Telephone: (011) 899-4036 (work)
(011) 917-1634 (fax)
e-mail: delportst@ekurhuleni.com

Ekurhuleni Metropolitan Municipality
Department: Municipal Infrastructure
Electricity Division
PO Box 215
Boksburg
1460

AMEU (SA) Convention 26-28 September 2005: in Polokwane

Author & Presenter: Stephen Delport (Electrical Engineer's Certificate of Competency (Factories)- Chief Engineer Operations: Electricity Division: Corporate Office: Municipal Infrastructure Department of Ekurhuleni Metropolitan Municipality.

Title of Paper: "SENFIS"

Statistical Electrical Network Fault Interruption Spreadsheet – or – Super Electrical Network Fault Interruption Spreadsheet – or – Support Electrical Network Fault Interruption Statistics – or – Stephen's Electrical Network Fault Interruption Spreadsheet or may be we could call it

"PENFIS"

Predictable Electrical Network Fault Interruption Surprises

INTRODUCTION

Mainly with reference to NRS 048 and NRS 047 Rationalized User Specifications, an innovative spreadsheet was developed in order to report on Quality of Supply (QOS) within Ekurhuleni Metropolitan Municipality (EMM). NRS 048 and NRS 047 are based on the work initiated by the NER in setting up minimum standards and reports on QOS. Data is captured and received from nine Service Delivery Area's namely: - Alberton, Boksburg, Benoni, Brakpan, Germiston, Kempton Park, Tembisa, Springs and Nigel who now mainly forms EMM.

These EMM distribution networks are supplied with electricity from 45 Eskom intake points, at voltage levels ranging between 132kV and 6.6kV. From here a mixed customer base of approximately 330 000 customer are supplied with electricity connections. The sum of all the installed distribution transformer capacities (excluding major step-down transformers), exceeds 3 000 000 kVA with an estimated possible high and medium voltages node points that needs to be monitored and are controlled by more than 5400 switching circuits. The sum of all the maximum demands at the various Eskom intake points during the winter months of 2005 exceeded 2100 MVA.

A "tool" (spreadsheets) was therefore developed to provide meaningful, minimum required network fault interruption information to all managers/engineers. The original aim was to characterize and report interruption statistics in order to monitor performance as required by NRS 048 part 3 and report it to the NER. However, as with any software development, the need to expand the data capturing requirements are all the time demanding that new fields be added in order to assist the users and management with important information.

SYNOPSIS OF THE TOPIC

- This presentation aims to give a brief insight into typical municipal electrical network problems that are experienced on a day to day basis.
- It is based on actual experience, although figures were altered to ensure confidentiality.
- The real value added benefits gained from quantifying and graphically depicting interruption statistics to managers and decision makers are shared.
- Sharing the idea of the low costs involved to implement a spreadsheet application developed by the author.
- Although well known, to also demonstrate the powerful functions incorporated into today's modern spreadsheets and to demonstrate its almost data base like, data capturing functionalities in order to generate reports and graphs for electrical network fault interruption statistic (or for what ever other municipal services, water etc.)

KEY FOCUS AREAS

One of the primary causes of interruptions, namely "equipment failure", was broken down even further than what is required by NRS 048 –part 3. The additional categories contributed to compliment the analysis of the EMM electrical network performance monitoring.

The purpose of this paper is therefore primarily to focus on the components of required data capturing as specified in NRS048-3:2002, NRS 048-2:2003 and NRS 047-1:2004 and the Draft version of NRS048-6:2005. Due to the sensitivity of the information that may have negative reflections on certain service delivery areas, and without due consideration of having other Metropolitan Municipalities statistical information available to compare with one another, the information represented should be taken as sample data only unless otherwise stated.

To present the information, via a spreadsheet approach, is therefore to demonstrate the real value of the results obtained to all Electrical Engineers/Managers. To those who are involved with the day to day operations of an electrical network and who would normally consider this task of reporting network interruptions statistics as quite problematic, it can now be mentioned that the approach EMM followed were really implemented without difficulty.

A major factor that contributes to Ekurhuleni successful implementing a spreadsheet application programme was that a well established IT network through which e-mails can be sent/received electronically with ease exists. This has made it possible to transfer spreadsheet files between EMM head office and Service Delivery Areas, very effectively and without any hassles.

The excellent, existing in house knowledge of EMM personnel around the specific spreadsheet application used, also contributed a great deal to the successful implementation of the project. Minimum training/assistance was required.

Note: Where comparison of towns (or Service Delivery Areas) were made, within EMM, reference to their actual names were changed to A,B,C,D,E etc without any specific connection or reference to any of the towns(or Service Delivery Areas), for the purpose of this paper.

PREDICTABLE SURPRISES

- In a book titled "Predictable Surprises" (Harvard Business School Press), Max Bazerman and Michael Watkins define a predictable surprise as "an event or set of events that take an individual or group by surprise, despite prior awareness of all the information necessary to anticipate the events and their consequences." The authors make a case that many surprises are in fact foreseeable and can be avoided if we are clever enough to identify the clues and put the two-and-two together.

The important factor to consider from the above is probably that for any performance measurement with the aim to prevent surprises, you need a good measuring tool with accurate data to avoid the foreseeable surprises.

CATEGORIZATION OF EVENTS

General

The categorization and classification of interruptions and customer load reduction events in this part of NRS 048 are intended to be applied in evaluating the effects of such events on a specific customer's point of supply. The definition of interruption indices for the purposes of statistical system performance reporting, will be defined separately by the NER.

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

a) forced interruptions (see 4.3.1.2);
b) voluntary customer load reductions (see 4.3.1.3);
c) planned interruptions (see 4.3.1.4); and
d) involuntary customer load reductions (see 4.3.1.5).

Interruptions shall be further classified as either momentary interruptions or sustained interruptions.

NRS 047-1 Terms and definitions: Forced interruption:

a) occurs when a component is taken out of service immediately, either automatically or as soon as switching operations can be performed, as a direct result of emergency conditions, or

b) is caused by human error or by improper operation of equipment.

NRS 048-2: 2004 : (4.3.1.2 Forced interruptions)

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

Forced disconnection events typically occur when the only remaining circuit to a specific point of supply is disconnected in the event of either:

a) a failure of a component (such components include jumpers, joints, conductors, circuit-breakers and transformers),
b) a fuse or circuit-breaker operation,
c) a fault that does not result in reconnection of the circuit on all phases to the customer within 3 s,
d) a trip on one or more phases due to events such as an operator error or protection operation (for example, overload protection), or
e) a trip on one or more phases due to emergency action by the licensee.

Voluntary customer load reduction events

Customer load reduction events are characterized by the curtailment, partial curtailment, or reduction of customer load. Where both the following provisions are met, such events shall be categorized as voluntary customer load reduction events:

a) Actions to reduce load are required by the licensee specifically to protect the security of the supply system to its general customer base.

b) The customer has voluntarily agreed to such reduction before the event, and has been able to define the load to be interrupted or the load magnitude to be reduced (or both). (This agreement may be in terms of a contract, and may be executed by automatic relays designed to trip the load as agreed by the customer in such a contract). This includes voluntary under-frequency load shedding.

Planned interruptions

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

Planned interruption occurs when a component is deliberately taken out of service (by the utility or its agent) at a selected time, usually for the purpose of construction, preventative maintenance or repair.

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

Involuntary load reductions

Where a customer load reduction event is not classified as a voluntary load reduction event, it shall be classified as an involuntary load reduction event. Such events include liaison with a customer, by the licensee, just prior to requiring that the customer reduces load.

Planned and forced interruptions according to NRS 048-2

1	2	3	4	5	6	7	8	9
Category of network (see note 1)	Planned interruptions				Forced interruptions			
	Overhead distribution		Underground distribution		Overhead distribution		Underground distribution	
	Number	Total duration h	Number	Total duration h	Number	Total duration h	Number	Total duration h
Residential established	2	6	1 every 2 years	6 every 2 years	6	12	4	12
Residential developing	3	6	1	6	10	20	4	30
Commercial/small-to-medium industrial	2	6	1 every 2 years	6 every 2 years	6	10	2	10
Rural overhead (≤ 22 kV)			N/A	N/A	60	200	N/A	N/A

NOTE 1 For the purposes of this specification, the categories listed in column 1 are categories of network, not of customer (for example, a customer operating a commercial enterprise could be located in an area that has been designed to serve residential customers).

NOTE 2 The numbers and durations for overhead distribution assume bare conductors. These figures will also apply when aerial bundled conductors (ABC) are being assessed but, in general, better performance could be expected from ABC systems.

NOTE 3 Short-term interruptions owing to auto-recloser operation should be excluded from the number of forced interruptions allowed in developing residential areas and on rural overhead systems.

NOTE 4 A simple test can be used to determine whether an interruption should be classified as forced or planned (see 3.1.3 and 3.1.6 for definitions of a forced interruption and a planned interruption). If it is possible to defer the interruption when such deferment is desirable, the interruption is a planned interruption; otherwise, the interruption is a forced one. Deferring an interruption might be desirable, for example, to prevent overload of facilities.

NOTE 5 A mixed overhead and underground network should be regarded as an overhead network for the purpose of determining the allowed number of forced or planned interruptions.

NRS 048-3:2002 (third edition) defines the following:-

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

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

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

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

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

Category 6 sites are defined as the busbars of permanent generating stations and facilities that produce an output that is ultimately sold to customers.(Category 6 Not Applicable to EMM)

Although NRS 047-1 specifically specify categories of network , not of customer, the spreadsheet were designed to accommodate the complex and combined way generally in which a municipality network supply electricity to customers.

In terms of NRS 048-3: 2002, the primary cause of interruptions shall be categorized as follows:

EQUIPMENT FAILURE:

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

EQUIPMENT FAILURE:			
NRS 048-3		**SENFIS**	
A1	dielectric breakdown (includes breakdown due to pollution)	A1	PILC Cable breakdown
A2	mechanical failure	A2	XLPE Cable breakdown
A3	broken conductor	A3	Dielectric breakdown: Lines
A4	other	A4	Broken conductor
		A5	Switchgear: Mechanical failure
		A6	Capacitor Bank
		A7	Circuit Breaker Indoor
		A8	Circuit Breaker Outdoor
		A9	Transformer
		A10	Tap changer
		A11	Dielectric breakdown: Busbars
		A12	Blown Fuses
		A13	Other

OPERATIONAL CAUSES:

Operational causes			
NRS 048-3		**SENFIS**	
B1	incorrect protection operation	B1	incorrect protection operation
B2	incorrect control equipment operation	B2	incorrect control equipment operation
B3	operator error	B3	operator error
B4	Other	B4	B4: Protection operation Correct: Circuit Over/Loaded
		B5	Other

THIRD-PARTY CAUSES AND SENFIS

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

SENFIS only records “natural events” as the exact reason cannot always with certainty be determined.

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

BULK INTAKE:

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

UNKNOWN:

F1: interruptions for which there is no known cause

In an effort to capture at least some minimum important required network interruptions and related other information, the author has developed a comprehensive spreadsheet. To demonstrate some of the spreadsheet functions used the following is displayed in Table 1 below:-

1 Analysis of Electrical System Fault Incidents

SELECT TOWN NAME

DATE	TIME RECEIVED	TIME COMPLETED		SUMMARY TIME TAKEN TO REPAIR FAULT	
Actual Time of Interruption	00:00	0:00:00		DAYS	0
	00:00	00:00		HOURS	0
				MINUTES	0

Switchgear / Transformer/ Area Name:-

SELECT FEEDER NAME!!

Installed kVA Lost: #N/A

SIC: #N/A

Interruption	Forced Interruption	Planned Interruption	Voluntary Load reduction	Involuntary Load reduction
		x		

Select O/H or U/G Category

Network Category 2A; 2B; 3	Equipment failure	Operational causes	3 rd Party causes	Natural Events	Bulk Intake	Unknown Events	Overhead (O) Underground (G)
2A:Residential Rural	A1: PILC Cable		C1: Contractors				
0	A2: XLPE Cable		C2: Motor Vehichle accident		0		
2B: Residential Urban	A3: Dielectric breakdown: Lines		C3: Theft				
	A4 Broken conductor		C4: Cust prot failed to clear fault				
0	A5 Switchgear : Mechanical failure		C5: Human interference				
	A6 Capacitor Bank		C6: Other				
Predominantly Commercial/Industrial >1kV <=22kV	A7: Cicuit Breaker Indoor						
	A8: Cicuit Breaker Outdoor	Operational causes					
0	A9: Transfomer	B1: Incorrect protection operation					
	A10: Tapchanger	B2: Incorrect control equip operation					
Category 3: MV Distrution >22kV<44kV	A11: Busbars	B3: Operator error					
0	A12: Blown Fuses	B4: Other					
Voltage	A13: Other						

Voltage
- 2A > 1kV up to 22kV MV O/H Rural
- 2B > 1kV up to 22kV MV Urban
- 3 > 22kV up to 44kV
- 4 > 44kV up to 132kV
- 5 > 132kV
- 6 > Generation Station

ENTER PLANNED DATE & TIME

SELECT O or G

WITH IN	0	Planned mintues		
00:00	0:00:00		DAYS	0
00:00	00:00		HOURS	0
			MINUTES	0

Description of event / fault /:

Action Taken:

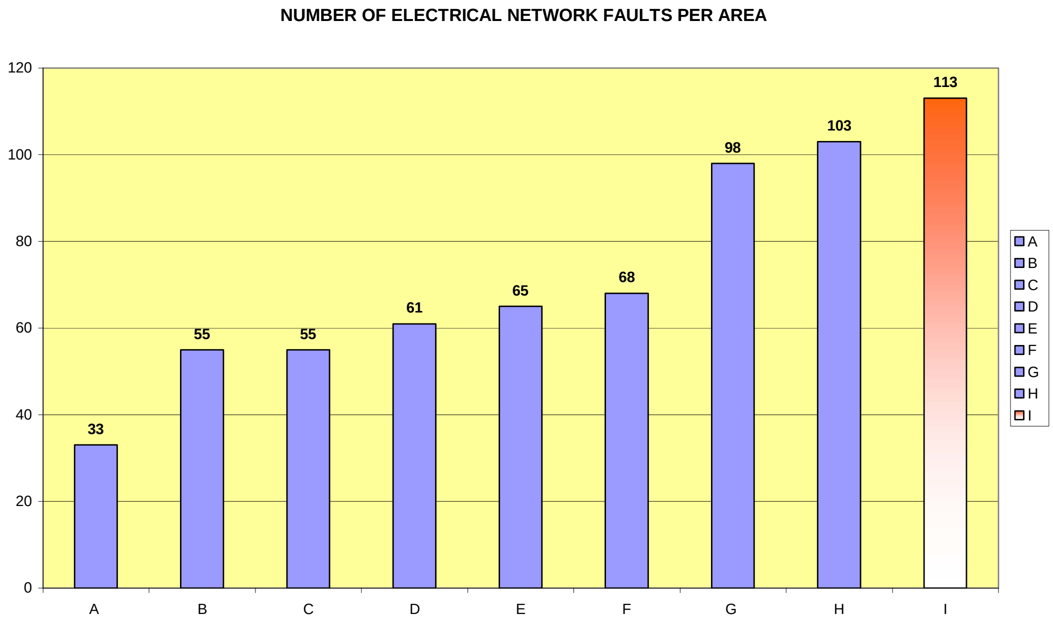
SELECT NAME ?

Responsible Person : NAME __________ Signature: __________

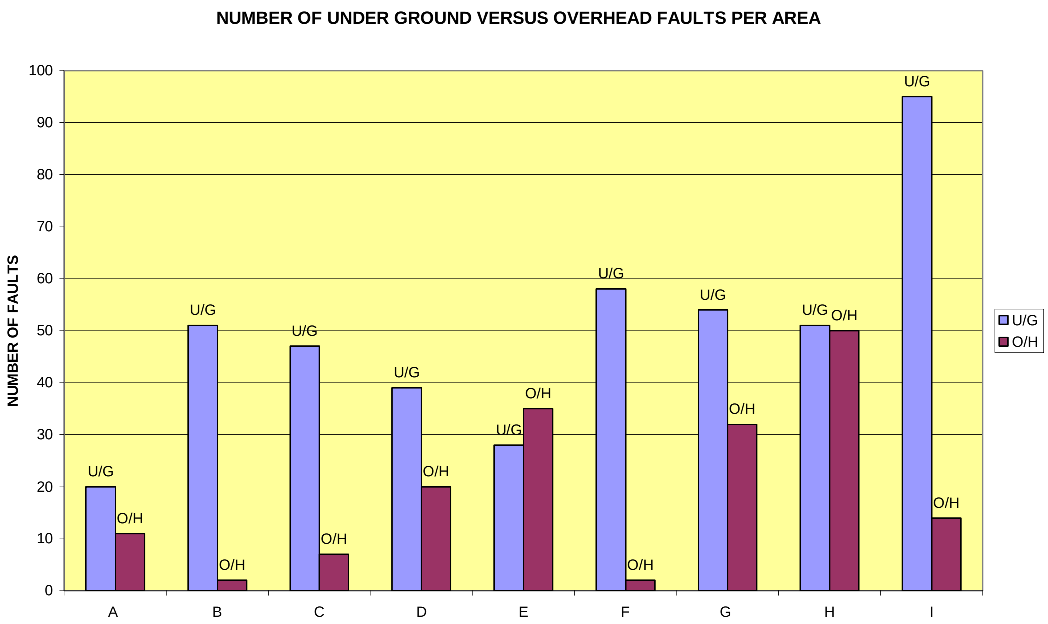
Table 1 above

In order to demonstrate some of the results obtained from the spreadsheet interruption statistics Graphs 1 to 11 are inserted to depict some specifics.

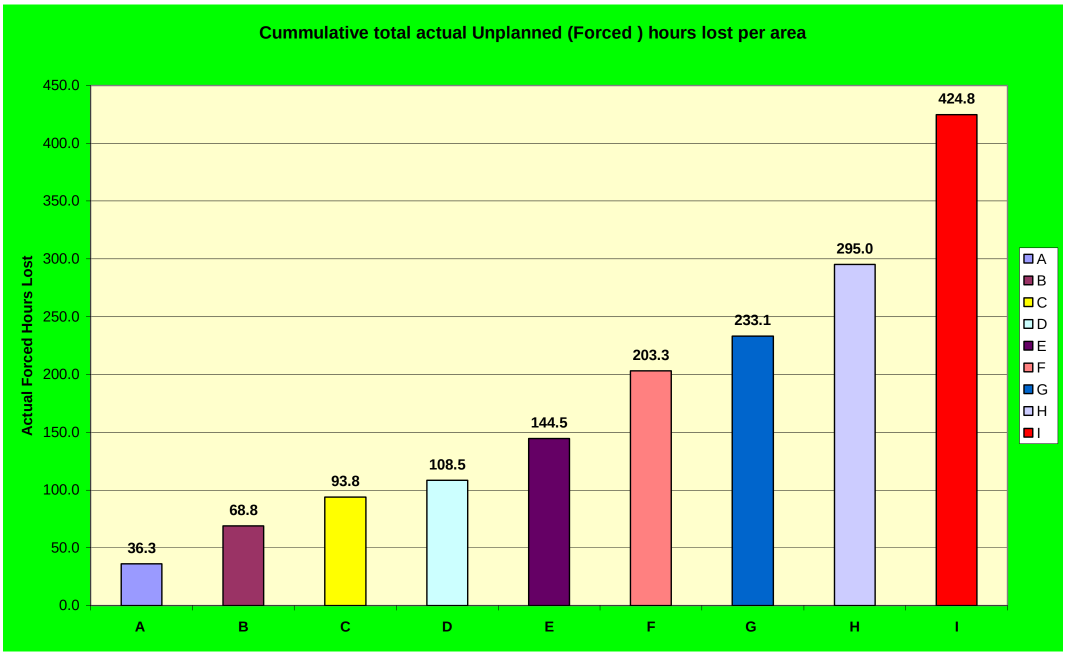
Graph 1 below typically indicates the number of electrical network faults that occurred over affixed period. The red bar shows the service delivery area or network where the most faults occurred over the measured period.



Graph 2 below the number of under ground cable faults versus number of overhead line faults per area. There may be good reasons why one area is expected to have more overhead line faults than another due to the network design. Surprising statistics for an area with few lines may also be forthcoming.



Graph 3 depicts typically cumulative hours of all Unplanned (Forced) Interruptions without taken consideration of what connected transformer capacity or load were affected. The red bar is indicating that a specific area have experienced the surprisingly the longest cumulative hours of unplanned interruptions in comparison with other areas that may even have larger networks.



In terms of NRS 048-3:2002 the following requirement is stated:

4.6 MV and HV forced interruption statistics

4.6.1 Forced interruption indices

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

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

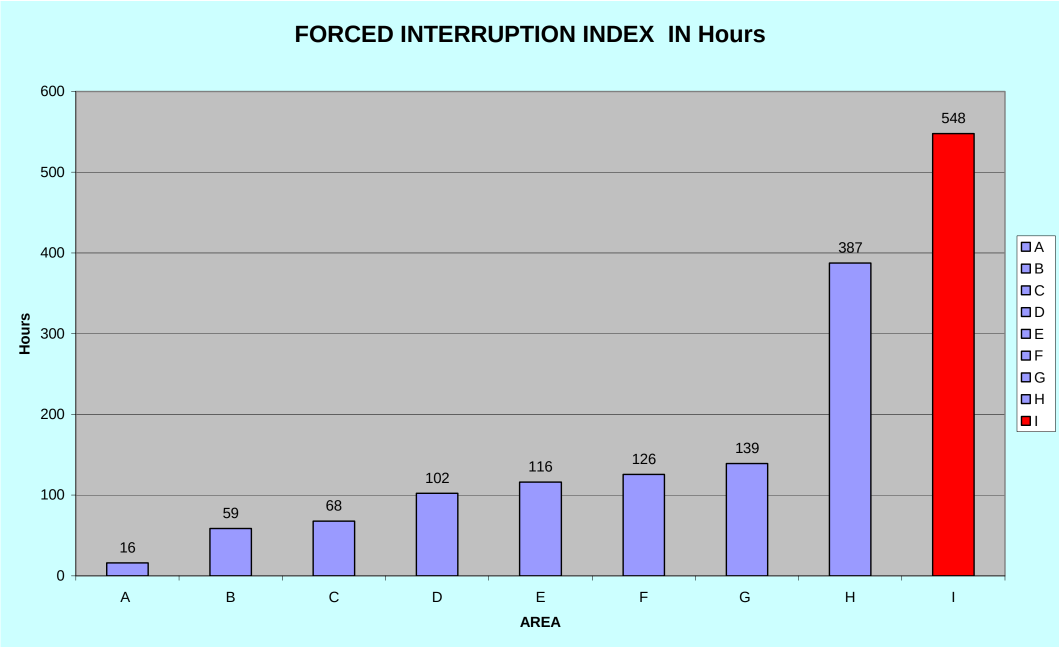
$$F_1 = AB / T$$

where

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

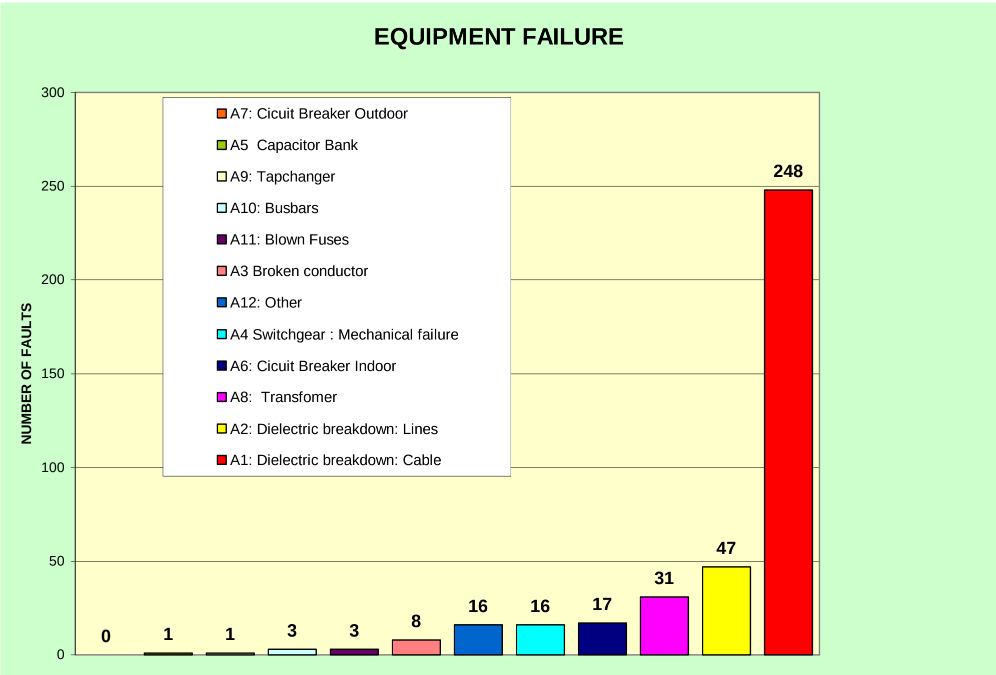
Therefore, in order to demonstrate the value of possible results that may be obtained from comparing various service delivery areas indices within a municipality. The reason why indices (F1) are being calculated is to actually compare larger and smaller networks with one another on the same basis by using the aforementioned method. Graph 4 is displayed as follows:

Graph 4

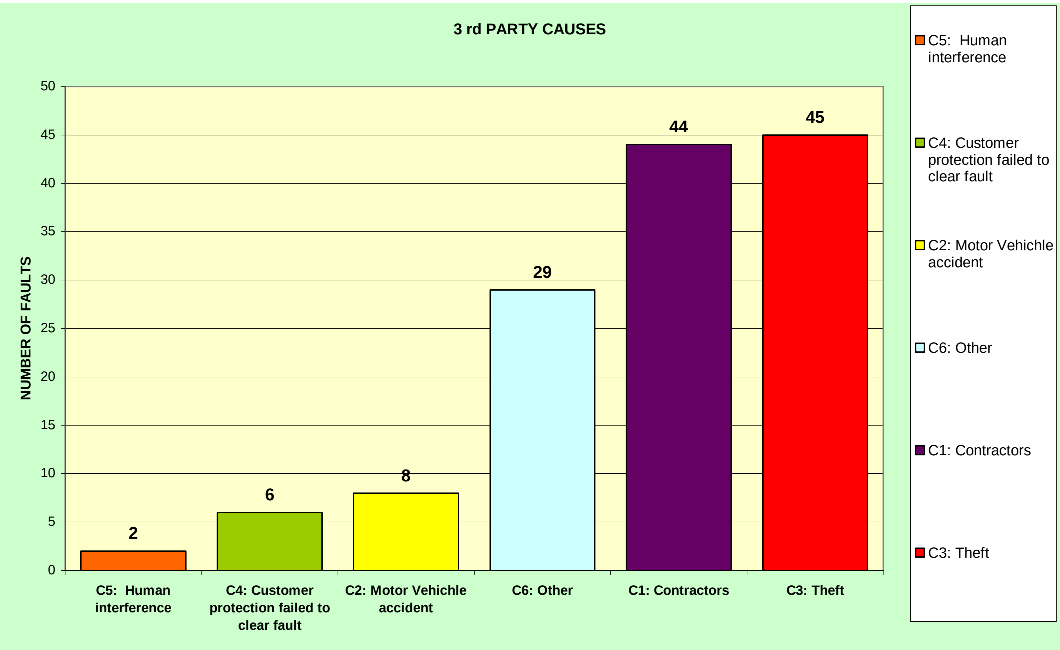


Graph 5 depicts the number of different equipment failures and clearly indicates that Equipment Failures “Cables faults” are the most serious contributing reason within a specific network. The ratio between cable faults and overhead lines, the next highest contributing equipment failure is 5:1.Can we predict that all underground cables is the biggest contributing factor or is the type of cable, XLPE or PILC, or the type of joints used, or the workmanship of joints and terminations suspect?

Graph 5

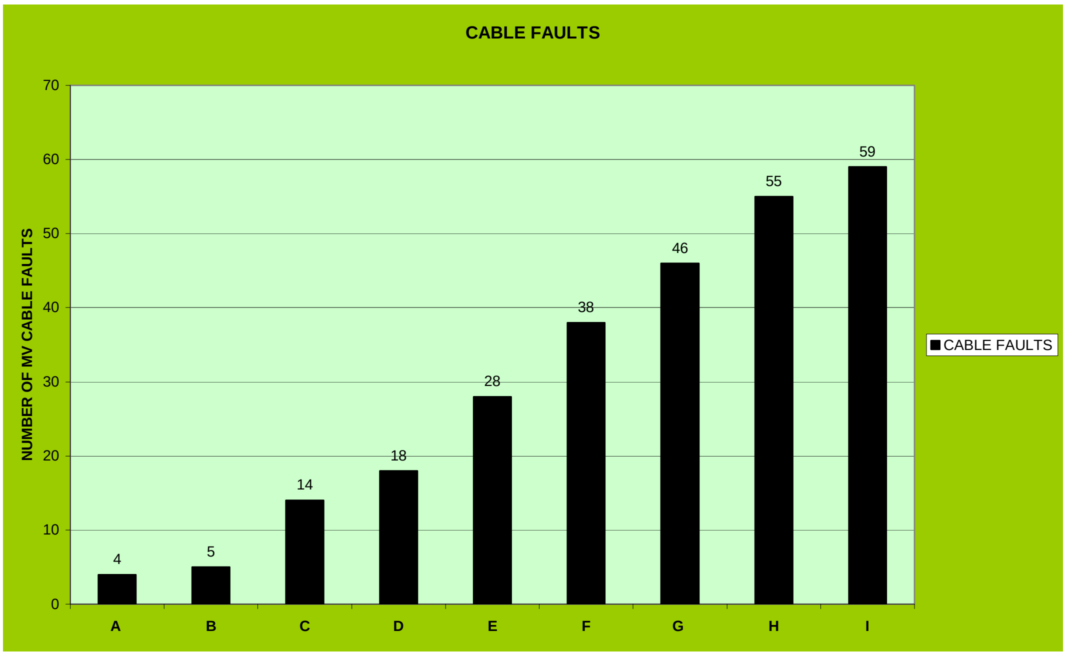


Graph 6 indicates that in terms of 3rd Party causes "THEFT" related incidents are the most serious contributing factor. Contractors causing damage to electrical services within a municipality is also a cause of concern:-



Graph 7: Because cable faults is causing the most faults it can be further broken down over a specific period per area in order to determine specific reasons for this.

Graph 7



In terms of NRS 047-2:2001 the following requirement is stated:

NRS 047-2:2001 18

4.5.3 Recommended reporting format for the restoration of supply after a forced interruption

1	2	3	4	5	6	7	8	9	10
Month	**Total number of forced interruptions after which supply is restored**	**Supply restored within 1,5 h**		**Supply restored within 3,5 h**		**Supply restored within 7,5 h**		**Supply restored within 24 h**	
		Actual	**Percent-age**	**Actual**	**Percent-age**	**Actual**	**Percent-age**	**Actual**	**Percent-age**
January									
February									
March									
April									
May									
June									
July									
August									
September									
October									
November									
December									
Average									

Comments:

NOTE 1 In column 2, state the total number of forced interruptions after which supply was restored each month.

NOTE 2 In column 3, write the actual number of forced interruptions after which supply was restored within 1,5 h.

NOTE 3 The value in column 4 is the value in column 3 divided by the value in column 2 multiplied by 100. Calculate the average of column 4.

NOTE 4 In column 5, write the actual number of forced interruptions after which supply was restored within 3,5 h. This would include those forced interruptions where supply was restored within 1,5 h.

NOTE 5 The value in column 6 is the value in column 5 divided by the value in column 2 multiplied by 100. Calculate the average of column 6.

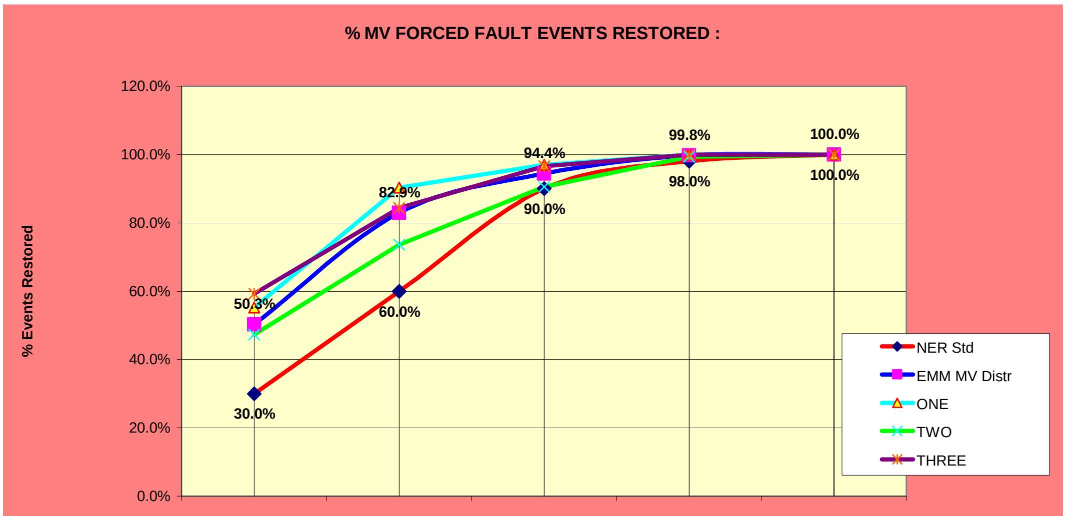
NOTE 6 Similarly, in column 7 and column 9, write the actual number of forced interruptions after which supply was restored within 7,5 h (will include the forced interruptions where supply was restored within 1,5 h and 3,5 h) and the actual number of forced interruptions after which supply was restored within 24 h (will include the forced interruptions after which supply was restored within 1,5 h, 3,5 h and 7,5 h) respectively.

NOTE 7 The value in column 8 is the value in column 7 divided by the value in column 2 multiplied by 100. Calculate the average of column 8.

NOTE 8 The value in column 10 is the value in column 9 divided by the value in column 2 multiplied by 100. Calculate the average of column 10.

Graph 8 depicts the performance of the above mentioned reporting requirement (NRS 047-2) The red line shows the expected standard set to be met, whilst the dark blue line shows that the average of all faults are performing better than the standard. The other three lines are performance indicators per a specific region.

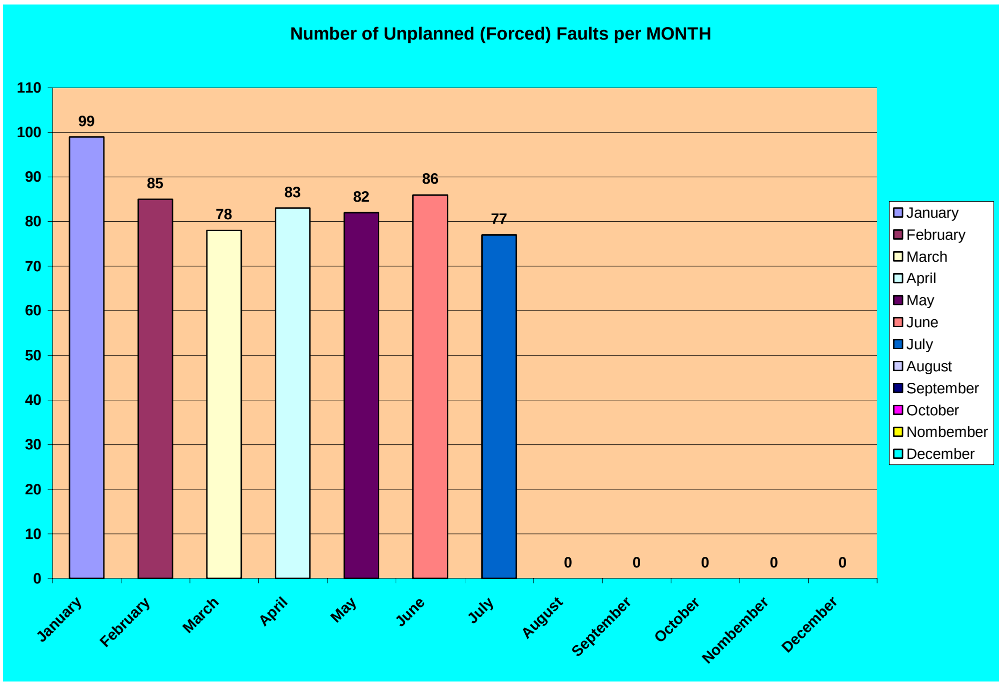
Graph 8



NER Std	30.0%	60.0%	90.0%	98.0%	100.0%
EMM MV Distr	50.3%	82.9%	94.4%	99.8%	100.0%
ONE	55.3%	90.3%	97.0%	100.0%	100.0%
TWO	47.3%	73.6%	90.5%	99.3%	100.0%
THREE	59.2%	84.4%	96.6%	100.0%	100.0%

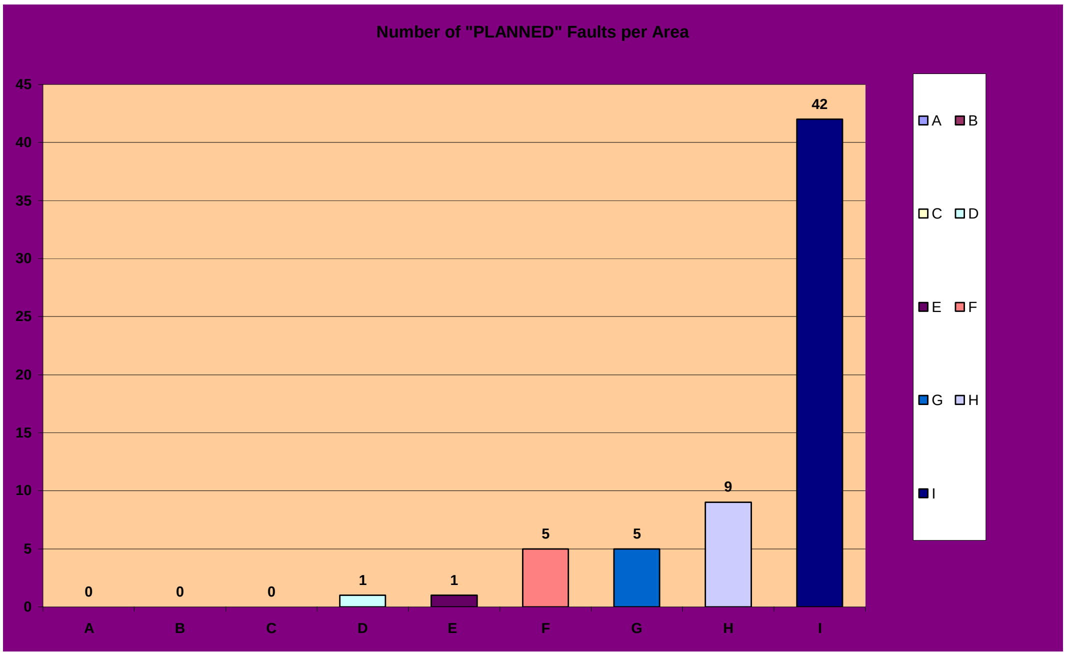
Graph 9 depicts the number of unplanned (or forced) altered faults per month. Once annual data is available, this may indicate in which month predictable surprises may arise.

Graph 9



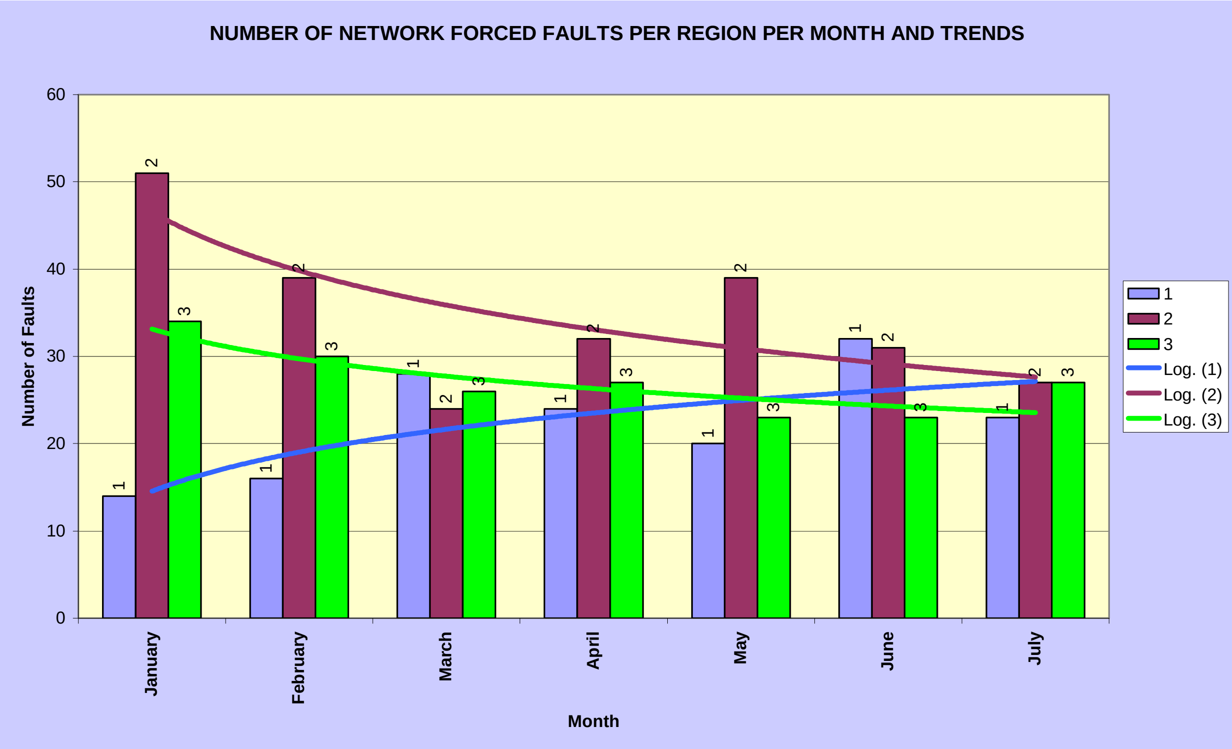
Graph 10 depicts the number of planned faults per month. This is fault where as required customers have received prior notice that there electricity supply will be interrupted at a specific date and between specified times.

Graph 10



An advantage of being a Metropolitan Municipality is that a broad base of similar areas exists to compare its network performances with one another. To demonstrate the value of possible results that may be obtained and the difference in trends, Graph 11 is displayed to compliment this viewpoint. The blue line indicates that the number of faults in region one is on the increase whilst those within regions 2 and 3 is decreasing.

Graph 11



In summarizing, the following remarks can be concluded with:-

In order to effectively manage and monitor the quality of supply and electricity service within the Ekurhuleni Metropolitan Municipality Electrical Network, effort was made to implement a cost effective solution, SENFIS was implemented at a real low cost to the municipality. The results are proving to be of real and tangible value to engineers and managers alike. Electrical network performance information is now available for EMM managers that will assist all involved to face the challenge of improving power quality.

It is realized that the spreadsheet (SENFIS) by far do not fully address all possible interruption detail that needs to be addressed. There are many other challenges that also need to be address e.g. ageing networks, growth in energy losses, quality of products, quality of workmanship, etc. However, with some accurate data and management involvement, critical problems can immediately be identified, and this may assist in improving the reliability of a network. The aforementioned are important challenges the EDI faces for sustainable business.

It is acknowledged that the management of power quality is a multi-dimensional task and that the implementation of SENFIS is only part of it. The effectiveness of any power quality management program is determined by the commitment of senior managers within any organization, and the author therefore really wants to express his thanks to all EMM electricity directors and their staff for their continued commitment in capturing data and full support to the SENFIS spreadsheet.

It is further envisaged that valuable electrical network benchmark interruption statistics will be forthcoming from EMM and submitted to the NER. These statistics can then be compared with those received from other utilities.

Minimum training was required for Ekurhuleni as most of the personnel were familiar with the well known specific spreadsheet functions.

- If we do have all the data, will we face the challenges to anticipate the events and their consequences?

- Networks are live but may die if not well maintained and refurbished.

- NB!!" Max Bazerman and Michael Watkins do make a case that many surprises are in fact foreseeable and can be avoided if we are clever enough to identify the clues and put the two-and-two together.

- How clever are we?

Note:-The author & presenter wants to make it clear that the content, discussions, comments or views included in/on this paper do not necessarily represent the position or views of Ekurhuleni Metropolitan Municipality.

References:

NRS 047: Electricity Supply - Quality of Service

NRS 048: Electricity Supply - Quality of Supply

Book titled "Predictable Surprises" (Harvard Business School Press), 2004, Max Bazerman and Michael Watkins

SENFIS: Stephen Delport