ISO55000 Series: Maintenance Strategies

Presented by: Tebogo Mokwana
Date: 11/06/2020
1. Introduction

2. Maintenance & ISO55000

3. Maintenance Strategies

4. AMP vs Maintenance Standard

5. Practical Examples

6. Future of Maintenance

7. Summary
1. Introduction
1. Introduction

**Eskom T&D Maintainable Power Plant Assets**

<table>
<thead>
<tr>
<th>Asset Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substations</td>
<td>2,948</td>
</tr>
<tr>
<td>Circuit Breakers</td>
<td>27,425</td>
</tr>
<tr>
<td>Isolators</td>
<td>45,171</td>
</tr>
<tr>
<td>Power Transformers (Tx – about 560)</td>
<td>4,719</td>
</tr>
<tr>
<td>Neutral Earthing Compensators</td>
<td>2,951</td>
</tr>
<tr>
<td>GIS Bays</td>
<td>135</td>
</tr>
<tr>
<td>Capacitor Banks</td>
<td>295</td>
</tr>
<tr>
<td>Reactors</td>
<td>98</td>
</tr>
<tr>
<td>Voltage Regulators</td>
<td>660</td>
</tr>
<tr>
<td>Medium Voltage / Low Voltage Transformers</td>
<td>341,015</td>
</tr>
</tbody>
</table>

**Network Lengths**

<table>
<thead>
<tr>
<th>Network Type</th>
<th>High Voltage</th>
<th>Medium Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead lines (ckm's)</td>
<td>78,099</td>
<td>301,883</td>
</tr>
<tr>
<td>Underground cables (ckm's)</td>
<td>334</td>
<td>7,592</td>
</tr>
<tr>
<td>Aerial Bundle Conductor (ckm’s)</td>
<td></td>
<td>87</td>
</tr>
<tr>
<td>Low Voltage (approx ckm's)</td>
<td>378,882</td>
<td></td>
</tr>
<tr>
<td>Low Voltage wood poles (approx)</td>
<td></td>
<td>5,060,784</td>
</tr>
</tbody>
</table>

Transmission regulatory asset base … R94Bn

Distribution regulatory asset base … R120Bn
Overall Maintenance Effectiveness is the product of:

- Accurate Asset Data
- Good Risk Modelling
- Good Reliability Basis
- Good Work Management
- Good Defect Elimination
1. Introduction

Run to failure

Asset Management Maturity

Business Impact

Performance

Asset value & Business Impact

Maintenance is an expense

Calendar based

Usage based

Condition based

Predictive

Cognitive

Maintenance is an investment

Instrumented

- Ever increasing range of sensors
- Volume, velocity, variety
- Event driven information

Interconnected

- Agility and Mobility
- Highly Connected Systems
- Cross Collaboration

Intelligent

- From data to actionable intelligence
- From reactive to proactive
- Whole lifecycle system optimization
1. Introduction

Continuous Maintenance Improvement

Evaluate Asset Health

Conduct Maintenance Assurance

Measure Process (end to end) and Manage Resources

Plan Work

Schedule Work

Execute Work

Implement and Train

Asset Base
M’nce Policy, Mnce Str, Procedures
Process
Org Struct
CMMS and Config
Resourse Req. and Management
Metrics
2. Maintenance & ISO55000

Asset Management Plans
(what to do for asset capacity)

Expansion/Growth Planning
Maintenance/Life Management Planning
Refurbishment/Renewal Planning
Operational/Flexibility Planning
2. Maintenance & ISO55000

- **POLICY STATEMENT**
  Aligned to assets policy, requirements of ISO 55000 and enables Eskom to meet its **objectives**

- **POLICY OBJECTIVE**
  Assets maintained in such a way as to enable the sustainable achievement of its business **objectives** in a **safe**, legal, environmental and regulatory compliant manner

- **KEY PRINCIPLES**
  - Compliance to SHERQ
  - Maximise performance of assets over their life
  - Trade-off between cost and risk
  - Follow maintenance Process Control Manuals
  - Maintenance Standards in line with the Design Basis
  - Asset risk framework for asset specific maintenance strategies
  - Maintenance is conducted by trained personnel
3. Maintenance Strategies

Purpose of maintenance is ‘ensuring that physical assets perform as per design’
John Moubray (1997), Reliability-Centred Maintenance,
3. Maintenance Strategies

RCM:

• Originated in the airline industry

• Process of most effective maintenance approach

• Rigorous FMEA and criticality analysis

• Sound technical and economic justification
3. Maintenance Strategies

Distribution of failure rates

- Pattern A: 68%
- Pattern B: 14%
- Pattern C: 7%
- Pattern D: 5%
- Pattern E: 2%
- Pattern F: 4%

Patterns:
- A: Traditional View
- B: Bathtub Curve
- C: Slow Aging
- D: Best New
- E: Constant Random Failure
- F: Worst New
3. Maintenance Strategies

1. Select equipment
2. Determine functions
3. Describe failures
4. Describe failure modes
5. Describe effects
6. Use RCM logic (to select appropriate maintenance or engineering actions and determine task frequencies)
7. Document results and commence monitoring

Jan Braaksma (2012), Asset information for FMEA-based maintenance (thesis)
3. Maintenance Strategies

RCM Part I: Select Equipment
## RCM Approach Part II: FMEA / FMECA

<table>
<thead>
<tr>
<th>RCM Information Worksheet</th>
<th>Bachhus 132kV breaker</th>
<th>SN</th>
<th>Facilitator</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Failure</td>
<td>SN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Loss of function)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure Mode</td>
<td>SN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cause of failure)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criticality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure Effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(What happens when it fails)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open breaker</td>
<td>Fails to open breaker</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Opening Spring discharge</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open coil faulty</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanism slow</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interconnecting rod broken</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of supply on Coil</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of SF6 pressure</td>
<td>H</td>
<td>Upstream breaker clears fault. Loss of supply</td>
<td></td>
</tr>
</tbody>
</table>
3. Maintenance Strategies

RCM Approach Part III: Decision Logic

- **H1**: Is a task to detect whether the failure is occurring or about to occur technically feasible and worth doing?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **H2**: Is a scheduled restoration task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled restoration task
  - No: Scheduled restoration task

- **H3**: Is a scheduled discard task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled discard task
  - No: Scheduled discard task

- **H4**: Is a failure-finding task to detect the failure technically feasible and worth doing?
  - Yes: Scheduled failure-finding task
  - No: Could the multiple failure affect safety or the environment?

- **H5**: Combination of tasks
  - Yes: Redesign is compulsory
  - No: No scheduled maintenance

- **S**: Does the failure mode cause a loss of function or other damage which could hurt or kill someone?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **E**: Does the failure mode cause a loss of function or other damage which could breach any known environmental standard or regulation?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **O**: Does the failure mode have a direct adverse effect on operational capability (output quality, customer service or operating costs in addition to the direct cost of repair)?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **N1**: Is a task to detect whether the failure is occurring or about to occur technically feasible and worth doing?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **N2**: Is a scheduled restoration task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled restoration task
  - No: Scheduled restoration task

- **N3**: Is a scheduled discard task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled discard task
  - No: Scheduled discard task

- **S1**: Is a task to detect whether the failure is occurring or about to occur technically feasible and worth doing?
  - Yes: Scheduled On-Condition task
  - No: Scheduled restoration task

- **S2**: Is a scheduled restoration task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled restoration task
  - No: Scheduled restoration task

- **S3**: Is a scheduled discard task to reduce the failure rate technically feasible and worth doing?
  - Yes: Scheduled discard task
  - No: Scheduled discard task

- **S4**: Is a combination of tasks to avoid failure technically feasible and worth doing?
  - Yes: Redesign is compulsory
  - No: No scheduled maintenance

- **S5**: Could the multiple failure affect safety or the environment?
  - Yes: Redesign is compulsory
  - No: No scheduled maintenance
## 3. Maintenance Strategies

### RCM Tasks

<table>
<thead>
<tr>
<th>Maintenance Strategy</th>
<th>Action Required</th>
<th>RCM- based application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run to failure</td>
<td>Repair / replace upon failure</td>
<td>Non-critical failures. Cost to detect / eliminate failure exceeds benefits</td>
</tr>
<tr>
<td>Scheduled discard / restoration (Preventative)</td>
<td>Repair / replace on time or cycles</td>
<td>Well documented MTBF. Small std dev</td>
</tr>
<tr>
<td>Redesign / Redundancy (proactive)</td>
<td>Improvement on design / introduce redundancy</td>
<td>Critical assets. No other viable approach.</td>
</tr>
</tbody>
</table>
3. Maintenance Strategies

Eskom’s Current Maintenance Practice

- Current practice is predominantly condition based activities triggered by time
- Setting-up systems to progress condition based maintenance
- Online sensors and computational intelligence are required to get there
Maintenance Determination Approach

**Maintenance Strategy Determination**

- OEM
- PMO
- RCA
- FMECA
- HAZOP
- RCM

**FMECA**
- Study asset potential failures and recommend feasible maintenance recommendation
- Risk based approach

**Asset Classification**
- Functional importance
- Environment
- Duty cycle
- Health

**Optimized Maintenance Tasks**
- Grouping of related maintenance activities into tasks
- Outage optimization

**Eskom Approach**
3. Maintenance Strategies

Engineering Process Control Manual (PCM)

Technology Management (choices)
Design Base (Asset) Creation
Design Base (Asset) Maintenance
3. Maintenance Strategies

The Design Process

Need → Design Process → Defined Solution

Stakeholder Requirements

Converge

Balance

Design
- Physical
  - Dimensions
  - Weight
  - etc
- Operating
  - Limits
  - Interlocking
  - Start up sequence
- Maintenance
  - Tasks
  - Triggers
  - Logistics
  - Application Notes

Intent
- Life Cycle Cost
  - Capital
  - Maintenance
  - Operating
  - Decommissioning
- Scope
  - What the plant must do
- Performance
  - Reliability
  - Maintainability
  - Availability
  - Safety
- Aging Profile
4. AMP vs Maintenance Standard

<table>
<thead>
<tr>
<th>Title: MAINTENANCE STANDARD FOR</th>
<th>Unique Identifier: 240-61182655</th>
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<tbody>
<tr>
<td>SUBSTATION ELECTRICAL</td>
<td>Alternative Reference Number: 240-103004532, 240-103004534 &amp; 240-97897644</td>
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<tr>
<td>COMPONENTS</td>
<td>Area of Applicability: Engineering</td>
</tr>
<tr>
<td>Documentation Type: Standard</td>
<td>Revision: 3</td>
</tr>
<tr>
<td>Total Pages: 35</td>
<td>Next Review Date: April 2025</td>
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<td>Disclosure Classification:</td>
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</table>

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   3.1 Asset Identification ......................................................... 8
   3.2 Design Intent ................................................................. 9
   3.3 Maintenance Engineering Strategy ......................................... 9
      3.3.1 Maintenance Activity Determination .................................. 9
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      3.4.1 Asset classification .................................................. 11
      3.4.2 Maintenance task selection .......................................... 12
      3.4.3 Functional equipment grouping .................................... 14
   3.5 Manage Asset Exclusions ............................................... 14
   3.6 Asset health ........................................................................ 14
      3.6.1 Design life expectancy and failure issues ............................ 14
      3.6.2 Condition assessment techniques .................................... 14
      3.6.3 End of life criteria and condition rating ............................ 14
      3.6.4 End of life criteria ................................................... 16
   3.7 Asset Performance ............................................................ 17
      3.7.1 Failure causes to be recorded in performance management systems .................................................. 17

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5. Revisions .............................................................................. 20

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4. AMP vs Maintenance Standard

3. Requirements
   3.1 Asset identification .................................................. 8
   3.2 Design intent ........................................................... 8
   3.3 Maintenance Engineering Strategy
       3.3.1 Maintenance Activity Determination ......................... 9
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       3.3.3 Required task manuals .................................. 10
       3.4 Maintenance spare .............................................. 10
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   3.4 Maintenance Execution Strategy ................................... 10
       3.4.1 Asset classification ....................................... 11
       3.4.2 Maintenance task selection ................................. 12
       3.4.3 Functional equipment grouping ........................... 14
   3.5 Manage Asset Excursions ........................................... 14
   3.6 Asset health ............................................................ 14
       3.6.1 Design life expectancy and failure issues .................. 14
       3.6.2 Condition assessment techniques .......................... 14
       3.6.3 End of life criteria and condition rating .................. 14
       3.6.4 End of life criteria ........................................... 16
   3.7 Asset Performance ..................................................... 17
       3.7.1 Failure causes to be recorded in performance management systems ........................................... 17
4. Authorization ................................................................... 19
5. Revisions .......................................................................... 20
6. Development Team ........................................................... 20
7. Acknowledgements .......................................................... 20
Annex A - Maintenance analysis ........................................... 21
Annex B - Maintenance Activity Table ................................. 31
Annex C - Maintenance Data Fields ....................................... 35
## Maintenance Activity Determination

### FMECA TEMPLATE

**MAINTENANCE STANDARD FOR POWER TRANSFORMERS AND REACTORS (>1MVA AND >1000V)**

<table>
<thead>
<tr>
<th>Template Identifier</th>
<th>240-xyz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template Revision</td>
<td>1</td>
</tr>
<tr>
<td>Document Identifier</td>
<td>240-69387838</td>
</tr>
<tr>
<td>Effective Date</td>
<td>December 2014</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>Function of Component</th>
<th>Functional Failure</th>
<th>Failure Mode</th>
<th>Failure Effect Component</th>
<th>Failure Effect System</th>
<th>Root Cause</th>
<th>Likelihood</th>
<th>Consequences</th>
<th>Risk score</th>
<th>Maintenance Activity</th>
<th>Outage (Y/N)</th>
<th>Job Plan</th>
<th>Skills group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Practical Examples

<table>
<thead>
<tr>
<th>Component</th>
<th>Function of Component</th>
<th>Functional Failure</th>
<th>Failure Mode</th>
<th>Failure Effect Component</th>
<th>Failure Effect System</th>
<th>Root Cause</th>
<th>Likelihood</th>
<th>Consequences</th>
<th>Risk score</th>
<th>Maintenance Activity</th>
<th>Outage (Y/N)</th>
<th>Job Plan</th>
<th>Skills group</th>
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</thead>
<tbody>
<tr>
<td>6</td>
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</tr>
</tbody>
</table>

### Consequences

- A: Low
- B: Medium
- C: High
- D: Very High
- E: Extreme

### Likelihood

- A: Low
- B: Medium
- C: High
- D: Very High
- E: Extreme
## Classification per specific individual asset

### Functional Importance

<table>
<thead>
<tr>
<th></th>
<th>Critical</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the substation/corridor un-firm?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the supply to a Major Customer/s?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the substation directly connected / Supply to a power/converter stations?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the answer to the question above ‘No’?</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

### Duty Cycle

<table>
<thead>
<tr>
<th></th>
<th>Critical</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the transformer loaded above 90%?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the transformer tapping more than 1000 times a month?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are more than fifty line faults recorded at the substation per annum?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the answer to the question above ‘No’?</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

### Environment

<table>
<thead>
<tr>
<th></th>
<th>Critical</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the substation within 100 km from the coast?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the substation near a water source?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the substation in a high pollution environment?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Prevalence of theft and vandalism at the substation</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is the answer to the question above ‘No’?</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

### Health Status

<table>
<thead>
<tr>
<th></th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the asset health status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 5. Practical Examples
## FMECA Example: Substation Earthing

### FMECA Template

<table>
<thead>
<tr>
<th>Component</th>
<th>Function of Component</th>
<th>Failure Mode</th>
<th>Failure mechanism / cause</th>
<th>Failure effects local</th>
<th>Failure effects next higher</th>
<th>Probability</th>
<th>Severity ranking</th>
<th>Risk score</th>
<th>Maintenance Task</th>
<th>Outage?</th>
<th>Job Plan/File</th>
<th>Skills group</th>
</tr>
</thead>
</table>
## 5. Practical Examples

### Maintenance Task Table

<table>
<thead>
<tr>
<th>Equipment Class:</th>
<th>Equipment Sub Class:</th>
<th>Equipment Sub Class Family:</th>
</tr>
</thead>
</table>

| Trigger Modifiers | Permutations | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|------------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| **Functional Importance** |                |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Critical         |               | X   | X   | X   |     | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Significant     |               |     | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Economic        |               | X   |     | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Run to Fail     |               |     | X   | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Usage / Duty Cycle |             | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| High            |               |     | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Low             |               | X   |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Environment     |               | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Harsh           |               |     | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Mild            |               | X   |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Health          |               | X   |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Very Good / Good|               |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Fair / Poor     |               | X   | X   | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Poor / Very Poor|               |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Spare           |               |     | X   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                |                | In Store |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

<table>
<thead>
<tr>
<th>Activity No</th>
<th>Maintenance Activities</th>
<th>FMECA Ref No</th>
<th>Trigger (Time and/or Status)</th>
<th>Outage Y/N</th>
<th>Manual Y/N</th>
<th>Quality Criteria</th>
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<tbody>
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<td>Statutory Maintenance</td>
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</tbody>
</table>
Asset Health Formulation

Asset ageing analysis encompasses:

- Asset degradation review
- Condition assessment technique
- Setting criteria for end of life

5. Practical Examples
### 5. Practical Examples

<table>
<thead>
<tr>
<th>Condition rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>DP &gt; 911 – No detectable paper degradation</td>
</tr>
<tr>
<td>B</td>
<td>DP 451 – 910 – Significant paper deterioration but still well away from the critical point</td>
</tr>
<tr>
<td>C</td>
<td>DP 351 – 450 – Paper is starting to approach the critical condition</td>
</tr>
<tr>
<td>D</td>
<td>DP 200 – 350 – The paper is near or at the critical condition</td>
</tr>
<tr>
<td>E</td>
<td>DP &lt; 200 – Extensive paper degradation has taken place and has exceeded the critical point. There is now a serious risk of failure.</td>
</tr>
</tbody>
</table>

#### Asset/asset health index criteria

<table>
<thead>
<tr>
<th>Health index</th>
<th>Condition</th>
<th>Description</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>85 - 100</td>
<td>Very Good</td>
<td>Some ageing or minor deterioration of a limited number of components</td>
<td>Normal maintenance</td>
</tr>
<tr>
<td>70 - 85</td>
<td>Good</td>
<td>Significant deterioration of some components</td>
<td>Normal maintenance</td>
</tr>
<tr>
<td>50 - 70</td>
<td>Fair</td>
<td>Widespread significant deterioration or serious deterioration of specific components</td>
<td>Update maintenance execution strategy as per section 3.4</td>
</tr>
<tr>
<td>30 - 50</td>
<td>Poor</td>
<td>Widespread serious deterioration</td>
<td>Start planning process to replace or rebuild considering risk and consequences of failure</td>
</tr>
<tr>
<td>0 - 30</td>
<td>Very Poor</td>
<td>Extensive serious deterioration</td>
<td>At end-of-life, immediately assess risk; replace or rebuild based on assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asset/asset health index criteria</th>
<th>Weight (1-4)</th>
<th>Condition rating</th>
<th>Factors</th>
<th>Maximum score</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>1 Insulation</td>
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<td>A,B,C,D,E</td>
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<td>3 Auxiliary Components</td>
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<td>Table 11</td>
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<tr>
<td>4 Transformer DGA</td>
<td>2</td>
<td>Table 28</td>
<td>A,B,C,D,E</td>
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</tbody>
</table>

Max. Score: 36
# 6. Future of Maintenance

**APM Tool Architect**

### Asset Strategy

<table>
<thead>
<tr>
<th>Risk Based</th>
<th>Performance Focussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset Health &amp; Performance</td>
<td>Spares Levels Determination</td>
</tr>
<tr>
<td>Asset Remaining Life &amp; Economic Analysis</td>
<td></td>
</tr>
</tbody>
</table>

Information exchange with other information environments
6. Future of Maintenance
6. Future of Maintenance

Statistical techniques, data mining, modelling patterns, machine learning, deep learning, all to **predict the future**

- Previously, circuit breakers at >=40yo failed during the summer after deviation from planned maintenance for 6 months
- You have many CBs at ~ 40yo that are **overdue** for maintenance by ~6months
- We are **approaching summer**
- You can **expect more failures** unless you attend to these CBs urgently
6. Future of Maintenance

Hierarchy of prognostic approach

T Tinga (2013), *Principles of Loads and Failure Mechanisms*
7. Summary

- Maintenance planning is a critical asset planning activity
- One of the 4 that engineer asset management activities
- Maintenance planning is clearly expected in ISO55000 sections
- There are various maintenance strategy determination approaches
- Eskom uses an RCM flavored approach that is both reliability and risk based