NETWORK RELIABILITY MEASUREMENT, REPORTING, BENCHMARKING AND ALIGNMENT WITH INTERNATIONAL PRACTICES

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1. Introduction

The Electricity Supply Industry (ESI) of South Africa is set to undergo a fundamental change over the next few years. The main driver is the restructuring of the Electricity Distribution Industry (EDI), with the integration of the local municipalities and Eskom Distribution Division into the six Regional Electricity Distributors (REDs).

The electricity customers in the REDs will have concerns about two basic issues (very important to them), 1) the price of electricity (and the annual increase) and 2) the reliability and quality of electricity supply received. Both of these two customer concerns will provide challenges to the future REDs. The National Energy Regulator (NER) will be required to effectively regulate these two customer issues in South Africa.

It will be expected that the REDs will achieve improvement in business performance over time due to the economies of scale, enhanced business efficiencies, improved operational processes, improved governance and the presence of competitors.

There is an expectation that the reliability of electrical supply will also improve in the future REDs and when regulatory incentives are fully implemented in South Africa. Experiences in the United Kingdom (UK) after electricity privatisation, show a 38% improvement in customer minutes lost and an 8% improvement in the frequency of interruptions (measured on a ten year rolling average) from 1986 to 2000. In the New South Wales and Victoria states of Australia, the customer minutes lost improved by 24% and 64% respectively [1].

Similar network reliability improvements were experienced in Italy when regulatory incentives were introduced. There was a 43% improvement in the average interruption duration and a 30% improvement of the average frequency of interruptions over 3 years [2].

2. Outline of Paper

This paper deals directly with the network reliability or the interruption performance issues that will affect the future EDI. The approach and methodology of measurement, reporting and benchmarking are discussed and key issues are addressed.

The relevant international standards and practices will be discussed with the focus on sharing of information of practices in the Eskom Distribution Division. A high level network reliability comparison of international utilities is provided.

The lessons learnt by Eskom Distribution will be discussed. The information will be applicable to all the municipalities and will be of direct use and benefit to all the AMEU members.

3. Power Quality

Power Quality comprises of quality of supply (QOS) and network reliability as shown in Figure 1 below. In other words, Power Quality is the measure of the quality of the voltage waveform received by the customer and how reliable (on and off) the voltage waveform received is.

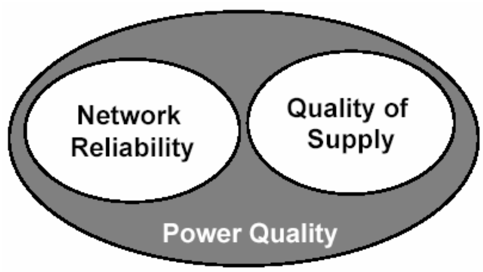

Figure 1 The components of Power Quality

QOS deals with voltage waveform quality and metrics such as voltage dips (X, Y, Z, T and S class), regulation, harmonics, flicker and unbalance are used.

Network reliability (as per Eskom Distribution and IEEE definitions) deals with the frequency and duration of network interruptions (or outages). These can be sustained interruptions (long) or momentary interruptions (short) for the network or the individual customers.

It is more correct in Eskom Distribution to refer to network interruption performance (NIP) as the network interruption performance has three key components of 1) reliability (frequency of related metrics) and 2) availability (duration related metrics) and 3) security of supply (under frequency load shedding related metrics).

4. Distribution and Transmission Network Reliability Indices

The two basic categories of network reliability indices are customer-based indices and load-based indices. Customer-based indices record the frequency and duration of interruptions for individual customers. Load-based indices record the frequency and duration of interruption of load.

The Transmission network reliability indices are not all internationally standard and can vary from one transmission utility to another. This is due to the difference in interpretation of concepts such as delivery points and reception points, the difference in operating scenarios (back feeding options, load status and interconnectivity) and the voluntary and involuntary load reductions. The Distribution indices are more internationally standard and consistent amongst the Distribution utilities, but difference in interpretation does exist (especially on the "finer details" of reporting).

The advantages of the network reliability key performance indicators (KPI) are :

- Forecasting and trend analysis on the network performance. Appropriate performance improvement plans can be implemented.
- The predicted performance can also be evaluated against actual performance. Sustainable (long term) performance levels can be introduced into the electrical utility.
- Appropriate performance target setting and incentive based regulation and monitoring
- The customer expectations and experiences can be compared against the actual performance (measured).

5. Network Reliability Standards

The American Institute of Electrical and Electronics Engineers (IEEE) working group (WG) on System Design (15.06.02) has compiled the P1366-2003 standard "*IEEE Guide for Electric Power Distribution Reliability Indices*", that provides the network reliability measurement methodology and reporting requirements of the IEEE [3].

The international IEEE Task Force on Outage Reporting Practises (under the custodianship of the IEEE WG on System Design) is busy drafting a standard that will provide information regarding data collection, validation, storage, and reporting practices related to interruptions and outages affecting electric power distribution systems. Eskom Distribution is represented on the task force.

The International Electrotechnical Commission (IEC) standards on power quality have been grouped under the broader set of the EMC (Electromagnetic Compatibility) standard IEC-61000. Although not focused on interruption performance directly, the IEC standard (and associated technical reports) is forming a starting point in the discussion on transmission voltage targets (defined as planning levels in the standard).

The European technical standard EN 50160 provides definitions on short and long interruptions.

The existing NRS 047 (electricity supply quality of service) and NRS 048-2 (MV and LV quality of supply requirements) are not network reliability standards but do provide the minimum performance requirements for planned and forced interruptions and the restoration times of supply after a forced interruption. The definition of network reliability for the purposes of statistical system performance reporting will be defined separately by the NER.

Eskom Distribution has recently published its own standard (DISASACT3) *"Distribution network performance KPI definitions standard".* The Eskom standard aligns with the IEEE P1366 document, revises the existing network reliability indices, "cleans up" certain existing definitions and introduces a set of new reliability indices for Eskom Distribution [4].

The implementation of this standard on existing Eskom systems and database is currently been reviewed due to the potential purchase of the Outage Management (OM) product of a Distribution Management System (DMS) vendor.

6. Overview of Distribution Network Reliability Indices

The following summary information is based on the measurement and reporting methodology applied in Eskom Distribution. The intention is share the application of network reliability measurement and reporting and the difficulties that can be experienced in the actual implementation (from paper definitions and formulas to working software systems and databases) in a large and complex utility.

6.1 Medium and High Voltage Categories For Reliability Reporting

For network reliability reporting purposes the following voltage group definitions are used in Eskom Distribution :

- Medium Voltage (MV) will be regarded as network voltage levels of 11kV, 22kV and 33kV. This also includes the “odd” 1.73kV, 2.2kV, 3.3kV, 6.6kV networks in Eskom.
- High voltage (HV) will be regarded as network voltage levels 44kV, 66kV, 88kV and 132kV. The 44kV networks are regarded as HV due to their HV related design characteristics and application as a distribution voltage in Eskom Distribution.

Internationally MV networks are generally classified in the voltage range of 1-35kV. SANS 1019 does specify MV ≤ 44kV, but does also lists 44kV under Range B with the other HV classified voltages. Eskom Distribution (B. Chatterton) has made representation to have the 44kV networks moved into the HV category of networks in the NRS 048 standards.

6.2 Network Interruption Definitions

In Eskom Distribution a sustained network interruption (or loosely referred to as an outage) is a network event for which electrical supply was off for 2 minutes or longer. This 2 minute time window applies to medium voltage (MV) and high voltage (HV) networks. It is required that there is a 100% loss of voltage on the affected phase. The NRS 048-2 defines an interruption in terms of the disconnection of the supply point. In Eskom Distribution the outage is either recorded accurately via the Supervisory Control and Data Acquisition (SCADA) system, or the manual validation and auditing of the paper operating logs from the field staff.

An outage is usually referred to in terms of the state of a component that is not available to perform its intended function due to some event directly associated with that component.

A momentary interruption (short event) is an event less than 2 minutes. The momentary interruption can be the auto-reclose (ARC) operation of a circuit breaker and a 100% voltage loss on the phase is assumed. These momentary interruptions are reported separately and excluded from the sustained interruption reliability index calculations.

The primary network interruption is called the event and the associated network operation due to fault finding or switching is called a state change. On average an event can consist of 2 to 5 associated state changes (depending on the nature and complexity of the event). The state changes are counted in the reliability indices, if their duration is equal to or longer than 2 minutes. This detailed practice does tend to “penalise” Eskom Distribution in network reliability benchmark exercises.

Eskom Distribution will be changing the sustained interruption time window to 5 minutes for MV networks to align with the IEEE P1366 standard. In some cases automatic switching operations on MV networks (actual performance) do not get completed for several minutes and extending the window out to five minutes will also more accurately classify real sustained MV interruptions. This time requirement is also to differentiate between an automatic (system) and manual (operator) intervention to restore network supply to the customer.

The sustained interruption time for HV networks is proposed to be reduced to 1 minute to align with Eskom Transmission practices (one minute classification is commonly used internationally by transmission utilities) but may have to be reviewed and maintained at 2 minutes due to the potential telecontrol constraints.

These Eskom Distribution definitions align with the NRS 048 definition of a forced interruption and the subsequent classification into sustained and momentary interruptions.

6.3 Planned and Forced Interruptions

NRS 048-1 provides the definitions of planned and forced (unplanned) interruptions. In the Eskom Distribution context, forced interruptions are loosely referred to as “faults”. The sustained interruptions can then be broken down into their planned and unplanned (fault) components. The planned interruptions are regarded as controllable events and the unplanned (fault) interruptions as uncontrollable events.

A planned interruption is the loss of supply that results when a component is deliberately taken out of service at a selected time, usually for the purposes of construction, preventative maintenance or repair.

A forced interruption (fault) is the loss of supply that results when a component is taken out of service immediately, either automatically or as soon as switching operations can be performed, as a direct result of emergency conditions, or an interruption that is caused by improper operation of equipment or human error.

In Eskom Distribution the planned and unplanned (fault) interruption categories are time based and depend on the amount of notification time about the pending loss of supply that was provided to the customer. Where possible, at least 48 hours advance notification (and the use of the appropriate media), should be given of any planned interruption to the customer.

Customer voluntary load reduction events are characterised by the curtailment, partial curtailment, or reduction of customer load. These are not regarded as “pure” network interruptions and included as part of the network reliability indices. These events are measured and reported separately the under frequency load shedding (UFLS) metrics.

6.4 Sustained Interruption Indices

The following are the key sustained interruption indices used and their definitions.

SAIFI (System Average Interruption Frequency Index) : The SAIFI of a network indicates how often on average (frequency) the customer connected would experience a sustained interruption per annum. Mathematically SAIFI can be expressed as :

$$\text{SAIFI} = \frac{\text{Total number of customer interruptions p.a}}{\text{Total number of customers served}} \quad (1)$$

CAIFI (Customer Average Interruption Frequency Index) : The CAIFI of a network indicates how often on average (frequency) only the customers affected by an interruption experience a sustained interruption per annum. The customer is counted only once in this calculation regardless of the number of times interrupted. This index differs from SAIFI in that only the number of customer interruptions is used in the denominator and not all the customers connected. Mathematically CAIFI can be expressed as :

$$\text{CAIFI} = \frac{\text{Total number of customer interruptions p.a}}{\text{Total number of customers interrupted}} \quad (2)$$

SAIDI (System Average Interruption Duration Index) : The SAIDI of a network indicates the average duration of a sustained interruption the customer would experience per annum. It is commonly measured in customer minutes or customer hours of interruption. Mathematically SAIDI can be expressed as :

$$\text{SAIDI} = \frac{\sum \text{customer interruption durations p.a}}{\text{Total number of customers served}} \quad (3)$$

CAIDI (Customer Average Interruption Duration Index) : The CAIDI of a network indicates the average duration of a sustained interruption that only the customers affected would experience per annum. It is commonly measured in customer minutes or customer hours of interruption.

This index differs from SAIDI in that only the total number of customer interruptions is used in the denominator and not all the customers served. Mathematically CAIDI can be expressed as either :

$$\text{CAIDI} = \frac{\sum \text{customer interruption durations p.a}}{\text{Total number of customers interruptions}} \quad (4)$$

CAIDI is also the ratio of SAIDI and SAIFI. Or expressed as :

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}} \quad (5)$$

Numerically SAIDI = CAIDI x SAIFI. The general case is for CAIDI < SAIDI, as CAIDI only takes into account the number of effected customers.

The network reliability indices SAIDI and CAIDI are a measure of availability of supply (duration of interruptions) and SAIFI and CAIFI are indices that measure the reliability (frequency of interruptions) of the electrical supply. The indices can be broken down into their planned and unplanned (fault) components for detailed analysis.

CAIFI is very useful when a given calendar year is compared with other calendar years. In any given calendar year, not all the customers will be affected. CAIFI can be used in recognising chronological trends in the reliability of a distribution system.

The European convention is to refer to SAIDI as Customer Minutes Lost (CML) and SAIFI as Customer Interruptions (CI).

6.5 Momentary Interruption Indices

The following are the key momentary interruption indices used and their definitions.

MAIFI (Momentary Average Interruption Frequency Index) : The MAIFI of a network indicates how often on average (frequency) the customers served would experience a momentary interruption (MI) per annum. Mathematically MAIFI can be expressed as:

$$\text{MAIFI} = \frac{\text{Total number of customer MI p.a}}{\text{Total number of customers served}} \quad (6)$$

MAIFIe (Momentary Average Interruption Frequency Index of events) : The MAIFIe of a network indicates how often on average (frequency) the customers connected would experience a momentary event per annum.

If two or more breaker reclose operations (ARC’s) or momentary interruptions occur, within the relevant window period for the HV and MV definitions, then these interruptions will be considered as part of the momentary event and will only recorded as a single momentary event. Mathematically MAIFIe can be expressed as:

$$\text{MAIFIe} = \frac{\text{Total number of customer MI events p.a}}{\text{Total number of customers served}} \quad (7)$$

6.6 Eskom Internal Reliability Indices

In Eskom Distribution there are internally reported indices that measure the transformer availability (only count Distribution caused interruptions) and indices that are a modified form of SAIDI and SAIFI for the field work staff.

HSLI (HV Supply Loss Index) : The HSLI of a network indicates the average network loss duration by the HV plant installed due to sustained interruptions caused by only Distribution per month. It is a measure of the HV transformer availability and is expressed as hours per month. The HSLI will also include HV plant that has been affected by MV related through faults on the network. Mathematically HSLI can be expressed as :

$$\text{HSLI} = \frac{\sum \text{MVA.Hours lost per month}}{\text{Installed HV MVA base}} \quad (8)$$

MSLI (MV Supply Loss Index): The MSLI of a network indicates the average network loss duration by the MV and LV plant installed due to sustained interruptions caused by Distribution only per month. MSLI is mathematically similar to equation 8 above but with the MV transformers and MV related MVA used in the equation.

The SAIDI-N and SAIFI-N which are reliability indices of the network. The “N” represents the network. These are similar to the SAIFI, (equation 1) and SAIDI (equation 3) indices except the numerator only includes the events and not the associated state changes due to switching and fault finding and the denominator is the total number of installed transformers and not the total served customers on the network.

The state change fluctuations do not accurately reflect the level of “network performance” but do reflect the level of “customer reliability experienced”. The customer is more interested in that he had an interruption (customer reliability) and lost supply than that 5 successive operations occurred while fault finding (network performance). The fault finding is irrelevant as the customer is without supply anyway. From a network performance perspective, it is the event that counts not the number of state changes. The field work may feel that they should rather be compacted on SAIFI-N and SAIDI-N.

6.7 Major Events

A major event (ME) is an event that exceeds the reasonable design or the operational limits of the electrical network.

The IEEE P1366 standard proposes that a statistical approach is used (Beta Method) to identify major event days (MEDs). The purpose of this statistical approach is to allow major events to be studied separately from daily normal operation and in the process, to better reveal trends in daily operation that would be hidden by the large statistical effect of major events.

A major event day is a day in which the utility daily SAIDI (SAIDI/day) exceeds a pre-determined threshold SAIDI value The SAIDI reliability index is used as the basis of the ME definition since it leads to consistent results regardless of utility size and because SAIDI is a good indicator of operational and design stress [3].

Daily SAIDI values are preferred to daily SAIFI values because the SAIDI index is a better measure of the total cost of reliability event (including utility repair costs and customer losses), than the SAIFI index. The total cost of unreliability would be a better measure of the size of a major event, but collection of this data is not practical.

The calculation of SAIDI per day for Eskom Distribution is a system challenge (there are six independent databases for each region) and a process challenge (90% of all interruptions in a month have to be manually validated and audited) at this stage.

The Eskom Distribution proposed definition of a Major Event is when *“10% or more of all customers at a regional level only are affected by an abnormal event in a 24 hour period”* [4]. The application of this ME process has to be transparent and auditable. This definition aligns with the commonly used major event criteria of electrical utilities in the USA.

Currently in Eskom Distribution the network reliability values include the major events.

6.8 Step Restoration of Supply

Step restoration is the process where the actions of the utility during interruption supply restoration mimics the actual customer minutes experienced by the customer. The customer minutes are accurately tracked as customers have their supply restored. To assume the situation of ”all the customers off and all the customer on at the same time” will be the worst case scenario for the network reliability indices.

Depending on the step restoration methodology used by the utility the defined start and end time of an interruption can have a huge effect on the performance indices.

The following two definitions of a interruption duration that are used internationally :

- The interruption starts when the customer calls to the customer call centre and the interruption ends when supply is restored by the field work staff.
- The interruption starts when for the SCADA monitored substations and breakers, there is a lock out signal. The end time is when the breaker is returned back to supply signal that is provided by the SCADA system.

In Eskom Distribution both of the above approaches can be used (including the paper operating logs) to ensure that the step restoration process accurately reflects what the customers experienced.

6.9 Data Connectivity

Data connectivity refers to complete and accurate number of customers connected to a transformer. In Eskom Distribution this is referred to as the customer network link (CNL). The process of connectivity refers to the ability of the system to infer the interruptions onto all the affected customers (even those customers who did not call in), from data related to the received calls or the location of the affected device on the network.

When a transformer that serves 12 customers fails, but only two customers call in, does the system count 2 or 12 affected customers ? A utility with complete circuit connectivity takes the two calls, knows that the transformer serves 10 other customers and will record a loss of supply to all 12 customers. Utilities without circuit connectivity may only count the two calls as the total affected customers.

Without proper connectivity throughout the network and system, there is simply no way to know the exact number of customers that are out of supply for any given component failure and record the number accordingly. After implementing automated mapping systems with circuit connectivity and automated outage management systems (OMS), utilities have been known to experience increased reliability levels (but more accurate).

7. NER Reliability Requirements

The NRS 047-1 standard provides the minimum performance requirements of planned and forced interruptions of overhead and underground networks. The requirements shall be met with regard to at least 95 % of the customers.

Table 1 Summary of the frequency and duration of sustained interruptions for overhead networks (taken from Annex B NRS 047)

Category of network	Planned Interruptions		Forced Interruptions	
	Number	Total duration	Number	Total duration
Residential established	2	6	6	12
Rural overhead (≤ 22 kV)	N/A	N/A	60	200

In Eskom Distribution, greater than 97% of the networks consist of overhead conductors. In effect the network reliability requirements of rural overhead lines (≤ 22 kV) are SAIFI ≤ 60 and SAIDI ≤ 200. The major concern about these indicative values are that they do not take into account the network length. What network reliability levels should be expected by a customer on the end of a 300km radial, rural line in South Africa ?

The NRS 047-1 standard provides the following minimum customer restoration of supply times after a forced interruption :

- 30% of customers within 1.5 hours
- 60 % of customers within 3.5 hours
- 90 % of customers within 7.5 hours
- 98 % of customers within 24 hours

8. Future Regulatory Reporting

The NER Power Quality Advisory Committee in 2003, recommended the use of the IEEE network reliability definitions and calculation methods for regulatory reporting in South Africa.

The interruption performance indices SAIDI, SAIFI, CAIDI and MAIFI (and in their planned and unplanned components), are part of the requirements of the future Electricity Distribution Performance Monitoring System (EDPMS) to be implemented by the NER.

The relevant information to be managed by the EDPMS includes financial performance statistics, safety statistics, environmental performance statistics, customer service performance statistics, technical performance statistics, and human resource statistics. This information will be used to support strategic goal setting and economic regulation [8].

The EPDMS will promote the use of incentive based regulation (IBR). Accurate network interruption data and information systems will be critical for successful implementation of EPDMS and effective IBR. The IBR will require accurate reporting methods and accurate data to also facilitate appropriate target setting.

For example, in the case of Norway the data was accurate and based on over 10 years of monitoring, whereas in the case of Italy more “arbitrary” targets were set based on only 2 years of data and in the case of a few Italian distribution companies, no data was available at all.

The NER needs to ensure that there is uniform and consistent network reliability reporting of all the licensees in South Africa. The reality is that only providing a basic reliability index formula (such as SAIDI) will result in various different interpretations and various different approaches to which elements are included or excluded in the data. This may be a potential problem where licensees may be under pressure to seek "loop holes" that make their performance figures look better. This may require the compilation of a NRS 048 related standard to look at the MV network reliability measurement and reporting specification for all licensees in South Africa.

9. Future Incentive Based Regulation

The network reliability (interruption performance) indices will be one of the inputs to the total productivity factor (“X”) of the proposed Incentive Based Regulation (IBR). The “X” factor is calculated to represent the level of efficiency that the NER requires the regulated entity to achieve. The IBR method has replaced the existing Rate of Return (ROR) method used internationally. The IBR methodology is based on the simple economic principle of *“profit maximisation by cost minimisation”.*

The IBR is mathematically represented by equation 9 below [8] :

$$R2 = R1 \times (1 + RPI - X + Z \pm S) \qquad (9)$$

Where :
R2 is the new price and R1 is the current price

RPI is the regulatory price index which may be the Consumer Price Index (CPI), the Producer Price Index (PPI) or any other index which the NER may consider appropriate

X is the total productivity factor, which is calculated to represent the level of efficiency which the NER wants the regulated entity to achieve

Z is a factor for exogenous costs that are outside the control of the utility management. These costs are subject to the NER approval on whether they qualify or not.

S is the reliability and quality of supply incentive/penalty

By approving an increase less than the RPI, the NER forces the utility to control their costs to also increase at a rate less than the index. The utility should therefore make sure that they achieve productivity equal to or greater than the “X” factor. This is achieved by the utility combining inputs that are possible at the least cost but which achieves maximum productivity. The IBR targets are for long term improvement so are normally over several years (for example 3 years in Europe).

Network reliability improvements were experienced in Italy when regulatory incentives were introduced. There was a 43% improvement in the average interruption duration and a 30% improvement of the average frequency of interruptions over 3 years [2].

International Regulators have started to also consider momentary interruptions (MAIFI) and voltage dips as part of a holistic IBR application.

The challenge will be to find appropriate performance levels that are sustainable in the long term. Some of the short term based decisions by a utility, may result in the focus on the poor performing networks, but will not address the normal operation type maintenance and refurbishment requirements.

10. Reliability Benchmarking

10.1 International Benchmarking

Various utilities from around the world participate in international network reliability benchmark programs. The standard benchmark programs look at three values of network reliability indices, 1) for all events included, 2) for events excluding the planned interruptions and 3) excluding major events, as defined by the relevant criteria established by the participating utilities [9].

The Council of European Energy Regulators (CEER) established a working group (WG) on Quality of Electricity Supply in January 2000. One of the main objectives of this WG was to perform a European benchmarking study on quality of service. This study included interruption performance and QOS data. The countries that participated in the study were : Italy, Netherlands, Norway, Portugal, Spain, France and the United Kingdom. Most of the countries had data available at a regional or district level [10].

Eskom Distribution has participated in the international PA Consulting benchmark program (reliability certification program) since 2000, with utilities from Argentina, Australia, Chile, Brazil and Sweden. The intention of the program is to certify the reliability data capture, processing and reporting systems to align the metrics with international measures and best work practices.

A note of caution needs to be made about the difference between a direct performance comparison exercise and a true benchmark program. The difference needs to be clearly understood.

A direct performance comparison (number against number) does not portray the "true picture" and can provide very misleading results. Essentially one needs to "compare apples with apples" to ensure a more fair and representative benchmark exercise in order to gain any real value.

The figures below provide a high level network performance comparison (the sources of data are indicated in Table 2 below). There is no underlying analysis of the measurement and reporting methodology used. The intention is to provide reflective network reliability levels of countries/companies around the world

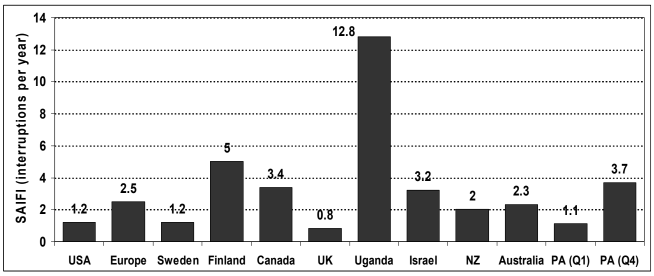

Figure 2 International SAIFI comparison results

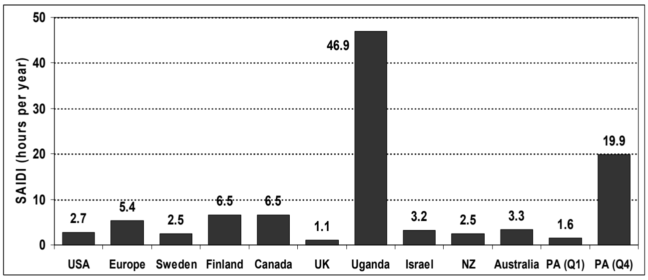

Figure 3 International SAIDI comparison results

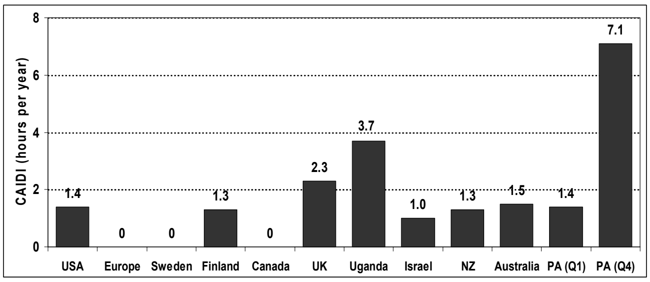

Figure 4 International CAIDI comparison results

Table 2 Sources of Data Used

Country or Company	Information about the data used
USA	IEEE WG on System Design 1997 survey Quartile 2 results comprising of 61 utilities across the USA
Europe	The Council of European Energy Regulators (CEER) data for Italy and France based on 1999 survey results
Sweden	CEER results for Sweden based on 1999 survey results
Finland	Rural Performance. Acknowledgements KEMA Consulting, USA (IEEE/PES T&D Conference)
Canada	Integrated utility from Canada (1991-2000). Acknowledgements Dr. Ali A. Chowdry (IEEE/PES T&D Conference)
UK	CEER results for UK based on 1999 survey results
Uganda	Stone and Webster Management Consultants (Oct 2003)
New Zealand	Waitaki Area results of 2001 for 7 utilities
Israel	Israel Electric Corporation (IEC) 2000 to 2003.
Australia	Average of results for 2001-2002 of 26 Australian utilities
PA (Q4)	Values from PA Consulting data Quartile 4 over 3 years
PA (Q1)	Values from PA Consulting data Quartile 1 over 3 years

10.2 Influence of Key Factors

The following are key factors that influence and need to be taken into account, when conducting a network reliability benchmark exercise [9].

- Step restoration methodology
- Geographic area
- Lightning ground flash density
- Network exposure and design
- Degree of Outage Management System (OMS) automation
- Completeness and accuracy of data connectivity
- Degree of system automation (SCADA and Distribution Automation)
- Performance measurement methodology
- Cost of domestic electricity price

Similar key factors are discussed in [11] A performance normalization model is proposed for the Distribution Network Operators (DNO) in the UK so that a fair and reflective performance comparison can be made amongst the DNO's.

Step restoration methodology
Discussed in detail in section 6.8. This might seem like a "basic concept" but the impact on the network reliability levels are significant.

Geographic area
The location of the networks, network distance from field service centers and the terrain (such as forests and mountains), have an impact on the reliability levels. Networks designed for rural areas are generally comprised of small substations with very long radial networks and with little network redundancy. Systems in dense

urban areas are normally made up of larger substations with multiple networks, redundant facilities, shorter line lengths and multiple interconnectivity.

Lightning ground flash density
The lightning parameter of importance for network lightning reliability is the lightning ground flash density. The ground flash density is the number of lightning strikes experienced per km^2 of ground per year. This is the measure of frequency of expected lightning strikes to an area or line. South Africa has a very high lightning ground flash density.

Network exposure and design
The percentage of the networks that are overhead compared to the percentage of the networks that are underground play an important part in the reliability levels.

It will be found that utilities with a large percentage of underground cables have better network reliability due to the low number of faults experienced on cable networks. On the rural networks, the basic insulation levels (BIL) of the woodpole structures is important. A rural network with 20km of exposure is inherently less reliable than an urban network of 5km.

Degree of OMS automation
For a fully connected model, the exact number of customers interrupted is known regardless of the system configuration. The most accurate OMS systems have fully integrated graphical information system (GIS) connected that provides network connectivity and customer counts.

The biggest impact is when a utility is in transition from a “legacy” system to a full OMS system. Legacy systems (paper and MS Excel) are typically systems capturing high level and sometimes inaccurate or incomplete data to assist with customer supply restoration. A full OMS system has complete and detailed data connectivity with fully integrated GIS and automatic tracing of events.

Completeness and accuracy of data connectivity
Data connectivity refers to complete and accurate number of customers connected to a transformer. The process of connectivity refers to the ability of the system to infer outages onto all affected customers (even those customers who did not notify the utility), from data related to the received calls or the location of the affected device on the network.

Degree of system automation
The degree of SCADA coverage and distribution automation (DA) used by a utility plays a important part in the automation of network fault identification, isolation and restoration. This usually improves the duration related reliability indices.

Performance measurement methodology
Many utilities have developed their own standards and eliminate such events as maintenance (planned) outages, customer caused interruptions, public caused interruptions and events over a certain duration.

Cost of domestic electricity price
The domestic electricity prices are a high level indication of the capital expenditure by a utility on the network. A high domestic electricity price indicates that the networks are built with redundancy and interconnectivity and should have better reliability levels.

10.3 Potential benchmarking of the NER

The end objective of a potential reliability benchmark program by the NER is to cost effectively improve the reliability of supply in South Africa. The benchmark can only be effectively done once there is a uniform and consistent reliability measurement and reporting of all licensees in South Africa.

The NER needs to compare "apples with apples" for accurate and reliable performance reporting and possible benchmarking between licensees in South Africa and potentially with international utilities. This will assist in determining which best work practices the licensees should implement, to improve the reliability of supply to acceptable levels.

11. Value Based Engineering

A new trend with international utilities is the concept of value based reliability engineering. This is the optimal design of a network to reduce costs, but still to ensure adequate quality of supply and network reliability for the customer. The value based reliability planning methodology attempts to provide the minimum cost solution for the financial investments of utilities.

In a value based approach, there are no absolute values for the reliability indices (like SAIDI and SAIFI) that are applied to all networks in a utility. Rather the customer’s reliability requirements, customer mix or industry, location of the network and design determine the acceptable reliability levels. The customer is offered various reliability levels (depending on network design and construction etc) and the associated costs for each option. The network planning is becoming more “customer driven”.

12. Lessons Learnt

- There needs to be a combined focus on QOS and network reliability. Eskom Distribution is focusing on improving the "3Cs" (customer complaints, claims and contracts), maintaining the very good QOS levels and significantly improving the network reliability levels.
- Improvement in the network reliability levels requires strong management leadership, drive and support. Sufficient funding is required to be made available with the engineering management role-players engaging the financial management role-players for support.
- Network reliability is to be compacted at all levels in the business (different weightings or components) so that there is "ownership" for all staff. "Tighter" network reliability targets are unpopular especially if financial bonuses are linked, but critical if the network reliability levels are to be improved.
- The "small things" can also make a "big impact" on the reliability levels. Optimised field staff switching and fault finding and the correct step restoration practices require a culture change in the business.
- The international reliability benchmark results can result in a "distorted picture" and "apples may not be compared to apples". A closer investigation and understanding of the "finer workings" of other utilities is important. What network reliability levels are acceptable for South Africa ?
- The reliability measurement and reporting methodology needs to be uniform, consistent and most importantly correct. Only then can performance enhancement programs be effectively implemented on accurate and reliable data.
- Greater communication and customer awareness of realistic performance reliability is required. Some performance improvement projects (such as woodpole replacements) may actually deteriorate the reliability levels in the short term.
- Appropriate systems (partial OMS or a full OMS) and people awareness to support the business are required. A culture change towards "data excellence" is also required.
- Value based planning needs to be established to take into the customer expectations and requirements.

13. Conclusions

Network reliability will be a focus area of the NER and one of the key inputs to the IBR. It is critical that a standard network reliability measurement and reporting methodology is established for South Africa.

Network reliability levels appropriate for South Africa need to be established taking into account the inherent conditions (theft, high lightning density, long radial rural lines and low cost of electricity etc). There needs to be alignment with customer expectation and actual network reliability. Technically this may not always be possible and can lead to "unsatisfied" customers. Customer awareness and education is vital to prevent this.

There is an expectation that the network reliability levels will improve in the future REDs and the IBR application. It is important that reliability benchmark programs are used to support this performance improvement drive.

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Biography

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