per year for each category of dip window

<table>
<thead>
<tr>
<th>Urban Network voltage range (see note)</th>
<th>Number of voltage dips per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dip window category</td>
</tr>
<tr>
<td></td>
<td>Z</td>
</tr>
<tr>
<td></td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Y (see note 2)</td>
</tr>
<tr>
<td>1 kV ≤ U_n ≤ 66 kV</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>300</td>
</tr>
<tr>
<td>1 kV ≤ U_n ≤ 66 kV rural</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>430</td>
</tr>
<tr>
<td></td>
<td>640</td>
</tr>
<tr>
<td>&gt; 66 kV to ≤ 220 kV</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>430</td>
</tr>
<tr>
<td></td>
<td>640</td>
</tr>
<tr>
<td>&gt; 220 kV</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
</tbody>
</table>

Note - The network voltage is not necessarily the voltage at which the consumer takes supply. It is the voltage of the network that feeds the point of common coupling.

5.7 **INTERRUPTIONS**

The maximum number of forced interruptions per year for each category of network, are specified in this sub-clause. The restoration time for forced interruptions is dealt with as a Quality of consumer service issue (ZS 397). For information see Annex C.

5.7.1 Number of forced interruptions per point of supply per year for consumers without multi-feeder contracts

5.7.1.1 Compatibility levels (number of interruptions)

The compatibility levels (number of forced interruptions) are shown in table 4.
Table 4 — Number of forced interruptions per year for consumers without multi-feeder contracts

<table>
<thead>
<tr>
<th>Category of network</th>
<th>Compatibility level (number of forced interruptions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overhead distribution</td>
</tr>
<tr>
<td>Residential established</td>
<td>6</td>
</tr>
<tr>
<td>Residential developing</td>
<td>10</td>
</tr>
<tr>
<td>Commercial/Industrial</td>
<td>6</td>
</tr>
<tr>
<td>Rural overhead up to 33 kV</td>
<td>24</td>
</tr>
</tbody>
</table>

5.7.1.2 Assessment method

Records shall be kept of the date, time and duration of all reported interruptions. As far as practicable, the reported interruptions shall be correlated with known disturbances on the network. A series of short-term interruptions due to a sequence of auto-recloser operations shall be classified as a single forced interruption (see 5.7.1.4). The number of interruptions for rural overhead networks shall be taken as the number of interruptions of duration exceeding 2 minutes.

A simple test can be used to determine if an interruption should be classified as forced or planned (see definitions of forced interruption and planned interruption). If it is possible to defer the interruption when such deferment is desirable, the interruption is a planned interruption; otherwise, the interruption is a forced one. Deferring an outage might be desirable, for example, to prevent overload of facilities or an interruption of service to consumers.

A mixed overhead and underground network should be regarded as an overhead network for determining the allowed number of forced interruptions.

Where consumers have agreed or contracted to take an interruptible supply, interruptions thus caused are excluded from the figures shown in table 4.

5.7.1.3 Assessment level

The number of forced interruptions per year shall be assessed from the information collected as set out in ZS 387-2. At least 95% of consumers shall be subject to fewer interruptions than the relevant compatibility number in table 4.

5.7.1.4 Criteria for classifying interruptions due to auto-recloser operation

In some automatic restoration sequences designed to minimize the interruption time, multiple interruptions can occur within a declared period associated with the particular event. Such multiple interruptions will be counted as one interruption.

Typically, for example, auto-reclosers will initiate a series of up to four interruptions in response to a fault. Generally this provides the affected consumer with less outage time than if the system is designed to interrupt the supply by means of breakers or drop-out fuse links which have to be manually reclosed.

If, during an auto-reclose sequence, the power is restored for a continuous time of more than 5 minutes, any subsequent interruption or sequence of interruptions will be classified as a new interruption.

5.7.2 Number of forced interruptions per point of supply per year for consumers with multi-feeder contracts
The number of forced interruptions for consumers with multi-feeder contracts shall be the subject of the particular supply contracts.

5.7.3 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 utility 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 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 classified as a voluntary load reduction event. Voluntary customer load reduction events shall neither be categorized as unplanned nor as planned interruptions, but shall be assessed separately.

5.7.4 CLASSIFICATION OF UNPLANNED INTERRUPTIONS

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

5.7.4.1 HV and EHV networks

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

5.7.4.1.2 Sustained interruptions: Unplanned interruptions of HV and EHV circuits longer than 1 minute 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 utilities 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).

5.7.4.2 MV and LV networks

5.7.4.2.1 Momentary interruptions

Unplanned interruptions of MV and LV circuits longer than 3 s and less than or equal to 5 minutes shall be classified as momentary interruptions.

5.7.4.2.2 Momentary interruption events

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 of operations shall be completed in a specified time not exceeding 5 minutes.

5.7.4.2.3 Sustained interruptions
Unplanned interruptions of MV and LV circuits longer than 5 minutes shall be classified as sustained interruptions.

5.8 VOLTAGE REGULATION

5.8.1 COMPATIBILITY LEVELS

Compatibility levels for voltage regulation are given in table 5.

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>Compatibility level</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>%</td>
</tr>
<tr>
<td>&lt; 11000</td>
<td>± 10</td>
</tr>
<tr>
<td>≥ 11000</td>
<td>± 5</td>
</tr>
</tbody>
</table>

Note — In the absence of any agreement to the contrary, the supply voltage shall not deviate from the compatibility level for any period longer than 10 consecutive minutes.

Note — Planners will have to make decisions on an economic basis, such that the infrastructure is optimally utilized, while providing consumers with acceptable voltage regulation for the majority of the time. In practice, consumers at the extreme ends of feeders might experience voltages outside the prescribed limits for short periods during times of peak or minimum load on those feeders.

5.8.2 ASSESSMENT METHOD

The assessment period is a minimum of 7 continuous days.

For each 24 h day (00:00 to 24:00), the highest 10 minutes root-mean-square values of the supply voltage within which the voltage remains for 95 % of the time are retained as the daily values. The assessed levels which are to be compared with the compatibility levels are the highest and lowest daily values over the full assessment period.

Note — When appropriate, measurements should be taken at points of supply of consumers connected to the near and far ends of the radial feeders.

5.8.3 ASSESSMENT LEVEL

At least 95% of the assessed levels shall be within the deviation from standard or declared voltages given in table 4.

5.9 FREQUENCY

5.9.1 COMPATIBILITY LEVELS

The standard frequency shall be 50 Hz, and the maximum deviation shall be:

a) for grid networks: ± 2,0 % at all times (49 Hz to 51 Hz)

b) for islanded networks: ± 5,0 % at all times (47.5 Hz to 52.5 Hz)

5.9.2 ASSESSMENT METHOD

The frequency shall be monitored continuously.
The frequency of the supply voltage shall be assessed at all points of generation.
5.9.3 ASSESSMENT LEVEL

The assessed levels which are to be compared with the compatibility levels in 5.9.1 shall be the instantaneous value of frequency.
ANNEX A
(Normative)

A.1 STANDARDS


EN 50160:1994  Voltage characteristics of electricity supplied by public distribution systems.

NRS 048 series:

NRS 048-2: 2007:  Electricity Supply — Quality of Supply
Part 2: Voltage characteristics, compatibility levels, limits and assessment methods

NRS 048-4: 1999:  Electricity Supply — Quality of Supply
Part 4: Application guidelines for utilities
ANNEX B
(Informative)

RECOMMENDED PLANNING LEVELS FOR HARMONIC VOLTAGE ON HV AND EHV SYSTEMS

Table B.1 — Indicative values of planning levels for harmonic voltage (expressed as a percentage of the rated voltage of HV and EHV power systems)

<table>
<thead>
<tr>
<th>Odd harmonics non-multiple of 3</th>
<th>Odd harmonics multiple of 3</th>
<th>Even harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order</strong></td>
<td><strong>Harmonic voltage HV-EHV %</strong></td>
<td><strong>Order</strong></td>
</tr>
<tr>
<td>h</td>
<td></td>
<td>h</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>13</td>
<td>1.5</td>
<td>21</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>&gt; 21</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>&gt; 25</td>
<td>0.2 + 0.5 × 25/h</td>
<td></td>
</tr>
</tbody>
</table>

Total harmonic distortion (THD) ≤ 3 % in HV networks
ANNEX C
(Informative)

INDICATIVE NUMBER OF VOLTAGE DIPS PER YEAR FOR EACH CATEGORY OF DIP WINDOW

Table C.1 — Indicative targets for the number of voltage dips per year for each category of dip window

<table>
<thead>
<tr>
<th>Network voltage range (see note)</th>
<th>Number of voltage dips per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
</tr>
<tr>
<td>1 kV to ≤ 66 kV</td>
<td>10</td>
</tr>
<tr>
<td>1 kV to ≤ 66 kV rural</td>
<td>20</td>
</tr>
<tr>
<td>&gt; 66 kV to ≤ 220 kV</td>
<td>5</td>
</tr>
<tr>
<td>&gt; 220 kV</td>
<td>2</td>
</tr>
</tbody>
</table>

Note — The network voltage is not necessarily the voltage at which the consumer takes supply. It may be the voltage of the network that feeds the point of common coupling. Therefore, the set of Z, T, S, X and Y values applicable to a consumer should be evaluated in each case, taking account of the network configuration supplying that consumer.
### ANNEX D

(Informative)

### NUMBER AND DURATION OF PLANNED AND FORCED INTERRUPTIONS PER YEAR

Table D.1 — Number and duration of forced and planned interruptions per year for consumers without multi-feeder contracts

<table>
<thead>
<tr>
<th>Category of network</th>
<th>Planned interruptions</th>
<th>Forced interruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overhead distribution</td>
<td>Underground distribution</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Total duration h</td>
</tr>
<tr>
<td>Residential established</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Residential developing</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Commercial/ small to medium industrial</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Rural overhead (≤ 33 kV)</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Notes:
1. For the purposes of this part of ZS 387, the categories listed in column 1 are categories of network, not of consumer (for example, a consumer might operate a commercial enterprise in an area that has been designed to serve residential consumers).
2. The numbers and durations for overhead distribution assume bare conductors. These figures will also apply when aerial bundled conductors (ABC) are being assessed, but in general, better performance could be expected from ABC systems.