Rationalized User Specification

ELECTRICITY SUPPLY — QUALITY OF SUPPLY

Part 3: Procedures for measurement and reporting

Requirements for applications in the Electricity Supply Industry
This Rationalized User Specification is issued by the NRS Project on behalf of the User Group given in the foreword and is not a standard as contemplated in the Standards Act, 1993 (Act 29 of 1993).

Rationalized user specifications allow user organizations to define the performance and quality requirements of relevant equipment.

Rationalized user specifications may, after a certain application period, be introduced as national standards.

Amendments issued since publication

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<thead>
<tr>
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</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

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Foreword

The needs of the National Electricity Regulator (NER) and the licensees were taken into account in the preparation of this part of NRS 048, to provide uniform monitoring and reporting procedures in respect of quality of supply (QOS) performance. This part of NRS 048 was compiled by a working group on behalf of the Electricity Suppliers Liaison Committee (ESLC), based on the work initiated by the NER.

The working group, which was appointed by the ESLC, comprised the following members:

A J Dold (Chairman) eThekwini Metropolitan Electricity
P Balgobind NER
D Bhana Eskom Transmission Group
A Botha Eskom Distribution Group
S Coghill Kimberley Municipality
D H Cretchley Eskom Resources and Strategy Group
D Erasmus Energy Intensive User Group
P A Johnson (Project Leader) NRS Project Management Agency
R G Koch Technology Services International, Eskom Enterprises
M W Küster City of Cape Town
I Langbridge Mondi Paper
L Maminza Mondi Kraft
J Marabwa Eskom Transmission Group
G R Marloth City Power (Pty) Ltd, Johannesburg
N J Masango NRS Project Assistant
M V Nkalashe NER
D Nxumalo Hillside Smelter
M T Outram Nelson Mandela Metropolitan Municipality
C F Schult Tshwane Electricity
R van der Riet Tygerburg Municipality
M Wilson East Gauteng Services Council

At the time that the ESLC accepted this edition of NRS 048-3, it comprised the following members:

R Wienand (Chairman) eThekwini Metropolitan Council, AMEU
M N Bailey Distribution Technology, Eskom
A J Claassens Electrotechnical Engineering Standards, SABS
N Croucher City of Cape Town, AMEU
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A H L Fortmann AMEU
P A Johnson Technology Standardization, Eskom
D Kruger Chamber of Mines
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J Machinjike Transmission Group, Eskom
D M Michie Nelson Mandela Metropolitan Municipality, AMEU
A J van der Merwe Mangaung Electricity, AMEU
J S van Heerden SABS NETFA
P J S van Niekerk City Power Johannesburg (Pty) Ltd, AMEU
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.

**Part 2:** Minimum standards. (Under review).

**Part 3:** Procedures for measurement and reporting.

**Part 4:** Application guidelines for utilities.

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

The third edition of this part of NRS 048 was prepared to bring it in line with the revised requirements for reporting, as agreed with the NER. Editorial improvements have also been made to aid understanding of the information to be provided to the NER. It takes account of the limitations of what information can be reported from currently installed network performance systems, and recognizes the need of the NER to have customer-based reporting systems in the future.

Annex A is for information only.

Recommendations for corrections, additions or deletions should be addressed to the NRS Projects Manager, c/o The Electrotechnical Standards Manager, SABS, Private Bag X191, Pretoria, 0001.

**Introduction**

In order to audit the quality of electricity supplied by the electricity supply industry, the NER will require licensees to install suitable measuring equipment at sufficient locations in their electrical networks to adequately characterize and report performance in terms of this part of NRS 048. In terms of the needs and principles of economical and affordable electricity supply in South Africa, it is essential to achieve a balance between the cost and the adequacy of the measurement strategy.

This part of NRS 048 specifies minimum requirements for QOS measurement at sites where customers are connected. Licensees should note that additional monitoring could be required to establish the QOS at bulk supply points and at other major network nodes. In addition, the temporary installation of specialized equipment might be necessary to investigate customer complaints.

**Key words**

Quality of supply; Measurements; Reporting; Electricity Supply Industry.
SPECIFICATION

Electricity supply — Quality of supply

Part 3: Procedures for measurement and reporting

Requirements for applications in the Electricity Supply Industry

1 Scope

This part of NRS 048 specifies minimum requirements for the measurement of quality of supply (QOS) parameters for electricity by licensees, and the reporting of QOS parameters by non-generating licensees to the NER.

NOTE Reporting to the NER by generating licensees is covered by the NER in its own report formats.

2 Normative references

The following specifications contain provisions which, through reference in this text, constitute provisions of this part of NRS 048. At the time of publication, the editions indicated were valid. All specifications are subject to revision, and parties to agreements based on this part of NRS 048 are encouraged to investigate the possibility of applying the most recent editions of the specifications listed below. Information on currently valid national and international standards and specifications can be obtained from the South African Bureau of Standards.

NRS 048-1: Electricity supply — Quality of supply — Part 1: Overview of implementation of standards and procedures.


NRS 048-5: Electricity supply — Quality of supply — Part 5: Instrumentation and transducers for voltage quality monitoring and recording.

3 Definitions and abbreviations

For the purposes of this part of NRS 048, the definitions and abbreviations given in NRS 048-1 and the following apply:

3.1 Definitions

3.1.1 system-minutes: A unit used to measure the relative loss of supply in an electricity supply network.

NOTE System-minutes lost are calculated as:
The load interrupted (in MW or MVA) multiplied by the duration of the interruption (in minutes), divided by the total system simultaneous maximum demand (in MW or MVA) (see 4.6.3).

3.1.2 installed system-minutes: A unit used to approximate a measure of the relative loss of supply in an electricity supply network.

NOTE Installed system-minutes lost are calculated as:
The sum of installed transformer capacity and direct connected loads interrupted (in MW or MVA) multiplied by the duration of the interruption (in minutes), divided by the total system installed capacity (in MW or MVA) (see note 2 to 4.6.3).
3.2 Abbreviations

3.2.1 QOS: Quality of supply.

3.2.2 THD: Total harmonic distortion.

4 Requirements

4.1 General

4.1.1 The QOS to customers will be continuously measured on a network sample basis, as specified in 4.4.

4.1.2 The availability of supply shall be measured through collating MV and HV network outage data as specified in 4.6.

4.1.3 Data shall be recorded as indicated in this part of NRS 048, and results shall be reported to the NER annually. The NER is expected to publish a report indicating the extent of compliance with the national minimum standards and the comparative performance of networks.

4.1.4 If a QOS complaint is referred to the NER by an electricity customer, the veracity of the complaint shall be established using the procedure specified in 4.5.

4.2 Format of information to be submitted to the NER

The NER requires the periodic return of information collected on QOS parameters and related data. Forms issued by the NER for this purpose are based on tables 1 to 17 of this part of NRS 048.

NOTE Licensees should take account of the stated need of the NER to correlate the network performance with the number and categories (as defined by the NER) and type of customers affected. To this end, network fault reporting systems will be required to be integrated with data that are normally maintained in the licensee's customer database. Typical international sustained interruption indices are as follows:

a) system average interruption frequency index (SAIFI) is total number of customer interruptions divided by the total number of customers served;
b) system average interruption duration index (SAIDI) is $\sum$ customer interruption durations divided by the total number of customers served;
c) customer average interruption duration index (CAIDI) is $\sum$ customer interruption durations divided by total number of customers interrupted; and
d) customer average interruption frequency index (CAIFI) is the total number of customer interruptions divided by the total number of customers interrupted.

A guide for electric power distribution reliability indices, IEEE P1366 is available from the IEEE. This guide could be used as the basis for establishing reliability indices for reporting to the NER in future. (See bibliography.)

Licensees shall provide the NER with a separate return of information for each logical area of electricity distribution within their licensed areas of supply. For example, Eskom would submit a separate return for each of its various districts. A metropolitan area with four substructures would provide a separate return for each substructure, while data in each of these areas are being separately maintained. Where there is any doubt as to what constitutes a logical area of supply, the NER should be consulted for a ruling. A “logical area of supply” is referred to in this part of NRS 048 as a “distribution area”.

A licensee shall advise the NER of any planned changes in the demarcation of logical areas of distribution.
In the case of each logical area of supply, the following data shall be acquired by licensees and submitted annually as directed by the NER:

a) customer and network data (see tables 1 to 5);
b) QOS instruments installed (see table 7);
c) QOS measurement statistics recorded (see tables 8 to 13); and
d) MV and HV forced outage performance (see tables 14 to 17).

4.3 Customer and network data

4.3.1 General

Unless stated otherwise, all customer and network data shall be records of the customers and equipment in the distribution area as at the first day of the period covered by the return.

4.3.2 Maximum diversified demand

The maximum diversified demand, in megavolt-amperes or megawatts, shall be taken as the maximum sum of simultaneous integrated half-hourly or hourly load measurements during the twelve-month period before the start of the period covered by the return, for the logical area of distribution under consideration. The maximum diversified demand of each distribution area shall be recorded as shown in table 1.

<table>
<thead>
<tr>
<th>Distribution area name(s)</th>
<th>Maximum diversified demand in MVA or MW</th>
</tr>
</thead>
</table>

4.3.3 Details of bulk intake points

Data for each bulk intake point shall be recorded as shown in table 2.

NOTE “Bulk intake points” refer to points where the designated distribution area receives a bulk (metered) supply of electricity. In the case of security of supply, there is likely to be more than one intake circuit at each bulk intake point.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Number of intake points</th>
<th>No. of intake circuits</th>
</tr>
</thead>
</table>

4.3.4 Number of customers

In the case of each site category, as defined in 4.4.1, the number of customers directly connected, and the number of sites monitored shall be recorded as shown in table 3.

Large-demand customers shall be listed as shown in table 4.
Table 3 — Number of customers and number of sites monitored

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Site definition</th>
<th>Number of customers directly connected at each site categorya</th>
<th>No. of sites monitored</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Residential developed ≤ 1 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>Residential developing ≤ 1 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1C</td>
<td>Commercial/industrial ≤ 1 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1D</td>
<td>Rural overhead ≤ 1 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LV (Subtotal):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>Rural overhead &gt;1 kV to ≤ 22 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>Urban &gt;1 kV to ≤ 22 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MV distribution (Subtotal):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&gt; 22 kV to ≤ 44 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&gt; 44 kV to ≤ 132 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt; 132 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Generators</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a The number of customers shall include any customers that are temporarily disconnected as at the first day of the period covered by the return.

b Enter number of generating stations defined in 4.4.1.

Table 4 — List of large-demand customers (maximum demand > 5 MVA)

<table>
<thead>
<tr>
<th>Customer name</th>
<th>Supply voltage kV</th>
<th>Notified maximum demand MVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3.5 Plant details

Plant details shall be recorded as shown in table 5.

Transformers shall be grouped according to their primary voltage, and nominal ratings shall be used to calculate installed capacity.

The total reactive compensation capacity shall be reflected in the voltage category at which the compensation equipment is connected. Compensation includes static plant and rotating plant that have been installed specifically for the purpose of reactive compensation.

Service connections shall be excluded from the LV network data.

Circuit kilometres shall be estimated where precise information is unavailable.

Circuit lengths for multiple circuit overhead feeders shall be accounted for on a per-circuit basis.
### Table 5 — Plant details

<table>
<thead>
<tr>
<th>Network category</th>
<th>Overhead lines</th>
<th>Cables</th>
<th>Installed capacity of transformers (excluding interposing transformers(^a))</th>
<th>Reactive volt-ampere capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length of circuits km</td>
<td>Length of circuits km</td>
<td>Number</td>
<td>Total capacity MVA</td>
</tr>
<tr>
<td>1 LV only (≤ 1 kV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Rural overhead: 1 kV to ≤ 22 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Urban: 1 kV to ≤ 22 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MV distribution: Subtotal 2 + 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 &gt; 22 kV to ≤ 44 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 &gt; 44 kV to ≤ 132 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 &gt; 132 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal 4 + 5 + 6</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (MV +HV):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Interposing transformers (or coupling transformers) are those that do not contribute directly to the capacity to supply customers. For example, 22 kV/11 kV transformers that interconnect 22 kV networks to 11 kV networks shall be excluded from the transformer capacity in this table.

### 4.4 Sampling measurements

#### 4.4.1 Classification of sites for measurement purposes

For the purposes of QoS measurements, sites are classified in ten categories, as indicated below. Measuring instruments shall be permanently installed at sites categories 2 to 6. Measuring instruments at sites categories 1A to 1D shall be installed periodically, in particular during seasonal periods of high load to sample specific LV networks, to verify that the voltage quality complies with the design parameters, taking into account the compatibility levels and limits specified in NRS 048-2 (see note). In the case of site categories 1A to 2B, instruments shall be connected at the points of supply to customers, wherever practicable; alternatively, they shall be connected at the point where the service connection is connected to the supply network. In the case of site categories 3 to 5, instruments shall be connected at the points of supply, by means of measurement voltage transformers. In the case of site category 6, instruments shall be connected at the busbars by means of measurement voltage transformers.

**NOTE** No minimum frequency for sampling specific LV networks is given. The decision to sample voltage quality on LV networks will be dependent on factors such as the licensee’s power quality management programme and the rate of load growth on specific LV networks, and might be guided by customers complaints.

- **Category 1A** sites are defined as points of supply in developed urban LV networks that predominantly serve residential customers and that operate at voltages not exceeding 1 kV.
- **Category 1B** sites are defined as points of supply in developing urban LV networks that predominantly serve residential customers and that operate at voltages not exceeding 1 kV.
- **Category 1C** sites are defined as points of supply in urban LV networks that predominantly serve commercial or industrial customers and that operate at voltages not exceeding 1 kV.
- **Category 1D** sites are defined as points of supply on LV networks that operate at voltages not exceeding 1 kV; these points of supply are supplied by means rural MV overhead networks that operate at voltages not exceeding 22 kV.
Category 2A sites are defined as points on rural MV overhead networks that operate at voltages exceeding 1 kV, but not exceeding 22 kV and at which end customers are connected direct.

Category 2B sites are defined as points on urban MV networks that operate at voltages exceeding 1 kV, but not exceeding 22 kV and at which end-customers are connected direct.

Category 3 sites are defined as points in MV distribution systems that operate at voltages exceeding 22 kV but not exceeding 44 kV and at which end customers are connected direct.

Category 4 sites are defined as points in HV transmission systems that operate at nominal voltage levels exceeding 44 kV but not exceeding 132 kV and at which end customers are connected direct.

Category 5 sites are defined as points in HV transmission systems that operate at nominal voltage levels exceeding 132 kV and at which end customers are connected direct.

Category 6 sites are defined as the busbars of permanent generating stations and facilities that produce an output that is ultimately sold to customers.

4.4.2 Measurements required at each site category

The minimum requirements for the measurement of QOS parameters at each of the site categories referred to in 4.4.1 are shown in table 6.

Flicker measurements are only required when real or potential flicker problems have been reported by customers.

NOTE For details on reporting the QOS parameters measured at monitored sites, see 4.4.5.

4.4.3 Number of sites to be monitored

Each licensee shall advise the NER on the results of all QOS monitoring. Such monitoring shall be integrated into a quality management system, so that the results demonstrate to the satisfaction of the NER that the minimum standards of QOS as specified in NRS 048-2 are being met. Such monitoring shall include sample monitoring of sites on a continuous basis as specified in table 6, and should include sampling of the voltage regulation of specific LV networks, and, if appropriate, other parts of the licensee’s network, to verify the planning parameters for that area. Planning parameters shall be based on the practices set out in NRS 048-4.

The transmission network operator shall monitor and report on all parameters given in table 6 at all bulk supply points to distribution licensees.
# Table 6 — Parameters to be measured at site categories

<table>
<thead>
<tr>
<th>Site categories</th>
<th>Site definition</th>
<th>Minimum customer sample size for continuous monitoring</th>
<th>Harmonics a b</th>
<th>Voltage Unbalance c</th>
<th>Voltage dips</th>
<th>Interruptions d</th>
<th>Voltage magnitude e f</th>
<th>Frequency g</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>Rural overhead 1 1 kV to ≤ 22 kV</td>
<td>2.0</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>Urban &gt; 1 kV to ≤ 22 kV</td>
<td>2.0</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&gt; 22 kV to ≤ 44 kV</td>
<td>2.0</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&gt; 44 kV to ≤ 32 kV</td>
<td>10.0</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&gt; 132 kV</td>
<td>10.0</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Generators</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a At least the 5th, 7th, 11th and 13th harmonic and THD shall be measured in the sample measurements.

b The number of days during the assessment period that the level of any harmonic or the THD level exceeds the applicable compatibility level given in NRS 048-2, shall be recorded.

c The number of days during the assessment period that the unbalance exceeds the applicable compatibility level given in NRS 048-2, shall be recorded.

d The number of days during the assessment period that the voltage magnitude falls outside the applicable compatibility levels given in NRS 048-2, shall be recorded.

e The number of days during the assessment period that the frequency falls outside the applicable compatibility levels given in NRS 048-2, shall be recorded.

f Where applicable, at least one of the monitored sites shall be at the end of a rural feeder.

g In cases where there are a large proportion of MV customers and where harmonics might be cause for concern, it is recommended that at least one portable QOS instrument, capable of measuring harmonics, be available for installation at several sites on a rotating basis.

## 4.4.4 Instrumentation

Instrumentation shall comply with the applicable requirements of NRS 048-5.

NOTE SABS 1816, a national standard for QOS instruments, is under consideration, and is expected to incorporate the measurement methods to be specified in IEC 61000-4-30. SABS 1816 proposes two classes of instrument:

a) Class A, intended for near limit assessments, which would conform strictly to the sampling requirements of the international standard; and

b) Class B, intended for measurements for the purpose of collecting sampling statistics as required in 4.4.5, which would conform to local specifications, such as those currently specified in NRS 048-5.

Instrumentation used to collect statistical data shall have its basic calibration checked periodically, as recommended by the instrument supplier.

In addition, instrumentation used to collect data for use in potential contractual disputes with customers shall be certified as having been calibrated with instruments that are traceable to national calibration standards.
Licensees shall keep an inventory of all QOS instruments in use in the licensed area of supply during the period of reporting. This shall include instruments used by a service provider contracted to provide a QOS monitoring service for licensees. The instruments in use shall be listed as shown in table 7.

Table 7 — QOS instruments in use

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Instrument type i.e. A, B or C (see NRS 048-5)</th>
<th>Serial number</th>
<th>Date purchased</th>
<th>Last calibration date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.4.5 Sampling statistics

4.4.5.1 General

All sites for which measurements are available shall be listed and the details recorded in the appropriate of table 8 to 13.

4.4.5.2 Interruptions

Table 8 shows the format of data required in order to record all supply interruptions, forced and planned, measured at sites monitored in accordance with the statistical sampling prescribed in table 6 (see 4.4.3). This table shall be completed with like site categories grouped together.

Table 8 — Sampling statistics: Interruptions

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site category (see 4.4.1)</td>
<td>Instrument location</td>
<td>Period monitored</td>
<td>Nominal voltage kV</td>
<td>Interruptions</td>
<td>Number a</td>
<td>Duration b min</td>
</tr>
<tr>
<td>Name 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) The number of interruptions will comprise both forced and planned interruptions.
b) Enter the sum of all durations of supply interruption.
c) Where a site is served by a hybrid network, the predominant network type should be entered.

4.4.5.3 Voltage harmonics

Table 9 shows the format of data to be provided in order to record all incidents where planning levels (see annex A of NRS 048-2) are exceeded in the case of voltage harmonics measured at sites monitored in accordance with the statistical sampling prescribed in table 6. Out-of-limit violations for each monitored location and for each harmonic order, including THD, shall be recorded.
### Table 9 — Out-of-limits incidents for voltage harmonics

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Instrument location</th>
<th>Period monitored d</th>
<th>Nominal voltage kV</th>
<th>Harmonic order or THD exceeded</th>
<th>No. of days the planning level was exceeded d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

#### 4.4.5.4 Voltage unbalance

Table 10 shows the format of data to be provided to record all out-of-limits incidents of voltage unbalance (see NRS 048-2) measured at sites monitored in accordance with the statistical sampling prescribed in table 6.

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Instrument location</th>
<th>Period monitored d</th>
<th>Nominal voltage kV</th>
<th>No. of days the unbalance limit was exceeded d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

### Table 10 — Out-of-limits incidents for voltage unbalance

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Instrument location</th>
<th>Period monitored d</th>
<th>Nominal voltage kV</th>
<th>No. of days the unbalance limit was exceeded d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.4.5.5 Voltage dips

Table 11 shows the format of data to be provided in order to record all voltage dips (see NRS 048-2) measured at sites monitored in accordance with the statistical sampling prescribed in table 6.

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Instrument Location</th>
<th>Period Monitored d</th>
<th>Nominal Voltage kV</th>
<th>Number of voltage dips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Z°</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

#### 4.4.5.6 Voltage magnitude

Table 12 shows the format of data required in order to record all out-of-limits incidents of voltage magnitude (see NRS 048-2) measured at sites monitored in accordance with the statistical sampling prescribed in table 6.
Table 12 — Voltage magnitude (all site categories)

<table>
<thead>
<tr>
<th>Site category (see 4.4.1)</th>
<th>Instrument location</th>
<th>Period monitored d</th>
<th>Nominal voltage kV</th>
<th>No. of days the limit was exceeded d</th>
<th>Total period recorded min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Above limit</td>
<td>Below limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Above limit</td>
<td>Below limit</td>
</tr>
</tbody>
</table>

4.4.5.7 Frequency
Table 13 shows the format of data required in order to record all out-of-limits incidents of frequency (see NRS 048-2) measured at generators.

Table 13 — Frequency (generators only)

<table>
<thead>
<tr>
<th>Station or unit name</th>
<th>Period monitored d</th>
<th>Grid or islanded</th>
<th>No. of days that limit was exceeded d</th>
<th>Total period recorded min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Above limit</td>
<td>Below limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Above limit</td>
<td>Below limit</td>
</tr>
</tbody>
</table>

4.5 Measurements in the event of customer QOS complaints

4.5.1 In the event of the licensee receiving a complaint about the quality of electricity supplied to a customers, the licensee shall attempt to resolve this by analysis of the prevailing circumstances and expected changes that will affect the QOS to the customer concerned. This might require the temporary installation of specialized measuring equipment in order to investigate the complaint.

4.5.2 If a complaint of poor QOS is referred to the NER, the following procedure is expected to be applied in an attempt to resolve the issue (It should, however, be noted that the NER shall be regarded as an institution of last resort for resolving complaints of poor QOS.):

a) The NER would first refer the customer to the licensee for resolution of the complaint.

b) If the licensee and the customer cannot reach an agreement, they should refer the complaint back to the NER, who would then call for

1) the results of the monitoring carried out and additional measurements taken, and
2) any other records maintained by the licensee.

c) If the information provided in terms of 4.5.1 is insufficient to enable the NER to resolve the complaint, the licensee shall appoint a QOS consulting body that is acceptable to the NER and the licensee, to investigate the licensee’s network and to advise the NER as to the technical QOS delivered.

The costs of the consulting body’s investigation shall be carried as follows:

a) if the licensee does not comply with the minimum requirements, the costs shall be recovered from the licensee; and
b) if the licensee complies with the minimum requirements, the costs shall be recovered from the customer.

The amount to be recovered from a customer for a QOS investigation may be limited to a fee set by the licensee to approximate the average cost of the required test(s), and should depend on the size/category of the customer.

4.6 MV and HV forced interruption statistics

4.6.1 Forced interruption indices

Only the annual calculated indices for all forced interruptions in each logical area of distribution and in the licensee’s total area of supply shall be submitted to the NER for the stipulated period in the return of forced interruption indices. Licensees should, however, maintain their own records of indices for each forced interruption and take these into account when calculating month-end totals.

Two sets of indices are required:

a) MV network indices, which reflect the effects of MV network interruptions on groups of LV customers (table 14), and

b) MV/HV network indices, which reflect the overall system performance (see table 15), used mainly for trend purposes per licensee.

In addition, the effect of interruptions on individual large usage customers shall be reported as in table 16.

A worked example for the calculation of forced interruption indices as set out in 4.6.2 and 4.6.3 is provided in annex A.

4.6.2 MV distribution network forced interruption indices (≤ 22 kV)

4.6.2.1 Forced interruptions in MV networks up to and including 22 kV, categorized as shown in table 14, shall be reported as indices derived as follows:

\[ F_1 = \frac{AB}{T} \]

where

- \( F_1 \) is the forced interruption index, in hours;
- \( A \) is the loss of supply, measured, for the sake of simplicity, as the sum of the installed transformer capacity, in kilovolt-amperes, connected to the MV circuit affected by the forced supply interruption, plus the maximum demand or installed capacity of any customers connected direct to that circuit (see note 1);
- \( B \) is the duration of the forced interruption, in hours (see also 4.6.2.2, 4.6.2.3 and note 2); and
- \( T \) is the total installed capacity, in kilovolt-amperes, and equals the transformer capacity connected to the MV networks (see note 3), plus the sum of the maximum demand of customers connected direct to those networks (see note 1).

NOTE 1 The maximum demand or installed capacity of a customer can be determined by any declared means. In practice, it will be convenient to use the highest recorded demand for the previous year.

NOTE 2 Short-term interruptions caused by successful auto-reclose operations are classified as specified in NRS 048-2.

NOTE 3 The total transformer capacity in each category of network is that specified in table 5.
4.6.2.2 For the purposes of the calculation, the duration of any forced interruption is measured either from the time of receipt of the first customer complaint, or from the first alarm/supervisory indication, whichever happens first, until restoration of supply to all customers affected by that forced interruption.

4.6.2.3 Where separate sections of the faulted network are restored progressively, the index may be calculated separately for each stage of the restoration, if this would give a result significantly different from an overall index for the incident that caused the interruption.

4.6.2.4 MV network forced interruptions shall be categorized as follows:

a) MV distribution: loss of supply because of a fault on a network at 22 kV and below;
b) HV/MV: loss of supply to a network of 22 kV and below, that results from a fault on the licensee’s transmission/distribution network at a voltage higher than 22 kV, or from loss of MV supply at a major step-down or main substation (for example, because of an 11 kV fault on the switchboard of a 132 kV/11 kV substation); and
c) bulk intake: loss of supply to a network of 22 kV and below, that results from a loss of supply at a bulk intake point.

Table 14 — Medium voltage distribution network forced interruption indices (≤ 22 kV)

<table>
<thead>
<tr>
<th>Source of interruption</th>
<th>Forced interruption indices ($F_1$) h</th>
<th>Overall Indices (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV/MV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk intake</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.6.3 MV and HV network forced interruption indices (> 22 kV)

Table 15 shows the format of data on forced interruptions on networks that operate at voltages exceeding 22 kV, including data on MV faults of up to 22 kV at the switchboards of major step-down or main substations (for example, where a forced interruption is caused by an 11 kV fault on the switchboard of a 132 kV/11 kV substation).

Such forced interruptions and interruptions caused by the loss of supply at bulk intake points, shall be recorded in terms of an index, in system-minutes, calculated as follows:

$$F_2 = LE$$

where

$F_2$ is the forced interruption index, in system-minutes;
$L$ is the actual loss of load (measured or assessed), in megavolt-amperes, or, alternatively, in megawatts;
$E$ is the duration of the forced interruption, in minutes (see also 4.6.2.1 and 4.6.2.2);
$F$ is the total system simultaneous maximum demand, in megavolt-amperes or, alternatively, in megawatts (see 4.3.2).
NOTE 1 Where MVA figures are not available, MW figures may be used for \( L \) and \( F \).

NOTE 2 Where licensees are unable to determine interruption indices \( F_2 \) as per procedure, the interruption indices for network categories of \( \leq 132 \text{kV} \) only, may be approximated by:

\[
F_3 = \frac{AB}{S}
\]

where

- \( F_3 \) is the forced interruption index, in installed system-minutes;
- \( A \) is the loss of supply, measured, for the sake of simplicity, as the sum of the installed transformer capacity, in kilovolt-amperes, connected to the networks affected by the forced supply interruption, plus the maximum demand or installed capacity of any customers connected direct to those networks;
- \( B \) is the duration of the forced interruption, in minutes;
- \( S \) is the total system transformer capacity, in kilovolt-amperes, minus the capacity of interposing (coupling) transformers connected to the networks, plus the sum of the maximum demand of customers connected direct to those networks.

### Table 15 — MV/HV network forced interruption indices

<table>
<thead>
<tr>
<th>Network voltage category *</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV: ≤ 22 kV at step-down or main substations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV: &gt; 22 kV to ≤ 44 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV: &gt; 44 kV to ≤ 132 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV: &gt; 132 kV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) In the case of incidents that occur on the licensee’s networks, the interruption indices shall be entered in column 3. Only one entry per event shall be made in the table in the network voltage category in which the faults originated. For example, if a fault in the HV: > 132 kV network voltage category results in loss of load in the lower voltage categories, the index entered in the HV: > 132 kV category shall reflect the total load lost. In the case of bulk supply failures, the interruption indices are to be entered in column 4 and in the network voltage category in which the bulk supply is received. The overall index for each network voltage category is a measure of the effect of all interruptions on customers in that voltage category.

b) The base is either \( F \), the total simultaneous maximum demand, or \( S \), the total system transformer capacity summated across all network voltage categories.

4.6.4 Forced interruptions to large-usage customers

Table 16 shows the format of data required on forced interruptions to large-usage customers, who, for the purposes of reporting to the NER, are customers that have a maximum demand exceeding 5 MVA. Each incident shall be recorded separately. In case of multiple infeed circuits to a customer of this category, the forced interruptions of one or more circuits without resultant loss of supply shall be excluded.

### Table 16 — Forced interruptions to large-usage customers

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer name</td>
<td>Maximum Demand MVA or MW</td>
<td>Estimated loss of load MVA or MW</td>
<td>Date of incident</td>
<td>Duration of Interruption min.</td>
</tr>
</tbody>
</table>
4.6.5 Major supply interruptions

Table 17 shows the format of data required for any single event that resulted in the loss of supply to a large area or to large-usage customers, such that the loss of load resulted in a forced interruption index greater than 5 system-minutes.

Table 17 — Major supply interruptions (> 5 system-minutes )

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident</td>
<td>Primary fault location a</td>
<td>Primary cause of incident b</td>
<td>Estimated maximum loss of load MVA or MW</td>
<td>Duration of interruption min.</td>
<td>Forced interruption index system-minutes</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total

NOTE Major supply interruptions are also included in other tables, where applicable.
a Enter site categories as in accordance with 4.4.1.
b Select applicable incident code from the list below.

The primary cause of interruptions shall be categorized as follows:

**Equipment failure:**
- A1: dielectric breakdown (includes breakdown due to pollution)
- A2: mechanical failure
- A3: broken conductor
- A4: other

**Operational causes:**
- B1: incorrect protection operation
- B2: incorrect control equipment operation
- B3: operator error
- B4: other

**Third-party causes:**
- C1: contractors
- C2: motor vehicle accidents
- C3: theft
- C4: customer’s protection failed to clear a fault, etc.
- C5: human interference (unrelated to the operation or maintenance of the network)
- C6: other

**Natural events:**
- D1: lightning
- D2: wind/storm
- D3: veld/sugar cane fires
- D4: birds
- D5: other

**Bulk intake:**
- E1: loss of supply due to technical problem
- E2: loss of supply due to non-payment
- E3: other

**Unknown:**
- F1: interruptions for which there is no known cause
Annex A
(informative)

Worked example for the calculation of forced interruption indices

A.1 General

This example is based on a distribution licence with the following statistics and faults:

a) Maximum demand during previous year = 400 MVA/380 MW

b) Installed transformer capacity (totals for the licensee) —
   - > 22 kV primary = 800 MVA
   - ≤ 22 kV primary — urban = 900 MVA
   - ≤ 22 kV primary — rural = 200 MVA
   - Total for licensee = 1 900 MVA

c) Fault incidents causing forced interruptions (See the schematic diagram in figure A.1) —
   - Fault F1 - Actual loss of 350 MVA for 5 min.
   - Fault F2 - Actual loss of 45 MVA for 40 min.
   - Fault F3 - Actual loss of 30 MVA for 120 min.
   - Fault F4 - Actual loss of 30 MVA for 80 min.
   - Fault F5 - Loss of 10 000 kVA of transformer capacity for 150 min.
   - Fault F6 - Loss of supply to MV customer with a notified maximum demand of 1,5 MVA for 180 min.

d) Installed transformer capacity in each region affected by faults —
   - Region 1 (urban) = 65 MVA
   - Region 2 (urban) = 75 MVA
   - Region 3 (rural) = 30 MVA
Figure A.1 — Schematic diagram of network indicating the location of faults F1 to F6
Annex A  
(concluded)

A.2 Record of MV/HV forced interruptions using table 15

NOTE Actual loss measured in MVA used for this example but this may also be measured in MW or loss of installed transformer capacity in which case the denominator to be used in the calculation would be 380 MW or 1 900 MVA respectively.

\[
F_1 = \frac{(350 \text{ MVA} \times 5 \text{ min})}{400 \text{ MVA}} = 4,375 \text{ system-minutes}
\]

NOTE This attributed to the voltage at which bulk supply is taken, i.e. 132 kV in this example

\[
F_2 = \frac{(45 \text{ MVA} \times 40 \text{ min})}{400 \text{ MVA}} = 4,5 \text{ system-minutes}
\]

NOTE This attributed to the 33 kV voltage level as no other 132 kV circuits affected in this example.

\[
F_3 = \frac{(30 \text{ MVA} \times 120 \text{ min})}{400 \text{ MVA}} = 9,0 \text{ system-minutes}
\]

\[
F_4 = \frac{(30 \text{ MVA} \times 80 \text{ min})}{400 \text{ MVA}} = 6,0 \text{ system-minutes}
\]

Table A.2 — Forced interruptions to large-usage customers

<table>
<thead>
<tr>
<th>Network voltage category</th>
<th>Source of interruption</th>
<th>Forced interruption indices (F or S) system-minutes or installed system-minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV: ≤ 22 kV at step-down or main substations</td>
<td>Licensee’s network</td>
<td>6,0</td>
</tr>
<tr>
<td>MV: &gt; 22 kV to ≤ 44 kV</td>
<td>Bulk intake</td>
<td>4,5</td>
</tr>
<tr>
<td>HV: &gt; 44 kV to ≤ 132 kV</td>
<td></td>
<td>9,0</td>
</tr>
<tr>
<td>HV: &gt; 132 kV</td>
<td></td>
<td>4,375</td>
</tr>
</tbody>
</table>

A.3 Record of MV distribution forced interruptions (≤ 22 kV) using table 14

F1 = \( \frac{(65 000 \text{ kVA} \times 5/60 \text{ h})}{900 000 \text{ kVA}} = 0,006 \text{ h (urban)} \)

plus \( \frac{(75 000 \text{ kVA} \times 5/60 \text{ h})}{900 000 \text{ kVA}} = 0,007 \text{ h (urban)} \)

plus \( \frac{(30 000 \text{ kVA} \times 5/60 \text{ h})}{200 000 \text{ kVA}} = 0,0125 \text{ h (rural)} \)

F2 = \( \frac{(65 000 \text{ kVA} \times 40/60 \text{ h})}{900 000 \text{ kVA}} = 0,048 \text{ h (urban)} \)

F3 = \( \frac{(75 000 \text{ kVA} \times 120/60 \text{ h})}{900 000 \text{ kVA}} = 0,167 \text{ h (urban)} \)

F4 = \( \frac{(75 000 \text{ kVA} \times 80/60 \text{ h})}{900 000 \text{ kVA}} = 0,111 \text{ h (urban)} \)

F5 = \( \frac{(10 000 \text{ kVA} \times 150/60 \text{ h})}{200 000 \text{ kVA}} = 0,125 \text{ h (rural)} \)

F6 = \( \frac{(1 500 \text{ kVA} \times 180/60 \text{ h})}{900 000 \text{ kVA}} = 0,005 \text{ h (urban)} \)
**Table A.3 — Medium voltage distribution network forced interruption indices (≤ 22 kV)**

<table>
<thead>
<tr>
<th>Network categories affected</th>
<th>Installed capacity of each network category kVA</th>
<th>Forced interruption indices ($F_i$) h</th>
<th>Source of interruption</th>
<th>Overall indices (total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV rural overhead: &gt;1 kV to ≤ 22 kV</td>
<td>200 000</td>
<td>0,125</td>
<td>MV Distribution</td>
<td>0,125</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HV/MV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0,048 + 0,167 + 0,111</td>
<td>Bulk intake</td>
<td>0,006 + 0,007</td>
</tr>
<tr>
<td>MV urban: &gt;1 kV to ≤ 22 kV</td>
<td>900 000</td>
<td>0,005</td>
<td>MV Distribution</td>
<td>0,005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HV/MV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bulk intake</td>
<td>0,006 + 0,007</td>
</tr>
</tbody>
</table>

NOTE A licensee may find it more practical to record each incident in terms of kVA-hours for their own routine performance management reporting and only divide by the installed capacity base when submitting their annual report to the NER.


SABS 1816, Power quality instruments (New project)