Industrial Project IV

Condition Monitoring and Preventative Maintenance of Medium Voltage Cables

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Background

- The North East Field Service Area comprises of five field service centers namely Pretoria, Witbank, Secunda, Nelspruit, Groblersdal and Hazyview.
- Pretoria has the longest medium voltage cable network totaling 1257km followed by 696, 65, 42.25, 34.2, 25km respectively. Regional (2119.45km)
- The Pretoria area was the area of concern.

Introduction

- Many of the major supply interruptions in the north east field service area were due to cable faults. The actual number of cable faults increased greatly over the last couple years hence leading to poor network performance.
- Many of the faults occurred during the rainy season.
- Some cables failed on switch which was worrying.
- These unpredictable networks were the main cause of a poor customer base.

Problem Statement

- High failure cable rate.
- Current test practices. (Approach)
- High operational cost.
- Inconvenience of customers. (Global interest)
  - High industrialized customer (Pretoria).
  - Employment is affected.
- Company image. (RED'S)

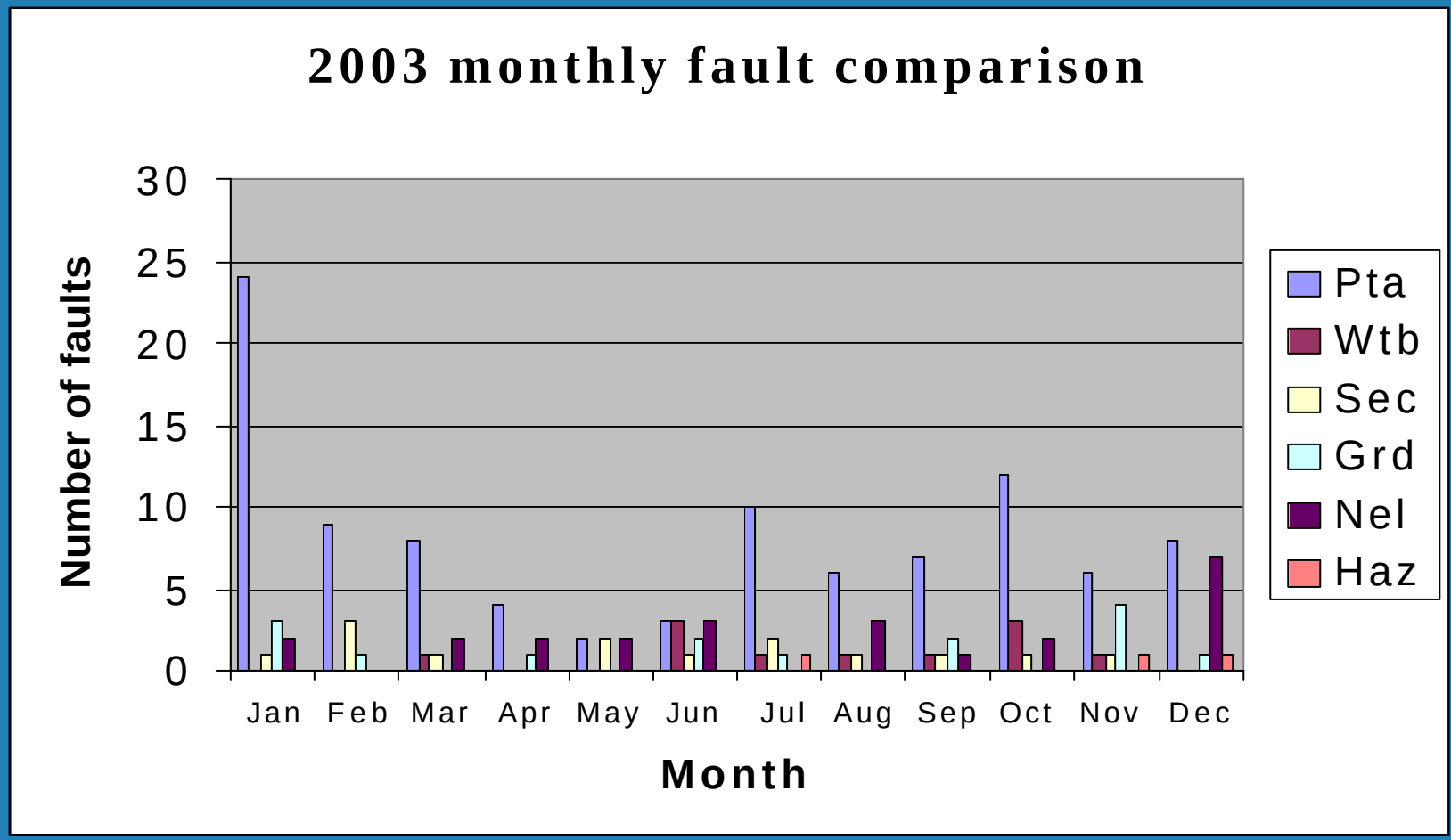
Cable Fault Level Study

- During 2003 there were a total of 161 cable faults in the North East Field service area.
- 99 of these faults were on the Pretoria networks followed by nelspruit having 23 faults.

Monthly breakdown of faults per FSC for 2003

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Area Tot.
Pta	24	9	8	4	2	3	10	6	7	12	6	8	99
Wtb	0	0	1	0	0	3	1	1	1	3	1	0	11
Sec	1	3	1	0	2	1	2	1	1	1	1	0	12
Grd	3	1	0	1	0	2	1	0	2	0	4	1	12
Nel	2	0	2	2	2	3	0	3	1	2	0	7	24
Haz	0	0	0	0	0	0	1	0	0	0	1	1	3
Mthly Tot.	30	13	12	7	6	12	15	11	12	18	13	17	161

Monthly fault comparison per FSC for 2003.

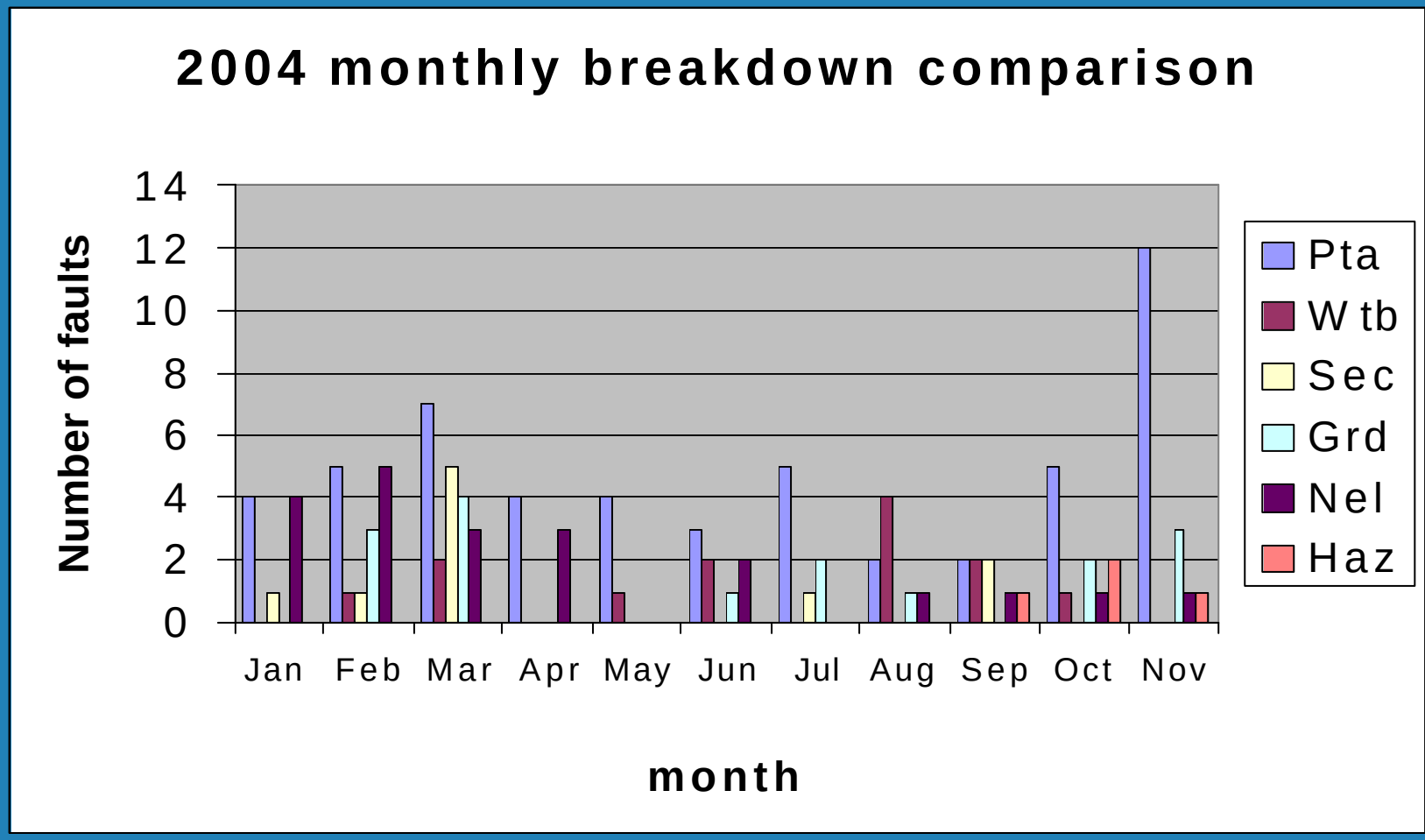


- There has been a marginal improvement in the cable network performance from 2003 to 2004 in certain areas.
- The total number of faults in 2004 ranged at around 134 faults. Pretoria (61) Nelspruit (33)

Monthly breakdown of faults per FSC for 2004

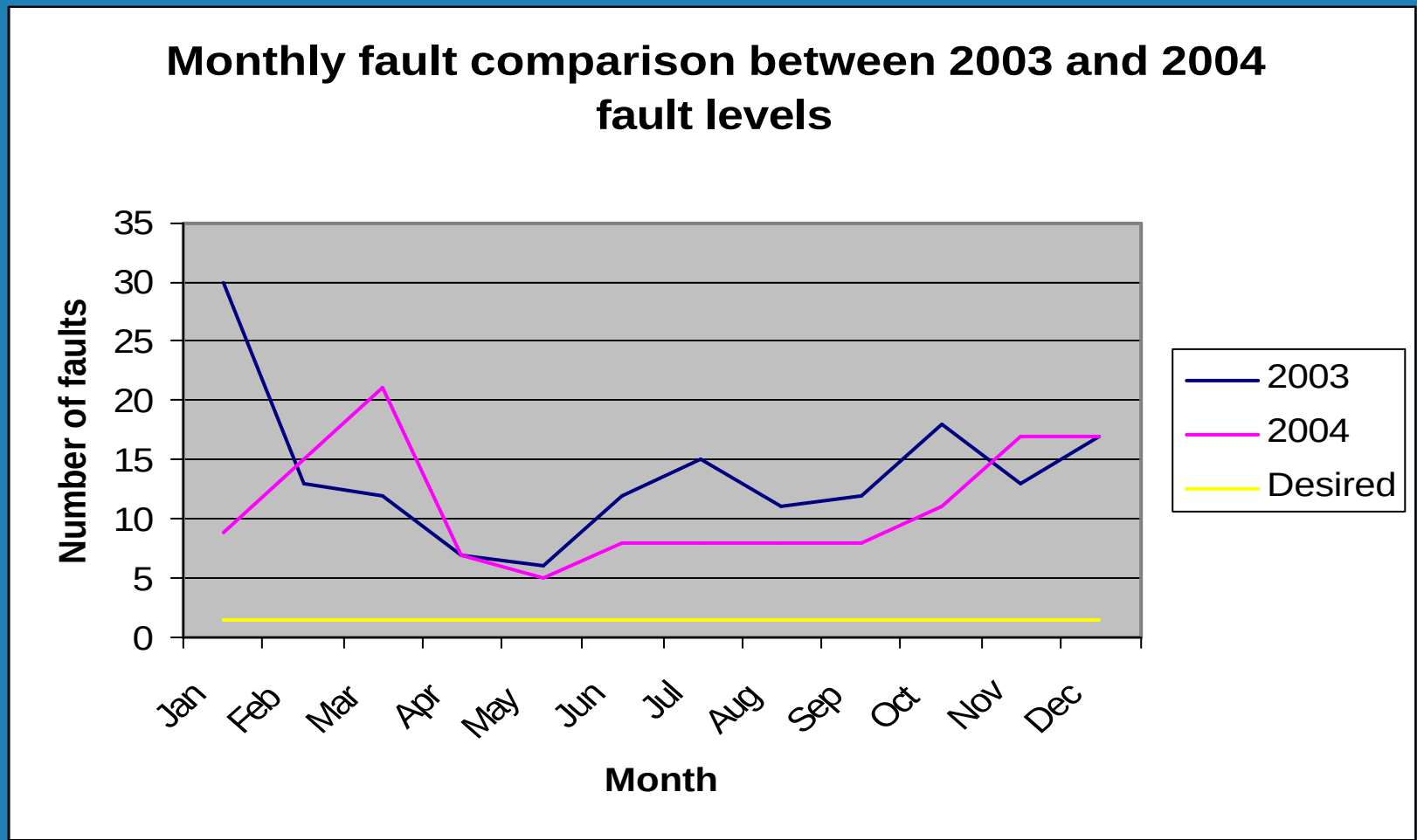
Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Area Tot.
Pta	4	5	7	4	4	3	5	2	2	5	12	8	61
Wtb	0	1	2	0	1	2	0	4	2	1	0	1	14
Sec	1	1	5	0	0	0	1	0	2	0	0	3	13
Grd	0	3	4	0	0	1	2	1	0	2	3	3	19
Nel	4	5	3	3	0	2	0	1	1	1	1	1	33
Haz	0	0	0	0	0	0	0	0	1	2	1	1	5
Mthly Tot.	9	15	21	7	5	8	8	8	8	11	17	17	134

Monthly fault comparison per FSC for 2004



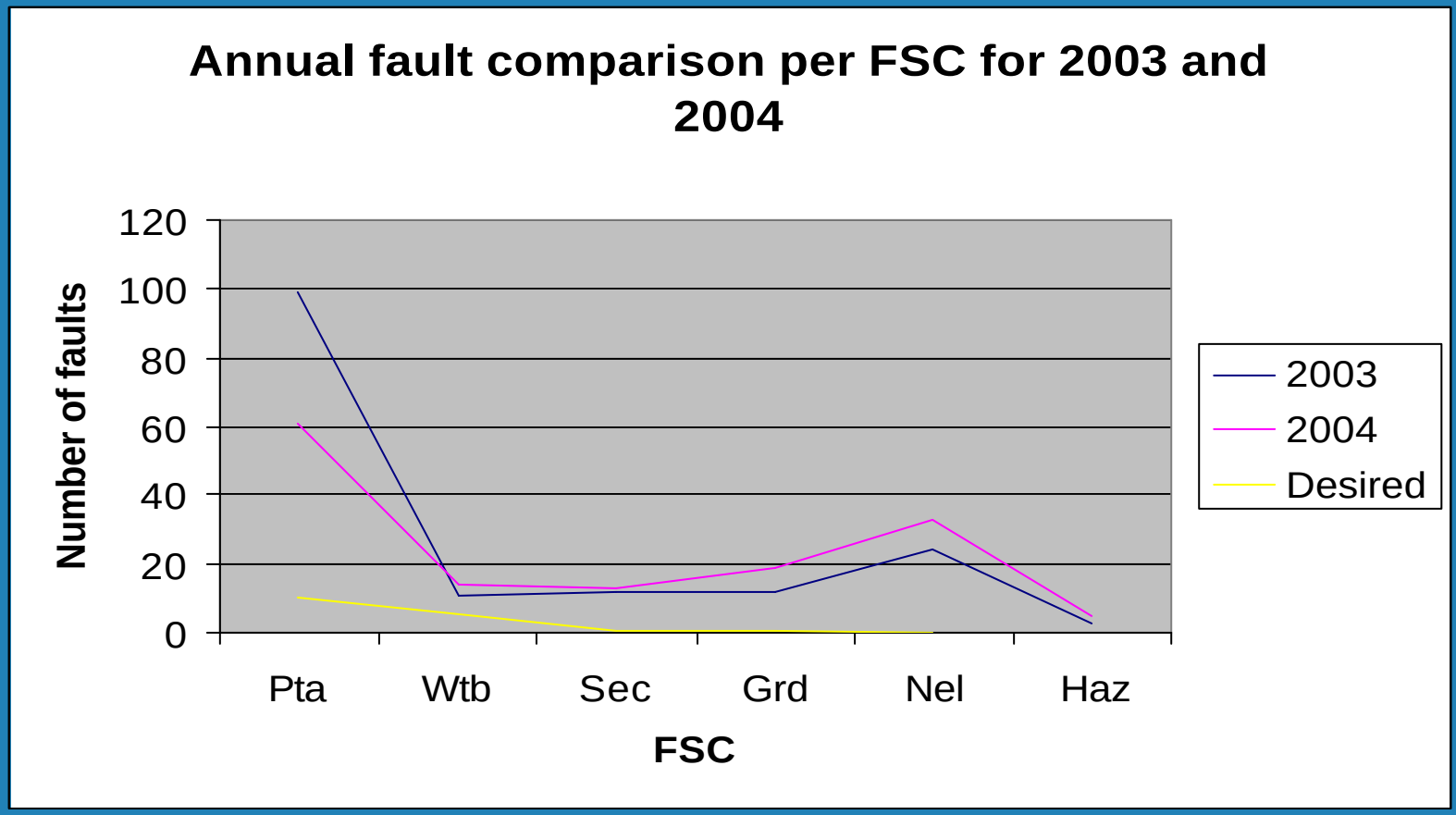
- Looking at the regional performance there has been very slight improvement and no set fault pattern.
- Network was never stable for a long period of time.

Comparison of the number of faults in 2003 and 2004 for the north east field service area



- Looking at the cable performance per field service center Pretoria still by far has the most number of faults followed by Nelspruit.
- Witbank, Secunda and Groblersdal are fairly stable but still far from the desired.

Regional comparison between the number of faults per FSC for 2003 and 2004



Findings

The root causes of cable faults in the region were broken up into four categories

- Faults on cable joints
- Faults on cable terminations
- Faults due to mechanical damage
- Others such as theft, lightning, insulation co - ordination.

- In 2003 there was a total of 60 joints and 23 terminations that failed in service. Mechanical damage were at minimum levels. Theft was the result of 15 other faults.
- In 2004 there was a total of 64 joints and 39 terminations that failed in service. Mechanical damage was at minimum levels.
- Viewing the tabulated breakdown we have.....

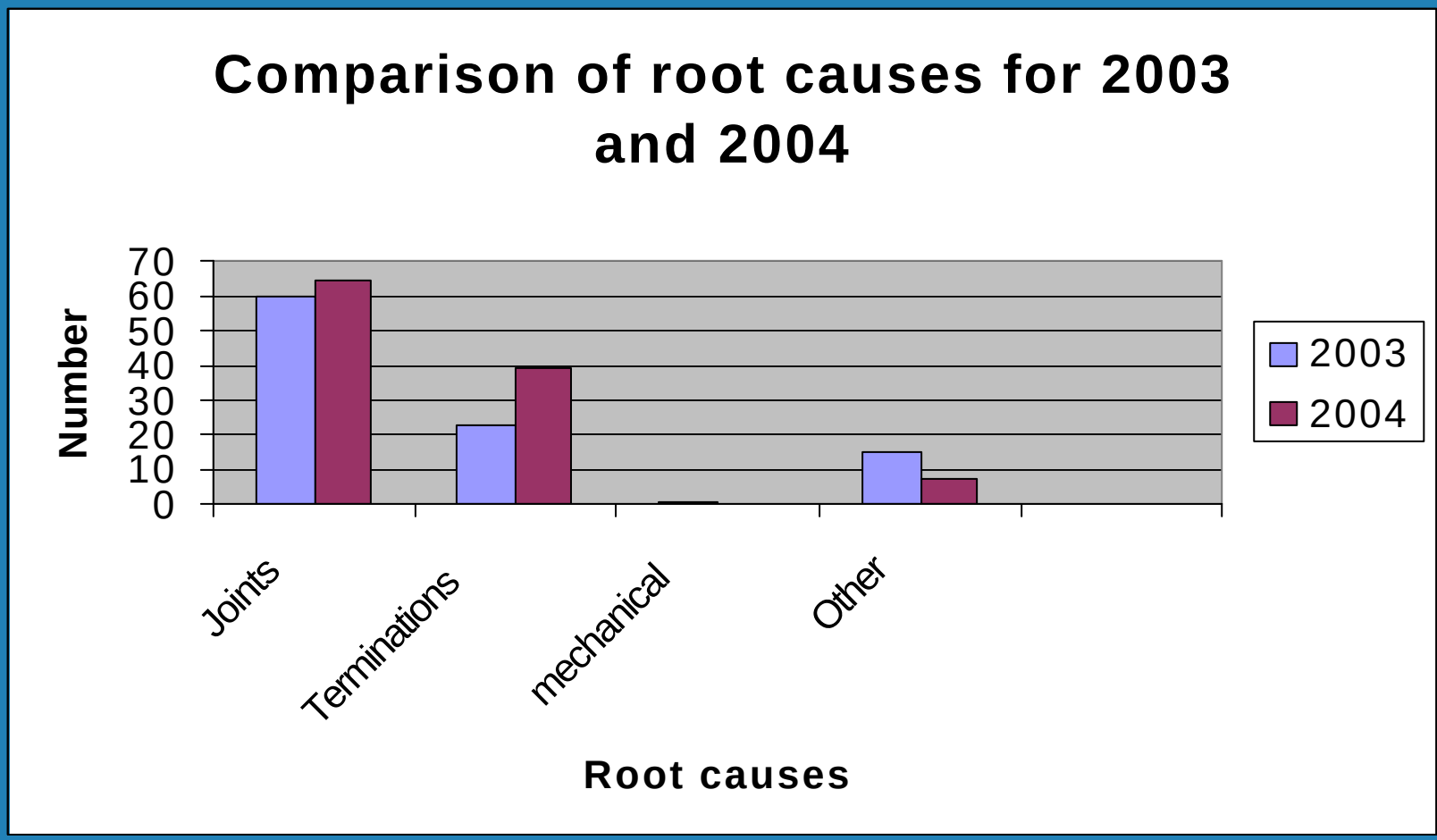
Monthly breakdown of root causes for 2003

Month	**Main contributing factors**			
	Joints	terminations	mechanical	Other
January	17	2	0	6
February	4	2	0	5
March	7	0	0	0
April	2	2	0	0
May	1	1	0	0
June	3	0	0	0
July	7	3	0	0
August	4	2	0	0
September	5	2	1	0
October	3	6	0	3
November	4	2	0	0
December	3	4	0	1
Totals	**60**	**23**	**1**	**15**

Breakdown of root causes for 2004

Month	**Main contributing factors**			
	Joints	terminations	mechanical	Other
January	4	5	0	0
February	3	4	0	0
March	5	2	0	3
April	5	1	0	0
May	4	0	0	0
June	2	2	0	0
July	6	2	0	1
August	1	2	0	0
September	2	0	0	1
October	5	2	0	0
November	16	9	0	1
December	11	10	0	1
Totals	**64**	**39**	**0**	**7**

Root cause comparison for 2003 and 2004



Further investigations revealed that the high failure rate on joints and terminations were due to :

- Water trees
- Overloading
- Incorrect joints and jointing techniques being used
- Stresses

Water trees

- These are basically water filled micro cavities.
- There are basically two types of water trees, bow tie trees and vented trees
- They form over a period of time of time.
- When this water tree forms into a electrical tree the cable will fail immediately.
- Sign of water trees is when cable failure rate is high in the rainy season.

Overloading

- The demand for electricity is increasing daily but the cable networks are not upgraded accordingly.
- This inturn affects the insulation properties of the cable.
- This results in the cable failing due to the first short circuit in the network.

Incorrect joints and jointing techniques used

- Non standard joints such as taped joints
- Incorrect crimping techniques.
- Bimetallic ferrules not used when joining copper and aluminum cables

Stresses

- Cables are exposed to thermal stress under operation.
- Space charges also cause increase in stress due to the fact low loss material tend to electron enrichment.
- Thermo mechanical stresses. (Effects of temperature on paper)

Solutions

- The cable network performance can be improved by the introduction of proper diagnostic testing techniques.

Current Testing Practice

DC testing

- Preferred for testing cables whose insulation is uniform (not older than 5 years)
- As the cables age defects form in the insulation. The electrical stresses vary resulting in space charges forming at defective areas.
- Due to the fact DC testing has no changing electrical field there is no discharge hence insulation defects cannot be detected.

Proposed Testing Methods

Proposed testing methods include:

- Very low frequency,
- partial discharge testing
- tan delta testing

Very low frequency testing

- It is a destructive test.
- It brings out faults that are about to occur in the near future
- It is a test can be conducted for 15, 30 or 60 minutes.
- Disadvantage of terminating a test early.

Partial discharge testing

- The main objective of partial discharge testing is to identify a fault in a non destructive way.
- It is small electrical sparks that occur on the surface of the insulation
- Partial discharge mapping indicates the number of joints and discharge levels

Tan delta testing

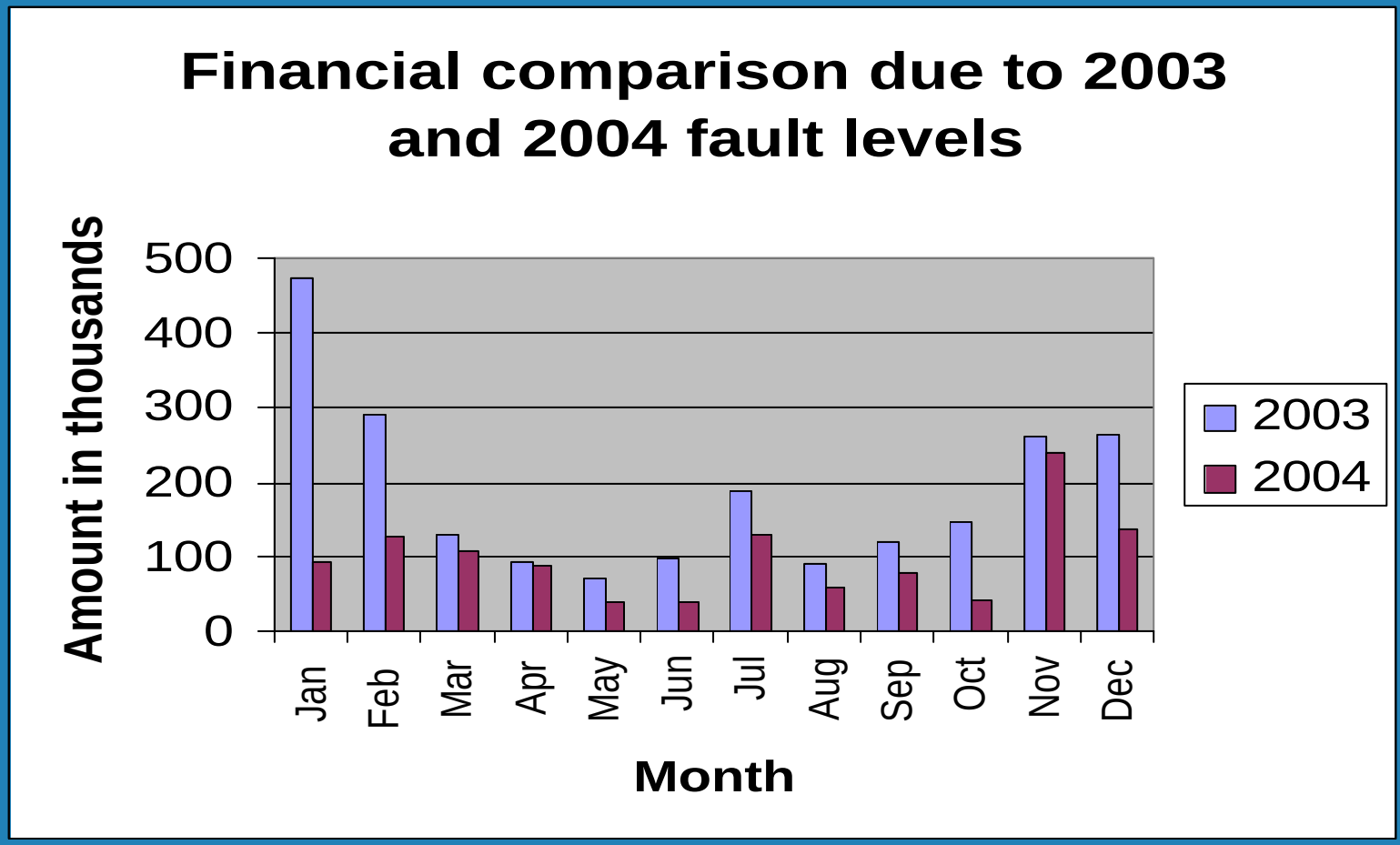
- Tan delta is basically a angle between the resistive and capacitive leakage currents.
- It is a good indication of water treed cables
- It provides a accurate measurement on PILC and XLPE cables

Costs

Operational Costs

- Cost incurred to repair all faulted cables in 2003 was 2.2m
- Cost incurred to repair faults in 2004 ranged at around 1.2m in 2004
- This total of 3.4m excludes fines from customers and the field service centers.

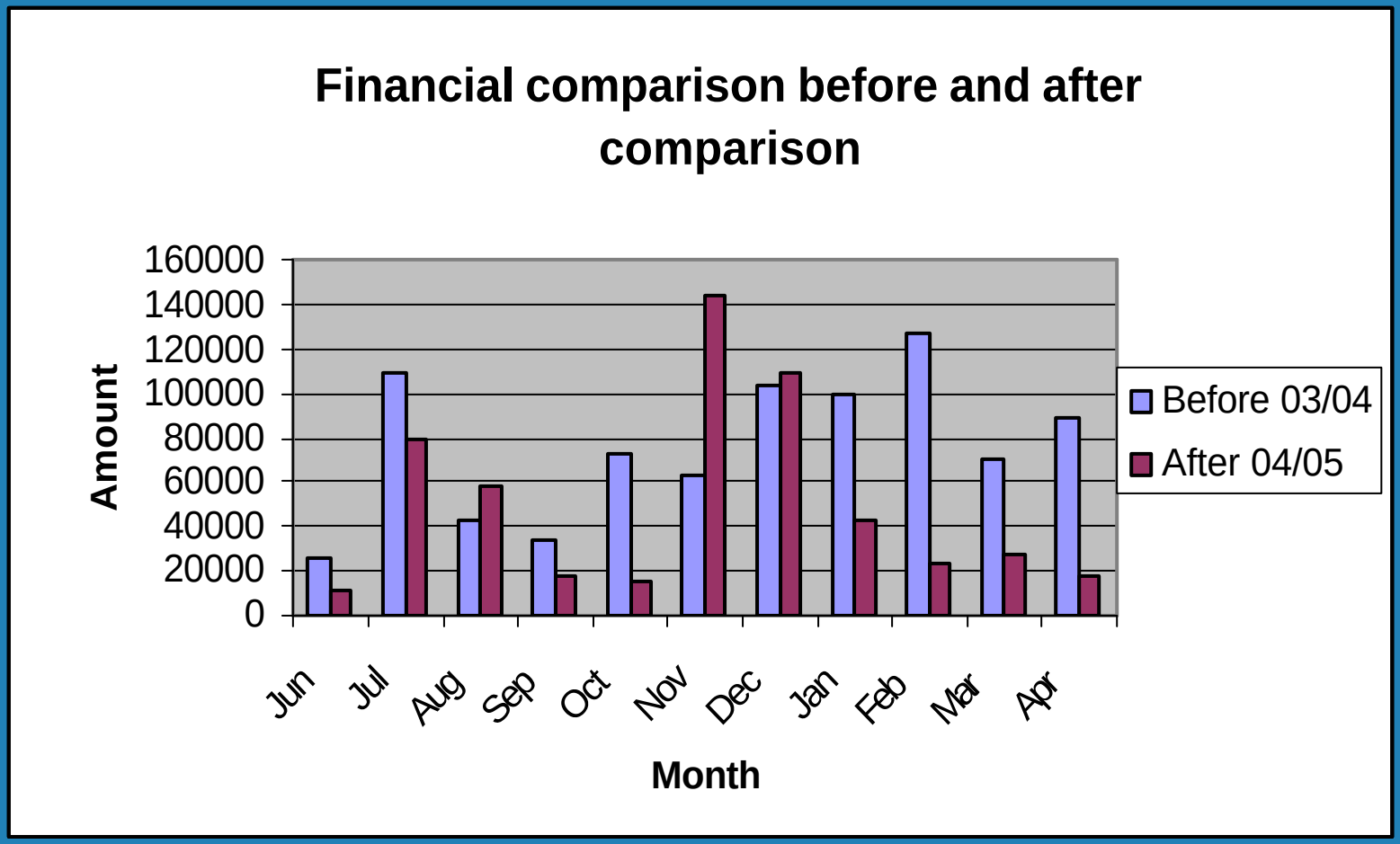
Financial comparison on a monthly basis for 2003 and 2004



Implementation Costs

- Pretoria network diagnosed, problems areas identified.
- A sum R125 000 was spent conduct proper diagnostic testing on these cables.
- Once diagnosed preventative measures were put in place.
- Fault levels reduced by 50 %.
- Organization saved R 402 000 for the period in question.
- Comparison of cable performance and cost before and after implementation.

Monthly financial Comparison before and after implementation



Recommendations

- Phase 1 (Short term approach)
  - Identify all faulty cables.
  - Arrange outages to conduct diagnostic testing.

Advantages

- Fast track remedial action

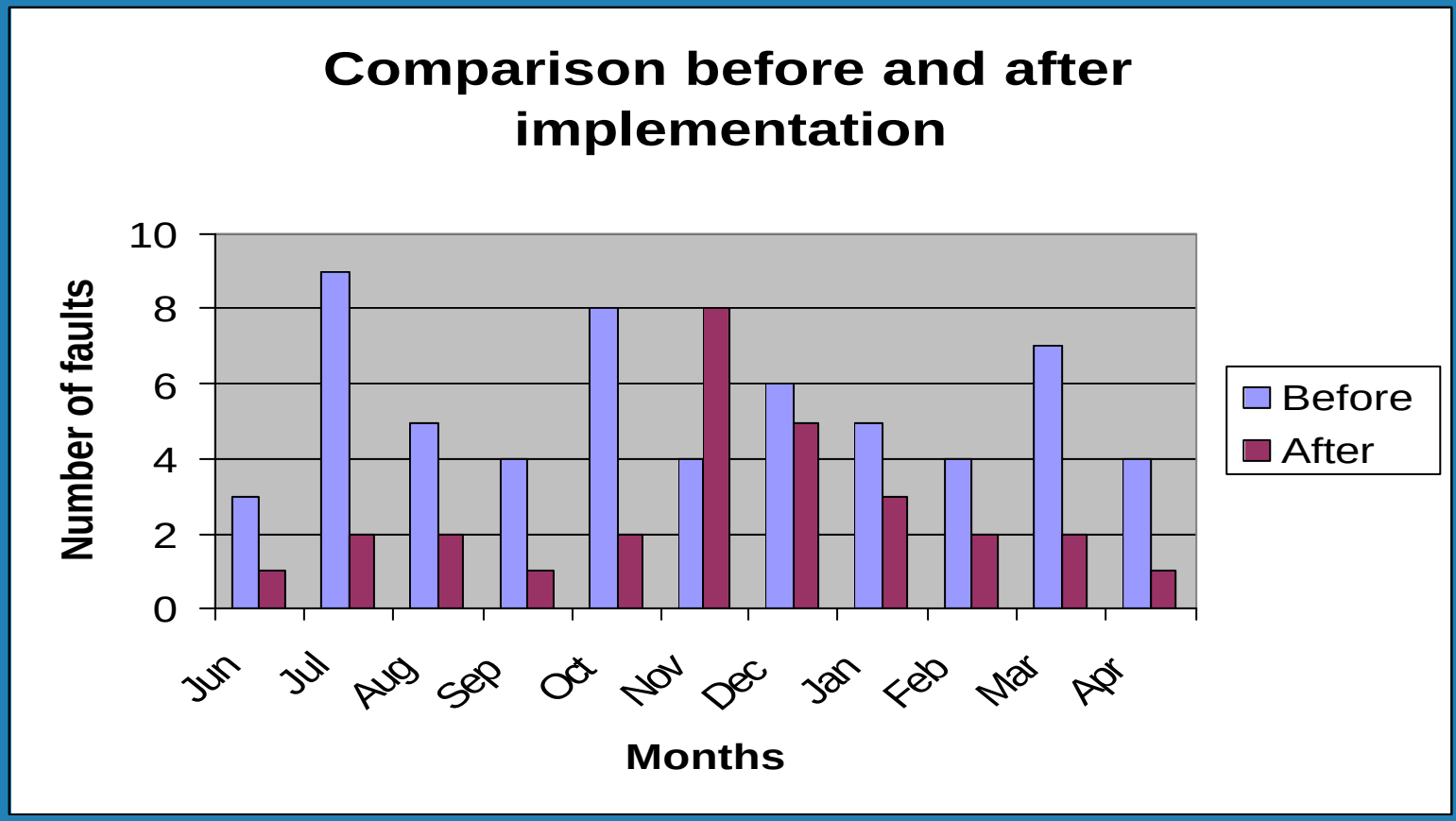
Disadvantages

- Contractors used for testing
  - Availability
  - Time frame
  - Cost

Monthly fault comparison before and after implementation

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Before 03/04	3	9	5	4	8	4	6	5	4	7	4
After 04/05	1	2	2	1	2	8	5	3	2	2	1

Fault patterns before and after implementation



Phase 2 (Long term approach)

- Eskom to invest in own diagnostic equipment.

Advantages

- This will enable Eskom to condition monitor cables by creating a data base where all cables identified by this exercise will be entered.
- Time base cables tests monitor the cable condition hence fast tracking preventative action before failure.

Disadvantages

- Initial test equipment cost.

Conclusion

- Water trees are the main course of failure.
- DC testing is not the way forward on a long term basis.
- Introduction of a data base to monitor cables is the way forward for Eskom Distribution.

Thank You

Questions ?