ISBN 978-0-626-23203-0

# NRS 048-8:2009

Edition 1

# ELECTRICITY SUPPLY — QUALITY OF SUPPLY

## Part 8: Measurement and reporting of extra high voltage (EHV) and high voltage (HV) network interruption performance

This document is not a South African National Standard.

N R S

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

**Table of changes**

| Change No. | Date | Text affected |
|---|---|---|
| | | |

Correspondence to be directed to

The NRS Projects Manager
Standardization Section
Industry Association Resource Centre
Eskom
Private Bag X13
Halfway House 1685

Telephone : (011) 651-6842
Fax : (011) 651-6827
E-mail : nrs@eskom.co.za

Website : http://www.nrs.eskom.co.za

Printed copies obtainable from

SABS Standards Division
Private Bag X191
Pretoria 0001

Telephone : (012) 428-7911
Fax : (012) 344-1568
E-mail : sales@sabs.co.za

Website : http://www.sabs.co.za



Printed in the Republic of South Africa
by the SABS Standards Division
1 Dr Lategan Road, Groenkloof, Pretoria

## Foreword

This part of NRS 048 addresses the requirements for reporting the interruption performance of high voltage (HV) and extra high voltage (EHV) networks in the South African Electricity Supply Industry. This part of NRS 048 is aimed at providing the basis for annual regulatory performance reporting and incentive-based regulatory reporting. This part of NRS 048 also provides a basis for the calculation of indices that can be used in the benchmarking of HV and EHV systems.

It is recognized that the present systems of licenses might not comply with the minimum requirements specified in this part of NRS 048 and therefore, that the implementation of this part of NRS 048 will require resources, time and additional work. It is anticipated that the National Energy Regulator of South Africa (NERSA) will specify the time frame and compliance level for such implementation, in consultation with the various Transmission and Distribution Industry stakeholders.

It is recognized that, at the time of the compilation of this part of NRS 048, the method of interruption reporting differs substantially from one country to another. In compiling this part of NRS 048, the working group was therefore guided by the most recent international recommendations provided in Cigré Technical Report TB261, *Power Quality Indices and Objectives.*

The regulatory requirements of the NERSA and the business and operational needs of licensees were taken into account in the preparation of this part of NRS 048. In particular, the anticipated implementation of Incentive-Based Regulation (IBR) will require accurate and consistent reporting methods and accurate and complete data collection, to facilitate appropriate target setting.

This part of NRS 048 was compiled by representatives of the South African Electricity Supply Industry (ESI), in a working group appointed by the Electricity Suppliers Liaison Committee (ESLC). The working group membership included customer representation, inter alia formal representation of the Energy Intensive User Group (EIUG), NERSA, and Government, Department of Public Enterprises (DPE), representation.

This part of NRS 048 was compiled by a working group on behalf of the Electricity Suppliers Liaison Committee (ESLC). At the time of publication, the working group, which was appointed by the ESLC, comprised the following members:

| | |
|---|---|
| AJ Dold (Chairman) | eThekwini Electricity |
| SA Adams | Nelson Mandela Metropolitan Municipality |
| DK Bhana | Eskom Holdings Ltd (KSACS Division) |
| G Botha (Dr) | Eskom (Sustainability & Innovation) |
| BG Chatterton | Eskom Industry Association Resource Centre |
| G de Beer | Sasol |
| S Delport | Ekurhuleni Metropolitan Municipality |
| PA Johnson (Project Leader) | Eskom Industry Association Resource Centre |
| AC Kachelhoffer | City of Tshwane Metropolitan Municipality |
| I Kekana | City of Tshwane Metropolitan Municipality |
| M Kneen | Consultant |
| RG Koch | Eskom (System Operation and Planning) |
| D Marais | uMhlathuze Electricity |
| J Maree | Mondi Paper |
| RR McCurrach | Eskom (Transmission Division) |
| U Minnaar | Eskom (Sustainability & Innovation) |
| ME Motaung | National Energy Regulator of South Africa |
| B Peterson | Eskom (Transmission Division) |
| V Rampersad | City Power Johannesburg |
| T Rangakile | City Power Johannesburg |
| V Shikoana | Eskom (Distribution Division) |
| I Sigwebela | Eskom Holdings Limited (Transmission Division) |
| T Thenga | National Energy Regulator of South Africa |
| P van Niekerk | Energy Intensive User Group |

## Foreword *(concluded)*

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

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

*Part 4: Application practices for licensees.*

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

*Part 7: Application guidelines for end customers.*

*Part 8: Measurement and reporting of extra high voltage (EHV) and high voltage (HV) network interruption performance.*

*Part 9: Load reduction practices, system restoration practices, and critical and essential load requirements under system emergencies.* (In course of preparation.)

Annex B forms an integral part of this document. Annexes A and C are for information only.

## Introduction

Indices that provide unambiguous information on system technical performance trends are important tools in the management of transmission and distribution interruption performance. Such indices can provide the basis for dialogue between major stakeholders such as the National Energy Regulator of South Africa (NERSA), its licensees, local and national government, and large customer groupings (such as the Energy Intensive User Group), who have an interest in the overall technical performance of South African electricity supply systems.

The move by NERSA to implement incentive-based regulation (IBR) requires technical quality to be quantified and managed in order to ensure that purely economic performance incentives do not result in a reduction in the quality of the electricity supply to customers. The separation of transmission and distribution licenses in South Africa requires indices that suitably differentiate the performance of the different licensees (particularly where these are interconnected). In particular, where the EHV or HV networks of two licensees are interconnected at several points, an interruption to one such interface point may or may not impact customers (i.e. may not result in an interruption to customers) – depending on the level of interconnection and on the ability of individual circuits to supply customers from an alternative point. As incentive-based regulation is focussed on *controllable* parameters, the performance of interconnected licensees needs to be reported independently from the impact of one licensee on another.

On the other hand, annual regulatory reporting of interruption statistics to NERSA may require the impact of all elements of the supply chain to be reported (for example, where the contribution of a transmission system to the customer interruption performance indices of a distribution licensee needs to be quantified).

For this reason, this part of NRS 048, together with NRS 048-6, defines two categories of indices, based on an underlying philosophy of reporting. When reporting for different purposes, one of these categories specified shall apply – i.e. the corresponding set of defined indices shall be used. This approach of defining the reporting philosophy avoids the problem of defining an extensive list of rules on how “unusual” interruption events should be reported.

The two categories of indices are:

a) connection point interruption indices; and

b) end-customer interruption indices.

**a) Connection point interruption indices**

This set of indices is recommended where there is a need to report the overall performance of a licensee’s EHV and HV system independently of the actual impact on end-customers (the majority of which are connected at MV and LV). This is typically of importance at the boundary between two licensees such as transmission supply points to distribution licensees. If an interconnection exists within a distribution network between two transmission supply points, loss of supply to one supply point is considered as an interruption even if no interruption of energy occurs to customers due to the distribution network interconnection. The interruption frequency and duration indices specified in this part of NRS 048 are based on the number of connection points affected by events which originate in the EHV or HV system. The term “connection points” is used to denote both “delivery” (load) points and “production” (generation) points. The connection point method provides most appropriate for transmission licensees as it allows the key aspects of transmission-caused interruption duration, frequency, and severity to be reported independently of distribution network performance. See annex A for further information about connection point reporting considerations.

# Introduction *(concluded)*

**b) End-customer interruption indices**

This set of indices describes the impact of the interruption performance of a given EHV and HV system in terms of its actual impact on the interruption performance of end customers. The interruption frequency and duration indices used are based on the number of end customers affected by interruption that originates in the EHV and HV system under consideration. If, for example, supply by the transmission grid to a distribution delivery point is lost, a customer interruption might not arise – and no end-customer load interruption is therefore reported. The indices specified in this part of NRS 048 mirror those defined in NRS 048-6 for reporting the frequency and duration of customer interruptions.

NOTE A third category of indices used in some countries has been documented by Cigré. In this case, the interruption frequency and duration indices are derived from energy not supplied (MWh) and power interrupted (MW), as opposed to actual (estimated) number of customers or connection points affected. The physical meaning of these indices is difficult to interpret in a country such as South Africa (where the size of a customer may range from 1 kVA to over 1 000 MVA), and these indices are therefore not included in this part of NRS 048.

Figure 1 illustrates the possible multiple connection points between the transmission grid (transmission company) and the other licensees and direct customers of the transmission company.

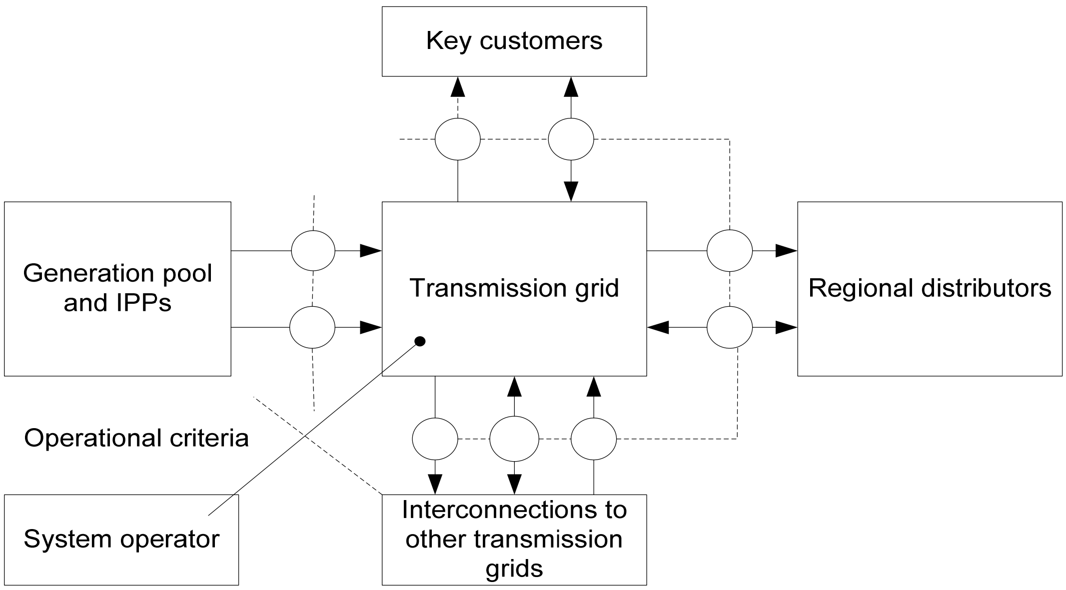



**Figure 1 — The transmission grid showing multiple connections with other licensees and with direct customers of the transmission company**

The relatively infrequent occurrence of a major system disturbance may result in a significant impact on reported interruption performance in a given year. Including the impact of such events in the indices used for reporting interruption performance trends will distort the interpretation of such trends from one year to another. For this reason, this part of NRS 048 addresses the identification of a category of "major events" to be reported separately from the underlying performance trends.
Common application of the indices outlined in this part of NRS 048 will facilitate interruption performance benchmarking between various licensees and international transmission and distribution companies. Where indices are not reported in accordance with this part of NRS 048, significant errors in comparative performance reporting may result. (Due care also needs to be taken that companies included in the benchmark comply with basic criteria for defining a suitable peer group - i.e. comparable networks, environmental conditions, geographic area, customer mix, etc.).


# Keywords

extra high voltage, high voltage, indices, interruption performance, major events, reporting.

## Contents

This page intentionally left blank

# ELECTRICITY SUPPLY – QUALITY OF SUPPLY

# Part 8: Measurement and reporting of extra high voltage (EHV) and high voltage (HV) network interruption performance

## 1 Scope

**1.1** This part of NRS 048 specifies the measurement and reporting of the interruption performance of extra high voltage (EHV) and high voltage (HV) electricity supply networks on a system-wide basis.

NOTE The definitions, requirements, and characteristic performance levels related to interruption performance to individual end-customers are addressed in NRS 048-2.

**1.2** The indices and reporting requirements defined in this part of NRS 048 are tailored to be consistent with the granting of separate transmission and distribution licenses by NERSA. As such, the requirements contained in this part of NRS 048 complement the requirements of NRS 048-6, which address the impact on medium-voltage (MV) and low-voltage (LV) customers of interruptions caused by events on MV, HV and EHV systems.

NOTE The reporting of MV and LV interruption performance is specifically separated from that of HV and EHV interruption performance reporting, because

a) the impact of an interruption to a given HV supply point might not impact on MV or LV customers, and

b) customer interruption indices (for example, SAIFI and SAIDI) consider each customer equally, for example an interruption to a 100 MVA customer and an interruption to a residential customer are weighted equally in the index.

**1.3** The indices defined in this part of NRS 048 are intended to be used to evaluate underlying trends in the frequency, duration, and severity of interruption performance related to HV and EHV systems. For this reason, this part of NRS 048 further provides for the identification of major incidents, and addresses the manner in which these should be taken into consideration in the overall reporting process.

**1.4** This part of NRS 048 also identifies the various reporting requirements in South Africa, and specifies which indices should be used to best comply with the objectives of these. Some guidance is also given for reporting interruption performance, as well as the risk of an interruption to an individual customer supplied directly from an EHV or HV system – although this is generally agreed upon between the parties.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

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

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

# 3 Terms, definitions and abbreviations

For the purposes of this document, the following terms, definitions and abbreviations apply.

## 3.1 Terms and definitions

**event**
fault or intervention on the network that causes a connection point interruption, end-customer interruption, or reduction in energy supplied or imported

NOTE 1 Each event should relate to a specific cause.

NOTE 2 Such an event could be planned (for example, in the case of maintenance), or unplanned (for example in the case of a fault on the network or where a breaker is tripped by accident).

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

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

NOTE The intention in reporting system interruption performance is to provide an assessment of the performance of networks of common purpose. In some cases 33 kV networks may be considered as HV networks, where applied in a similar manner, as agreed upon between NERSA and the licensee.

## 3.2 Abbreviations

**CAIDI:** customer average interruption duration index

**CPI:** connection point interruption

**DMP:** demand market participation

**ENS:** estimated energy not supplied

**HVSLI:** high-voltage supply loss index

**IPPs:** independent power producers

**MW:** megawatt

**NOI:** number of sustained interruption events

**NOLR:** number of involuntary customer load reduction events

**SAIDI:** system average interruption duration index

**SAIFI:** system average interruption frequency index

**SAIRI:** system average interruption restoration time index

**SEF:** system interruption energy factor

**SF:** system factor

**SM:** system minutes

# 4 System connection point interruption frequency and duration indices

## 4.1 Application of indices

System connection point interruption indices shall be used to define the interruption performance to all large customers and the networks of other licensees connected directly to the EHV or HV network of a given licensee. Connection points shall be defined at the boundary between the EHV or the HV system for the following

a) an end-user of electricity (including end-users with embedded generators);

b) another licensee;

c) a generator of electricity; and

d) an international interconnection.

NOTE 1 This part of NRS 048 makes a distinction between the indices used for customers connected directly to EHV and HV networks, and the indices used to define the impact of EHV and HV events on downstream MV and LV customers. The latter indices align with those of NRS 048-6, and are based on the number of customers interrupted rather than the number of HV or EHV connection points affected.

NOTE 2 When multiple traction stations are teed off a line, each incoming busbar at that station is considered as a connection point.

## 4.2 Connection point

All the circuits at the point that crosses the ownership boundary between two licensees or between the ownership boundary of the licensee and its customer at a given point in the network shall be considered as a single connection point. More than one connection point may therefore exist at a given busbar. Ownership boundaries at different voltage levels in one substation will give rise to multiple connection points.

Examples of connection points are provided in annex B.

## 4.3 Connection point interruption

A connection point interruption is considered to have occurred when the continuity of supply on all the circuits that define a connection point is interrupted. Only the circuits that leave the connection point are considered, no consideration is given to the end location of these circuits (i.e. whether these circuits are operated in parallel or are radial, as illustrated in annex B). The definition of a connection point is therefore independent of the configuration of the network within the licensee or end-customer that is supplied by the EHV and HV system under consideration.

Where an event within the licensee's EHV or HV network impacts on several connection points, the interruption at each connection point shall be considered as a separate connection point interruption.

NOTE 1 Such an interruption may occur as a result of the tripping of all the circuits that cross the ownership boundary or as a result of circuits upstream of these trippings. In general such an interruption is associated with the voltage on these circuits that drop below 0,1 p.u. of the declared voltage at the licensee's side of the connection point. It should, however, be noted that there are cases in which higher voltages may be measured at this point (for example, in the case of ferro-resonance between a transformer and the grading capacitors across an open breaker).

NOTE 2 It should also be noted that events that occur as a result of faults elsewhere in the network, which result in a voltage of less than 0,1 p.u. and do not result in local or upstream circuits supplying the connection point being tripped, are considered as category T or category Z2 voltage dips and not as a connection point interruption (see NRS 048-2).

## 4.4 Duration of a connection point interruption

The duration of a connection point interruption shall be determined from the moment that the interruption is initiated, until the time that the reporting licensee is able to supply all or a portion of the load (or import all or part of a generator's supply capacity) when at least one of the circuits that supply the connection point has been restored.

NOTE 1 The time taken for a licensee supplied at the connection point to restore supply to its customers is not included in the calculation of the duration of a connection point interruption.

NOTE 2 Long-term outages of one of multiple circuits to a supply point that result in the inability to supply the full load at certain times of the day, are not considered a connection point interruption. The energy not supplied is, however, counted in the interruption severity measures. If partial restoration of a connection point occurs (e.g. one of two circuits), and the system is not able to supply the full demand, the energy not supplied until the system is able to supply the full demand is aggregated in the system minute calculation (see 6.2.1).

NOTE 3 The consideration of only partial load aligns with the case when only a single circuit is lost in a dual circuit supply and load needs to be reduced. In this case no connection point interruption (and hence no interruption duration) is monitored. Only energy not supplied is reported for the duration of the load reduction incident.

NOTE 4 In most practical cases, typically over 30 % of the load is normally restored. It should be noted that the energy not served for the full event (including the constrained period), is included in the calculation of the energy not supplied that is associated with this event.

## 4.5 Planned versus unplanned connection point interruptions

The frequency and duration of connection point interruptions shall be reported separately in the case of planned and unplanned events.

NOTE Planned interruptions are generally negotiated well in advance and the customer will often take advantage of the outage to do maintenance as well.

## 4.6 Sustained and momentary connection point interruptions

A sustained connection point interruption shall be defined in the case of an interruption of duration more than 1 min. A momentary connection point interruption shall be defined in the case of an interruption of duration up to 1 min.

NOTE 1 These definitions of sustained and momentary interruptions are the same as in NRS 048-2 for customers directly connected to EHV and HV networks.

NOTE 2 The duration of 1 min differentiates between automatic and manual operator interventions due to transmission-caused interruptions.

## 4.7 Frequency of sustained connection point interruptions

The system average interruption frequency index (SAIFI) for sustained connection point interruptions (CPI) is given by:

$$\text{SAIFI-CPI} = \frac{\Sigma\ (\text{number of sustained connection point interruptions})}{\text{Total number of connection points}} \qquad \text{Equation 1}$$

The index is calculated over a 12-month period. Where the number of connection points changes during this 12-month period, the number of connection points at the beginning of the reporting period shall be used.

Connection point interruptions that arise during a major event are not included in the calculation of the index.

## 4.8 Cumulative duration of sustained connection point interruptions

The system average (aggregated) interruption duration index per connection point for sustained connection point interruptions is given by:

$$\text{SAIDI-CPI} = \frac{\Sigma\ \text{(duration of the sustained connection point interruptions)}}{\text{Total number of connection points}}\ \text{(min)} \qquad \text{Equation 2}$$

The index is calculated over a 12-month period. Where the number of connection points change during this 12-month period, the number of connection points at the beginning of the reporting period shall be used.

Connection point interruptions that arise during a major event are not included in the calculation of the index.

NOTE Including momentary events is not meaningful as the index will improve for more momentary events.

## 4.9 Restoration time of a sustained connection point interruption

The system average interruption restoration time index per connection point for sustained connection point interruptions is given by:

$$\text{SAIRI-CPI} = \frac{\Sigma\ \text{(restoration times of the individual sustained connection points interrupted)}}{\Sigma\ \text{(sustained connection point interruptions)}}\ \text{(min)} \qquad \text{Equation 3}$$

The index is calculated over a 12-month period. Where the number of connection points change during this 12-month period, the number of connection points at the beginning of the reporting period shall be used.

Connection point interruptions that arise during a major event are not included in the calculation of the index.

NOTE Including momentary events is not meaningful as the index will improve for more momentary events.

# 5 System event indices

## 5.1 Number of sustained interruption events

The number of sustained interruption events (NOI) is given by:

NOI = Sum of sustained interruption events Equation 4

Each event is associated with

a) a sustained interruption to one or more connection points due to a common cause; and

b) the inability to supply energy for more than 1 min.

The sum is calculated over a 12-month period.

All events (including major events) shall be included in the reported index.

Planned and unplanned events may be reported separately.

## 5.2 Number of involuntary customer load reduction events

The number of involuntary customer load reduction events (NOLR) is given by:

NOLR = Sum of involuntary customer load reduction events
Equation 5

Each involuntary customer load reduction event is associated with

a) an involuntary load reduction (without an associated sustained connection point interruption); and

b) the inability to supply the full energy for more than 1 min.

Generation-caused load reduction events such as demand-side programs and interruptible load agreements are not included in the calculation. Under-frequency load shedding events are not included in the calculation. These events shall be reported separately for each event.

The sum is calculated over a 12-month period.

All events (including major events) shall be included in the reported index.

NOTE Involuntary load reduction events exclude contracted load reductions (see NRS 048-2).

# 6 System event severity indices

## 6.1 Energy-not-supplied and energy-not-imported

**6.1.1** The severity of an interruption event (i.e. one or more sustained connection point interruptions) or an involuntary customer load reduction event is quantified by the associated energy-not-supplied, in MWh (in the case of end-use customers) or the energy-not-imported, in MWh (in the case of generators and international imports).

**6.1.2** The energy-not-supplied or energy-not-imported for each event shall be calculated as follows:

a) the calculation shall be the estimated load that could not be supplied aggregated over time for the full duration of the event. For example, where customer load is tripped due to an overloaded circuit, restored and later tripped again, the incidents shall be aggregated for the purpose of calculating the severity of the event;

b) in the case of short events, for example, 2 h or less, the energy not supplied may be estimated as the load (in MW) supplied just before the event. In the case of events, for example events that last several hours, the energy not supplied may be estimated by taking the typical historical load profile into consideration (i.e. excluding any reduction of the load profile due to system or generation constraints as a result of load reduction);

c) generation-caused load reduction events such as demand-side programs and interruptible load agreements are not included in the calculation;

d) voluntary and mandatory under-frequency load shedding events are not included in the calculation. These events shall be reported separately for each event; and

e) losses in the licensee's network are not included in the calculation (for example, the energy-not- supplied is the actual energy not delivered to the customer or to another licensee).

## 6.2 Event severity indices

### 6.2.1 System minutes

**6.2.1.1** In the case of loads, the severity of an individual interruption event is given as:

$$\text{SM (supplied)} = \frac{\text{Estimated energy not supplied (MWh)} \times 60}{\text{System annual maximum demand (MW)}} \text{ (min)} \qquad \text{Equation 6a}$$

**6.2.1.2** In the case of generators and international imports, the severity of an individual interruption event is given as:

$$\text{SM (imported)} = \frac{\text{Estimated energy not imported (MWh)} \times 60}{\text{System annual maximum demand (MW)}} \text{ (min)} \qquad \text{Equation 6b}$$

**6.2.1.3** The system annual maximum demand shall be that for the previous reporting year.

NOTE The previous year's value is used for practical purposes so as to ensure that the system minutes associated with a particular incident in the early part of the year does not have to be changed if a new system peak is reached. This would result in a higher system minute value for the reporting year in the case where the system peak increases from one year to another.

**6.2.1.4** The underlying performance related to the severity of interruption events over a 12-month period is given (in the case of events over the 12-month period) by the sum of system minute events of severity smaller than one system minute:

$$\text{SM(supplied<1)} = \Sigma\, \text{SM(supplied)}_i \quad \text{(minutes)} \qquad \text{Equation 7a}$$

$$\text{SM(imported<1)} = \Sigma\, \text{SM(imported)}_i \quad \text{(minutes)} \qquad \text{Equation 7b}$$

where only the system minutes associated with individual interruption events of severity less than one system minute are included in the summation.

### 6.2.2 System interrupted energy factor

**6.2.2.1** In the case of distribution licensees with HV (or EHV) networks, the system peak demand is difficult to define; for this reason an alternative severity index is defined. The severity of an individual interruption event is given as the ratio of annual MWh not supplied or not imported to the annual terawatt hours (TWh) supplied. In the case of end-use customer connections (and customers with imbedded generations), this is defined as follows:

$$\text{SF} = \frac{\text{Estimated annual energy not supplied (MWh)}}{\text{System total annual energy supplied (TWh)}} \qquad \text{Equation 8a}$$

**6.2.2.2** The severity of an individual interruption event is given for generator connection points as:

$$\text{SF} = \frac{\text{Estimated annual energy not imported (MWh)}}{\text{System total annual energy supplied (TWh)}} \qquad \text{Equation 8b}$$

**6.2.2.3** The system total annual energy supplied shall be that for the previous reporting year.

NOTE The previous year's value is used for practical purposes so as to ensure that the factor associated with a particular incident in the early part of the year does not have to be changed if a new system total annual energy supplied is reached. This will in fact result in a higher reported value for the reporting year in the case where the system peak increases from one year to another.

### 6.2.3 Major events

**6.2.3.1** The number of major events over a 12-month period is reported according to the degree of severity of the event, where

a) DEGREE 1: is an individual event with a system minute (SM) value of 1 to less than 10,

b) DEGREE 2: is an individual event with a system minute (SM) value of 10 to less than 100, and

c) DEGREE 3: is an individual event with a system minute (SM) value of equal to or more than 100,

or

d) DEGREE 1: is an individual event with a system ENS factor (SEF) of 3 to less than 30,

e) DEGREE 2: is an individual event with a system ENS factor (SEF) of 30 to less than 300, and

f) DEGREE 3: is an individual event with a system ENS factor (SEF) of equal to or more than 300.

**6.2.3.2** Each major event shall be reported individually and described by giving the following information:

a) the location of the event;

b) the cause of the event;

c) the degree of severity of the event and the aggregated system minutes associated with the event;

d) the number of connection point interruptions during the event; and

e) the duration of the event.

### 6.2.4 Network imposed demand constraints

The severity of a demand constraint at a connection point or group of connection points is quantified as the maximum value of the demand (MW) constrained (in the case of end-use customers) or supply constrained (MW) (in the case of generators and international imports) due to a network-related constraint.

The following information shall be captured for each event:

a) the estimated maximum MW constrained per event;

b) the total duration of the event; and

c) the total energy not supplied during the event.

Several consecutive network-imposed demand constraints due to the same underlying cause (for example loss of a transformer) are counted as one event of duration from the beginning of the event until the end of the event.

In the case of partial restoration of a connection point interruption, if not all the load can be served, this will be counted as a network-imposed demand constraint.

The estimated MW constrained shall include demand market participation loads (DMP) and interruptible loads (if these were used to manage the constraint).

Where load shedding at MV and LV is required due to EHV and HV network constraints, this shall be included.

NOTE DMP and interruptible loads are included, as network constraint can happen at any time, for example a 2 h interruptible load may have been interrupted because of generation capacity constraints and not available as a countermeasure.

### 6.2.5 Interruption severity: High-voltage supply loss index (HVSLI)

The severity of an interruption event can be approximated by the transformer capacity impacted. The HV supply loss index is calculated over a 12-month moving period as:

$$\text{HVSLI} = \frac{\Sigma\ (\text{HV transformer capacity lost (MVA)} \times \text{duration (minutes)})}{\text{Total installed HV transformer capacity on the network (MVA)}}\ \text{(min)} \qquad \text{Equation 9}$$

NOTE In the case of two transformers that supply a generally “firm” supply, the capacities of both transformers are counted in the numerator (and the denominator). In the case of the loss of only one transformer (and no actual interruption of customers), no lost capacity is recorded.

# 7 System end-customer interruption performance indices

## 7.1 Definition of an end-customer interruption

An interruption to any MV and LV customer as a result of an event on the HV or EHV network shall be considered to be an end-customer interruption. An end-customer interruption shall be considered to have occurred if the continuity of supply to any MV or LV end-customer is interrupted, regardless of whether the customer was using electricity at the time.

These shall be calculated separately for EHV and HV end-customer supply points affected by interruptions on the EHV and HV network. The indices defined for SAIFI, SAIDI and CAIDI in NRS 048-6 shall apply, as follows:

a) SAIFI (HV and EHV): system average interruption frequency index of EHV and HV end-customer supply point interruptions due to events on the EHV and HV network (sustained interruptions);

b) SAIDI (HV and EHV): system average (aggregated) interruption duration index for EHV and HV end-customer supply point interruptions due to events on the EHV and HV network (sustained interruptions);

c) CAIDI (HV and EHV): customer average interruption duration index for EHV and HV end-customer supply point interruptions due to events on the EHV and HV network (sustained interruptions); and

d) MAIFI (HV and EHV): momentary average interruption frequency index of EHV and HV end-customer supply point interruptions due to events on the EHV and HV network (momentary interruptions).

## 7.2 Individual end-customer interruption performance indices

Where requested, individual customers or other licensees connected directly to the EHV and HV network might require interruption performance reports related to their specific supply points. The indices given in 7.3 are recommended as the basis for such reporting.

### 7.3 Interruption performance reporting

Each event shall be reported individually, and the following information shall be made available for each 12-month period:

a) the number of connection point interruptions per supply point;

b) the duration of each connection point interruption per supply point; and

c) the estimated energy-not-supplied (MWh) per event shall be reported.

## 8 Defined supply contingency unavailability

**8.1** The risk of an interruption to a customer is affected by the unavailability of circuits and plant that provide supply contingency capability. This measure provides for reporting of this risk.

In the case of supplies to customers that provide single-contingency availability, generally referred to as “N-1”, the following information shall be made available on agreement between the customer and the licensee for the 12-month period:

a) defined supply unavailability (unplanned): the total number of hours that any of the defined contingent supply circuits are not available as a result of unplanned events, and where loss of any of the additional defined contingent circuits would result in a full or partial loss of supply to the customer. The unavailability shall be based either on the actual demand at the time or on the notified maximum demand of the customer. The metric used shall be declared;

b) defined supply unavailability (planned): the total number of hours that the defined supply is not available (i.e. the supply is non-firm) as a result of planned events. In this case, the unavailability shall be based either on the actual demand at the time or on the notified maximum demand of the customer. The metric used shall be declared;

c) frequency of defined circuit supply unavailability (unplanned): the number of times that supply was not available due to unplanned events;

d) frequency of defined circuit supply unavailability (planned): the number of times that supply was not available due to planned events.

**8.2** Unless otherwise specifically agreed upon between the parties, the indices shall be provided for

a) a defined supply network, i.e. the assessment is limited to a pre-defined section of the network – typically the elements paid for by the customer. Generally this will be the circuits (e.g. line circuit or transformer circuit – including breakers) that supply an individual supply point, or the circuits that supply several individual supply points in the case where the customer is able to provide for diversity in taking supply from another supply point; and

b) a condition where, after removal of one or more circuits in the defined firm supply network, a single event on any of the remaining circuits in the defined firm supply network would result in the customer being interrupted or having to reduce load.

NOTE 1 This measure is not intended for system performance reporting, but for reporting to a specific customer where the defined network has been agreed upon.

NOTE 2 Where applicable, the reporting could be extended to double-contingency (N-2) supplies.

# 9 Interruption performance reporting considerations

NOTE Examples of interruption index calculations are given in annex C.

## 9.1 Criteria for excluding data

Depending on the application, interruption performance reporting may in some cases include controllable and uncontrollable events, and in other cases only controllable events. The following events may be excluded from the reported index:

a) events caused by another licensee;

b) events caused by a customer and that impact only that customer;

c) events caused by force majeure (unavoidable circumstances) as defined in NRS 048-2; and

d) events that arise as a result of a specific request by a customer or an interconnected licensee for a network reconfiguration, where only this customer or licensee is affected, and where the event could have been avoided (or the severity reduced) had the network reconfiguration not been made.

NOTE In the case of incentive-based regulation, reporting is generally restricted to controllable events. In this case some or all of the above types of event may be excluded by agreement with NERSA.

## 9.2 Single-circuit supplies versus multiple-circuit supplies

Where a connection point is supplied by a radial single-circuit network, or the connection point itself is a singe circuit, it is more prone to experiencing an interruption. On request, a licensee shall be in a position to report indices separately for such connection points.

# Annex A
(informative)

# Connection point reporting considerations

## A.1 Advantages of connection point indices

**A.1.1** Analysis of the categories of indices shows that connection point indices have distinct advantages where the need is to show trends in the performance of the transmission network independently of the (positive or negative) impact of distribution companies. These advantages are described in A.1.2 to A.1.7.

**A.1.2** A good physical interpretation of the performance parameters: the indices can be directly interpreted, for example, an incident that results in a connection point interruption and no interruption of energy supply to customers would affect SAIFI-CP, SAIDI-CP and SAIRI-CP without system minutes being affected. Conversely, an incident where load shedding is employed to avoid an impending connection point interruption as a result of system constraints, would be accounted for in the system minute index without affecting SAIFI-CP, SAIDI-CP and SAIRI-CP.

**A.1.3** An accurate reflection of underlying transmission performance trends: note that in the first example above, under the other two reporting philosophies there would have been no impact on the indices. Connection point indices avoid the problem that underlying transmission interruption performance trends are affected by the availability and capacity of distribution (sub-transmission) circuits and by distribution supply restoration processes. A better interpretation of underlying performance trends in the transmission system is therefore provided (i.e. the same event that would have caused interruption of energy supply to a customer with the distribution interconnection unavailable would be counted whether the interconnection is available or not).

**A.1.4** An easily interpreted interruption duration definition: the duration of a connection point interruption is simply defined as the time taken to restore supply to the connection point (i.e. additional time taken by the distribution company to restore customers is not included here as this is under the control of the distribution company). Similarly, system minutes are measured until the required capacity to supply the necessary load is restored.

**A.1.5** An easily interpreted definition of momentary versus sustained events: these are defined in the context of transmission operational issues – the Cigré report TB261 recommends a common one-minute threshold for all transmission companies as this effectively separates automatic versus operator interventions. (Correct application of end-customer load interruption indices requires distribution momentary definitions to be used – these differ from region to region, for example, Canada uses 1 min, Europe uses 3 min, and many areas in the US use 5 min. This would impact issues such as benchmarking.)

**A.1.6** A good physical interpretation of the interrupted entity, which avoids the problem associated with end-customer indices; this problem entails that, when the number of customers affected is being defined, an LV residential customer and a large industrial plant (for example, 300 MW), are each considered as one customer (a significant problem with distribution indices, given the range in sizes of South African industrial customers).

**A.1.7** No need to estimate customers affected which, therefore, avoids the need for estimating how many customers were actually affected for a given interruption – i.e. this data is required from the distribution company.

# Annex A
*(concluded)*

## A.2 Application of connection point indices

**A.2.1** Application of connection point indices gives rise to some additional considerations, as given in A.2.2 to A.2.4.

**A.2.2** At face value, a "disadvantage" of the connection point philosophy is that collaboration between the transmission company and the distribution company to optimize network reliability initiatives is not encouraged (for example, a transmission company is encouraged to consider investments only in the transmission network to prevent a connection point interruption, rather than strengthening the sub-transmission system to act as a backup between two delivery points for transmission circuit outages). This disadvantage is off-set by the clarity with which the responsibilities are demarcated, and can be mitigated by clarifying investment criteria (a consideration to be taken into consideration in benchmarking different transmission systems).

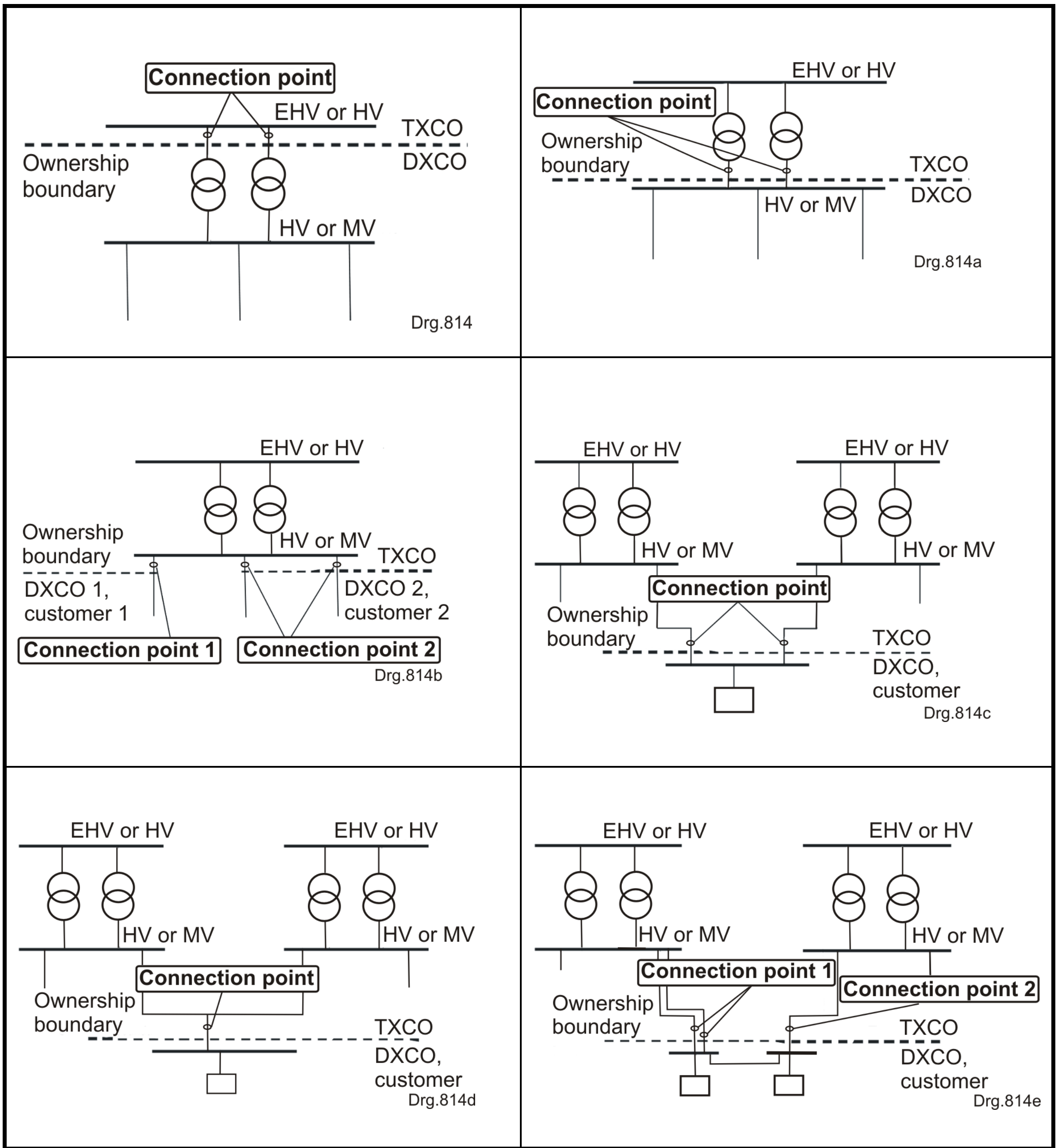
**A.2.3** Where an agreement is in place to operate split busbars for operational reasons requested by Distribution (for example, to shield sensitive customers from fault-caused dips on another distribution network), accounting of a transmission-caused interruption to one of the busbars needs to be considered. The connection point definition defined above implies that it is only considered as a connection point interruption if all circuits are interrupted.

**A.2.4** Where maximum demand exceeds the contracted value, accounting for the additional energy not supplied in the system minute count needs to be considered (possibly excluded).

# Annex B
(normative)

## Examples of connection points

Figure B.1 shows examples of connection points between a transmission licensee (TXCO), a distribution licensee (DXCO) and customers. The distribution licensee may also be a direct customer or an international customer (for example a transmission licence in a neighbouring country).




NOTE A connection point interruption is counted when all indicated circuits of a connection point are interrupted due to a TXCO incident (i.e. all the circuits at the connection point to a given customer are interrupted).

**Figure B.1 — Examples of connection points**

# Annex C
(informative)

## Examples of interruption index calculations

### C.1 Substation busbar

Figure C.1 shows an example of a substation busbar with connection points defined at each of the ownership boundaries.

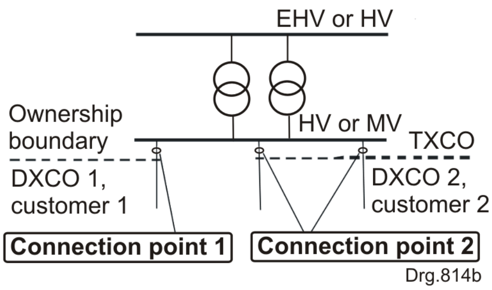



**Figure C.1 — Substation busbar with connection points defined at each of the ownership boundaries**

### C.2 Event considered

**C.2.1** Consider the case of two 100 MVA transformers that supply a maximum demand of 150 MW. The event as given in C.2.2 to C.2.7 is considered.

**C.2.2** A fault in one of the transformers results in both transformers being tripped at the time when the substation is supplying 90 MW of load during an off-peak period.

**C.2.3** The one transformer is returned to service in 30 min, and supply to the 90 MW of load is restored.

**C.2.4** The supply is constrained to the downstream loads for a further period of 24 h, due to the extended outage of the second transformer.

**C.2.5** During this period, 20 MW of load is reduced for a period of 3 h around the evening peak by customer load shedding at connection point 2.

**C.2.6** A further 30 MW of load is manually shed for one hour at the evening peak by opening the feeder breaker at connection point 1.

**C.2.7** To manage the supply constraint, 10 MW of load is reduced for a period of 2 h around the morning peak by agreement that customer load is shifted from connection point 2 to another supply point that supplies the distribution licensee.

### C.3 Number of interruption events

The underlying cause of the various interruptions is the same (a fault in the one transformer). The number of interruption events (NOI) is therefore only one.

This event is now described by the energy not served, the number of actual connection point interruptions, and the duration of each of these.

# Annex C
*(continued)*

## C.4 The number of individual connection point interruptions

The number of connection point interruptions as a result of the initial incident will be two (as both connection point 1 and connection point 2 were affected).

Opening the breaker on the feeder at connection point 1 for one hour at peak will result in a further connection point interruption.

The total number of connection point interruptions associated with this event, therefore, is three.

## C.5 The durations of the individual connection point interruptions

The individual connection point interruption durations are now recorded as follows:

a) connection point 1 (outage of both transformers for 30 min): 0,5 h,

b) connection point 2 (outage of both transformers for 30 min): 0,5 h, and

c) connection point 1 (opening of feeder breaker for 1 h): 1,0 h.

## C.6 The energy-not-served

During the outage of both transformers: 90 MW × 0,5 h = 45 MWh.

Load reduction at connection point 2 during the evening peak: 20 MW × 2 h = 40 MWh.

Load shedding at connection point 1 during the evening peak: 30 MW × 1 h = 30 MWh.

Load reduction at connection point 1 during the morning peak: 10 MW × 3 h = 30 MWh.

The total energy not served as a result of this event is therefore: 45 + 40 + 30 + 30 = 145 MWh.

This energy not served is used to calculate the system minutes associated with the event, and hence also to determine if the event is considered a major event.

## C.7 System minutes

If the licensee's peak demand supplied is 10 000 MW, the system minutes associated with this event are: 145 × 60 ÷ 10 000 = 0,87 min.

## C.8 System interrupted energy factor

If the annual energy supplied by the system in 40 TWh, the system interrupted energy factor is calculated as: 145 ÷ 40 = 3,63.

## C.9 Major event evaluation

As the system minutes associated with the event are less than 1 min, the event is not considered a major event.

The number and duration of individual connection point interruption events is therefore to be included in the calculation of the system frequency and duration indices (SAIFI-CP, SAIDI-CP and SAIRI-CP).

# Annex C
*(continued)*

## C.10 System connection point interruption indices

If the licensee has 30 connection points in total, and no other interruption events occur in the 12-month reporting period, the system (average) indices are calculated as follows:

a) SAIFI-CPI = 3 ÷ 30 = 0,1 connection point interruptions per connection point per year;

b) SAIDI-CPI = (0,5 + 0,5 + 1,0) ÷ 30 = 0,067 hours per connection point per year; and

c) SAIFI-CPI = (0,5 + 0,5 + 1,0) ÷ 3 = 0,67 hours per connection point interruption.

In the case of SAIFI-CPI and SAIDI-CPI, the above values can simply be added to those for the other events of the year to provide the total number of events (note that the number of connection points defined is that at the beginning of the year).

## C.11 Defined supply contingency unavailability

If the two transformers are the defined circuits for this measure in the case of the customer connected to connection point 1, and this is the only such transformer outage for the year, the defined supply contingency unavailability is:

Both transformer outages during first 30 min: 0,5 h.

Single transformer outage during the next 24 h: 24 h.

The total (unplanned) unavailability is therefore 24,5 h for the year.

## C.12 Network-imposed demand constraint

The network-imposed demand constraint for this event is given by the most severe case for the duration of the event, i.e. the maximum curtailed load during the evening peak: 20 + 30 = 50 MW.

## C.13 Customer interruption indices

**C.13.1** Consider the total number of customers supplied from connection point 1 as 2 000, and the number of customers supplied from connection point 2 as 10 000 customers.

The following occurs during the interruption:

a) during both transformer outages: all customers are interrupted for 30 min. It takes the licensee a further 30 m to reconnect all the customers;

b) during the outage of one transformer during the evening peak,

   1) 1 000 customers at connection point 1 are interrupted for 1 h, and the distribution licensee takes a further 45 min (0,75 h) to connect these customers;

   2) 4 000 customers at connection point 2 are interrupted for 3 h, and the distribution licensee takes a further 15 min (0,25 h) to connect 1 500 of these customers, and 30 min (0,5 h) to connect the remaining 3 500 customers.

c) during the morning peak,

   3 500 customers at connection point 2 are supplied for 2 h from another supply point.

# Annex C
*(concluded)*

The distribution licensee that takes supply from connection point 1 supplies a total of 10 000 customers.

The distribution licensee that takes supply from connection point 2 supplies a total of 300 000 customers.

**C.13.2** The contribution of the event to the interruption indices of the distribution licensees is hence as follows:

a) distribution licensee 1:

1) SAIFI = (2 000 + 1 000) ÷ 2 000 = 1,5 interruptions per customer per year;

2) SAIDI = {2 000*(0,5 + 0,5) + 1 000*(1,0 + 0,75)} ÷ 2 000 = 1,39 h per customer per year;

b) distribution licensee 2:

1) SAIFI = (10 000 + 4 000) ÷ 10 000 = 1,4 interruptions per customer per year;

2) SAIDI = {10 000*(0,5 + 0,5) + 1 500*(3,0 + 0,25) + 3 500*(3,0 + 0,5)} ÷ 10 000 = 2,75 h per customer per year.

NOTE No customers were interrupted during the morning peak and hence no impact on SAIFI and SAIDI is reported.

**C.13.3** A complete description of the event as reported by the licensee is given in table C.1.

**Table C.1 — Complete description of the event**

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| **Index** | **Value** | **Unit** | **Comment** |
| Event number: | 1 | Number | Event identifier for the period |
| Connection point interruptions | 3 | Number | |
| Energy not served | 145 | MWh | |
| Maximum demand not served | 90 | MW | |
| Network imposed demand constraint | 50 | MW | |
| Defined supply contingency unavailability | 24,5 | h | |
| System Minutes (SM) | 0,87 | min | Contribution to system SM |
| System Interrupted Energy Factor (SEF) | 3,63 | (ratio) | Contribution to system SF |
| Major event (degree severity) | 0 | | Not a major event |
| System SAIFI-CP contribution | 0,1 | interruptions/yr | Contribution to system index |
| System SAIDI-CP contribution | 0,67 | h/yr | Contribution to system index |
| System SAIRI-CP numerator | 2 | h | Numerator in system index |
| NOTE The SAIRI contribution to the system index can only be determined at the end of the reporting period, when the total number of interruptions is known. In all other cases where “contribution” is indicated, the value associated with this event can simply be added to that of all the other events for the reporting period in order to calculate the value for the actual performance index and the end of the period. | | | |

The number of interruption events (NOI) at the end of the reporting period is simply the sum of the events (i.e. the last event number for the year).

NOTE The customer interruption indices are not reported in the case of EHV and HV reporting.

## Bibliography

Cigré Technical Brochure TB261, *Power quality indices and objectives*. 2004. Available from World Wide Web: <www.e-cigre.org>.

KOCH R., McCURRACH R. *et al. Transmission technical performance reporting: considerations for reporting, benchmarking, and incentive-based regulation*. Cigré 5th Southern Africa Regional Conference, 2005.

This page has been left blank intentionally

## SABS – Standards Division

The objective of the SABS Standards Division is to develop, promote and maintain South African National Standards. This objective is incorporated in the Standards Act, 2008 (Act No. 8 of 2008).

### Amendments and Revisions

South African National Standards are updated by amendment or revision. Users of South African National Standards should ensure that they possess the latest amendments or editions.

The SABS continuously strives to improve the quality of its products and services and would therefore be grateful if anyone finding an inaccuracy or ambiguity while using this standard would inform the secretary of the technical committee responsible, the identity of which can be found in the foreword.
Tel: +27 (0) 12 428 6666 Fax: +27 (0) 12 428 6928

The SABS offers an individual notification service, which ensures that subscribers automatically receive notification regarding amendments and revisions to South African National Standards.
Tel: +27 (0) 12 428 6883 Fax: +27 (0) 12 428 6928 E-mail: sales@sabs.co.za

### Buying Standards

Contact the Sales Office for South African and international standards, which are available in both electronic and hardcopy format.
Tel: +27 (0) 12 428 6883 Fax: +27 (0) 12 428 6928 E-mail: sales@sabs.co.za
South African National Standards are also available online from the SABS website http://www.sabs.co.za

### Information on Standards

The Standards Information Centre provides a wide range of standards-related information on both national and international standards, and is the official WTO/TBT enquiry point for South Africa. The Centre also offers an individual updating service called INFOPLUS, which ensures that subscribers automatically receive notification regarding amendments to, and revisions of, international standards.
Tel: +27 (0) 12 428 6666 Fax: +27 (0) 12 428 6928 E-mail: info@sabs.co.za

### Copyright



Details and advice can be obtained from the Senior Manager.
Tel: +27 (0) 12 428 6666 Fax: +27 (0) 12 428 6928 E-mail: info@sabs.co.za