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CONTENTS

Page

1. INTRODUCTION 5

2. SUPPORTING CLAUSES 5

2.1 SCOPE 5
2.1.1 Purpose 5
2.1.2 Applicability 5
2.2 NORMATIVE/INFORMATIVE REFERENCES 5
2.2.1 Normative 5
2.2.2 Informative 5
2.3 DEFINITIONS 6
2.3.1 Disclosure Classification 6
2.4 ABBREVIATIONS 6
2.5 ROLES AND RESPONSIBILITIES 6
2.6 PROCESS FOR MONITORING 6
2.7 RELATED/SUPPORTING DOCUMENTS 6

3. HAND HELD CONDITION MONITORING SYSTEM 6

3.1 SYSTEM COMPONENTS 7
3.1.1 Sensors 7
3.1.2 Data collectors 7
3.1.3 CM Software 7
3.1.4 Display 7
3.1.5 Fundamental system functionality 8
3.1.6 Fundamental features 8
3.1.7 DATABASE 8
3.2 REMOTE VIEWING 8
3.3 ALARMING AND TRENDING 8
3.4 FAULT DIAGNOSTICS 9
3.5 SYSTEM INTERFACE WITH THE ESKOM LAN/WAN 9
3.6 MOUNTING OF INPUT MODULES 9
3.7 CONNECTIVITY OF THE SYSTEM 9
3.8 POWER SUPPLY TO THE SYSTEM 9
3.9 ANALOGUE AND BINARY INPUTS 9
3.10 MONITORING ABILITY 9
3.11 SOURCES OF DATA 10
3.12 REMOVAL/ADDING/CHANGING OF ADDITIONAL SYSTEMS 10
3.13 ANALYSING ABILITY 10
3.13.1 Data manipulation 10
3.13.2 Health assessment 10
3.13.3 Prognostic Assessment 11
3.13.4 Corrective action recommendation 11
3.13.5 Reporting 11
3.14 INTERVAL OF DETECTION 11
3.15 COMPUTER CAPABILITY 11
3.16 COMMUNICATION PROTOCOLS WITH OTHER SYSTEMS 11
3.17 EXPANDABILITY AND UPGRADEABILITY 11
3.18 TECHNICAL SCALABILITY 12
3.19 INTEROPERABILITY 12
3.20 STANDARDISATION 12
3.21 PARAMETERS TO BE MONITORED 12
3.22 MEASUREMENT PARAMETERS, LOCATIONS AND ALARMS FOR VIBRATION 13
3.23 MEASUREMENT PARAMETERS, LOCATIONS AND ALARMS FOR THERMOGRAPHY 13
3.24 MEASUREMENT PARAMETERS FOR OIL ANALYSIS 14

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4. EQUIPMENT TYPES AND CONDITION MONITORING TECHNIQUES 14

4.1 VIBRATION - FUNCTIONAL & TECHNICAL SPECIFICATIONS 14
4.2 VIBRATION PROBES OR SENSORS 14
4.3 SPECIFICATIONS FOR VIBRATION ANALYSIS 15
4.4 ESKOM STANDARDS FOR VIBRATION 15
4.5 THERMOGRAPHY - FUNCTIONAL & TECHNICAL SPECIFICATIONS 15
4.6 FAILURE MODES DETECTED WITH THERMOGRAPHY 16
4.7 FUNCTIONAL REQUIREMENTS FOR THERMOGRAPHY 16
4.8 TECHNICAL SPECS FOR IR CAMERAS 16
4.9 ESKOM STANDARDS FOR THERMOGRAPHY 16
4.10 OIL ANALYSIS - FUNCTIONAL AND TECHNICAL SPECIFICATIONS 16
4.11 LUBRICATING FLUIDS RESULTS DATA 17
4.12 ESKOM STANDARDS FOR LUBRICANT ANALYSIS 17

5. PORTABLE TOOLS GENERAL TECHNICAL SPECIFICATIONS 17

5.1 TECHNICAL SPECIFICATIONS FOR PORTABLE TOOLS 17
5.2 FEATURES REQUIRED FOR DATA TOOLS (ANALYSERS, ETC.) 18

6. FUNCTIONAL REQUIREMENTS - CONDITION MONITORING SOFTWARE 18

6.1 DATA HANDLING 18
6.2 CONDITION DIAGNOSIS 18
6.2.1 Condition detection 18
6.2.2 Faults or degraded state diagnosis 19
6.2.3 Diagnostic algorithms and alarms 19
6.3 ALARMS FOR VIBRATION 19
6.3.1 Alarm types required 19
6.3.2 Operations on alarms 19
6.4 ALARMS FOR THERMOGRAPHY 20
6.5 ALARMS FOR LUBRICATING FLUIDS 20
6.6 CONDITION PROGNOSIS 20
6.7 CORRECTIVE ACTION RECOMMENDATION AND REPORTING 20
6.7.1 Determine and specify corrective actions 20
6.8 SPECIFIC REQUIREMENTS WHEN USING PORTABLE INSTRUMENTS 20
6.8.1 Route management 20
6.8.2 Support for Portable instruments 20
6.9 REPORTING 21
6.10 EQUIPMENT MASTER RECORDS 21
6.11 EQUIPMENT MODEL ADMINISTRATION 21
6.12 GENERAL SOFTWARE FEATURES 21

7. REQUIREMENTS FOR PRESENTATION AND ANALYSIS 21

7.1 PRESENTATION 21
7.1.1 Data presentation features 21
7.1.2 Data viewing 22
7.1.3 Overall condition status 22
7.1.4 Condition, alarms, faults, degraded states, prognosis 22
7.1.5 History: Condition, alarms, faults, degraded states, prognosis 22
7.1.6 View fault and work status 22
7.1.7 View maintenance/work history/work status 23
7.1.8 Data Visualisation requirements for vibration 23
7.1.9 Data Visualisation requirements for Thermography 23
7.1.10 Data visualisation requirements for Lubricating fluids 24
7.2 ANALYSIS 24
7.2.1 Trend equipment condition 24
7.2.2 Failure analysis 24
7.2.3 Data requirements for analysis and investigations 24
7.2.4 Data analysis requirements for Vibration 24

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7.2.5 Data analysis for Thermography 25
7.2.6 Data analysis for lubricating fluids 25

8. REPORTS REQUIREMENTS 25

8.1 REPORTS FOR VIBRATION 25
8.2 REPORTS FOR THERMOGRAPHY 25
8.3 SCOPE OF WORK REPORT DETAILS 26

9. COLLABORATION, COMMUNICATION, PUBLICATION 26

9.1 COLLABORATION 26
9.2 COMMUNICATION 26
9.3 PUBLICATION 26

10. PROCESS INTEGRITY 26

10.1 MONITORING AND CONTROLLING PROCESS & SERVICE EXECUTION 26
10.2 PROCESS EFFICIENCY, ACCURACY, CONSISTENCY 26
10.3 MONITORING AND CONTROLLING PROCESS EFFECTIVENESS 27

11. AUTHORISATION 27

12. REVISIONS 28

13. DEVELOPMENT TEAM 28

APPENDIX A : EQUIPMENT DATABASE 29

A.1 IDENTITY AND SPECIFICATIONS 29
A.2 FUNCTION AND OPERATING CONDITIONS 29

FIGURES

Figure 1: Block diagram of typical condition monitoring system 7
Figure 2: System interconnection diagram 9

TABLES

Table 1: List of Condition Monitoring Techniques 10
Table 2: Monitoring techniques for equipment 12
Table 3: Eskom standards for condition monitoring techniques 13
Table 4: Measurement parameters and alarms per equipment type for vibration technique 13
Table 5: Measurement parameters and alarms per equipment type for thermography 13
Table 6: Minimum failure mechanisms and modes to be detected with vibration 14
Table 7: Probe sensitivities per machine speeds (Source Eskom Standard) 14
Table 8: Equipment monitored with IR Thermography 15
Table 9: Minimum Types of failures to be detected with Thermography 16
Table 10: Tests to be done on lubricating fluids 17
Table 11: Colour codes indicating condition 22

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1. INTRODUCTION

This standard pertains to the tools and software required to carry out monitoring of equipment condition at power stations. The purpose of monitoring is to identify any faults and required corrective actions. The monitored equipment includes plant auxiliary equipment and auxiliary plant equipment. This category of equipment includes:

- rotating and reciprocating equipment not on the centre-line (motors, pumps, gearboxes, compressors),
- electrical panels and junction boxes,
- transformer auxiliaries,
- conveyor belt idlers.

Several techniques may be applied non-routinely for in-depth investigations and analyses. This standard focusses on the tools and software required to implement the routine monitoring techniques applied to these equipment. Parameters to be monitored are indicated in Appendix A.

Software covered by this standard brings together results of individual monitoring techniques as applied to each piece of equipment. The standard is necessary to ensure that the chosen software meets Eskom's requirements.

2. SUPPORTING CLAUSES

2.1 SCOPE

This standard covers the following matters:

- End user functional requirements of the software system to process, alarm, and display condition related information.
- Technical and functional requirements of tools used to collect and analyse the necessary data
- Tools related to the following condition monitoring techniques are covered:
  - Vibration
  - Thermography

2.1.1 Purpose

The document serves as a reference to configure and validate the technology set for hand held condition monitoring. As a standard it fulfils technical governance requirements.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 NORMATIVE/INFORMATIVE REFERENCES

The most recent revision of documents listed in the next paragraphs applies when using this standard.

2.2.1 Normative

[1] Eskom 240 - 75850289 Hand Held Condition Monitoring Manual

2.2.2 Informative

[2] Eskom 36 - 1095 Vibration based condition monitoring of rotating auxiliary plant.

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[3] Eskom 36 - 511 Infrared Thermography Standard

[4] Eskom 36 - 53 In-Service Monitoring of lubricating oils and hydraulic fluids

[5] Eskom 36 – 579 Hand Held Condition Monitoring

2.3 DEFINITIONS

Definition	Description
Hand Held Condition Monitoring	Refers to condition data acquisition using portable specialised instruments with designated probes or in some cases without probes
IR Thermography	Use of infrared cameras to produce thermal images of objects under observation

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
CM	Condition Monitoring
LAN	Local Area Network
WAN	Wide Area Network

2.5 ROLES AND RESPONSIBILITIES

The persons involved in selecting tools and software for Hand Held monitoring needs to use this standard.

2.6 PROCESS FOR MONITORING

This document should be updated if related Engineering or IT standards are changed.

2.7 RELATED/SUPPORTING DOCUMENTS

The related PCM is “Optimise Operational Asset Performance” - 240-45921037

3. HAND HELD CONDITION MONITORING SYSTEM

NOTE: Please note that the requirements in this document are minimum requirements.

The system needs to serve three main purposes:

i) To identify the early onset of component defects

ii) To facilitate overall equipment condition management by combining related condition data with predictive condition monitoring data.

iii) Be the source of equipment condition data capable of machine to machine interface with other related Eskom IT systems.

Minimum requirements for each routine condition monitoring technique are specified in terms of:

- tools to collect data for each technique,
- software to support each technique,

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- software to manage equipment condition,
- outcomes that the techniques shall provide.

3.1 SYSTEM COMPONENTS

A logical view of a basic condition monitoring system is shown in Figure 1. Components include:

- sensors to detect the physical phenomenon that are to be measured,
- instruments to collect the data,
- software to process, organise, analyse and view data, results and reports a display,
- a database to store the data and any results.

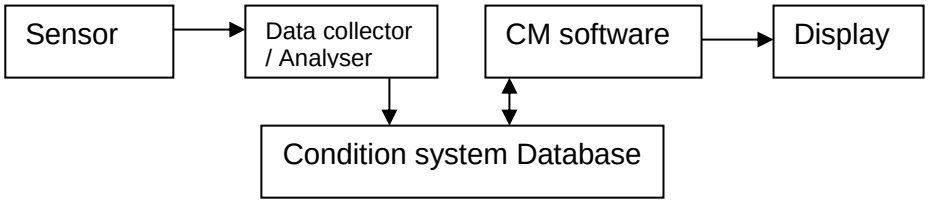

Figure 1: Block diagram of typical condition monitoring system

3.1.1 Sensors

Sensors include accelerometers, infrared cameras etc., which are used to detect and measure specific physical phenomenon. Sensors may be separate from data collectors or in some cases integrated.

3.1.2 Data collectors

Data collectors are devices that process data from the sensors. Data analysis capability is included in the data collection devices as well as the condition monitoring software suite.

3.1.3 CM Software

Software shall have capabilities for at least the following:

- Handling data associated with the database: (transfer, storage, etc.)
- Data analysis
- Alarming
- Presentation of data views.
- Creation of customised reports.
- Display, printing, and electronic transfer of reports and views.

3.1.4 Display

The preferred display mechanism shall be a Web based viewer, but a thick client shall also be acceptable. The mechanism for data display shall conform to all Eskom standards. The displays for each of the condition monitoring techniques need to be presented with a common appearance and human interface. Displays should be able to present multiple views simultaneously and be configurable to add/remove, overlay, etc. views.

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3.1.5 Fundamental system functionality

The system shall provide the following minimum functionality aligned with Eskom IM standards:

- data collection and storage
- manipulate, process, and analyse data
- algorithms for fault diagnosis and condition prognosis
- store faults, condition, diagnosis, prognosis, and remedy,
- ability to access information and functionality over the Eskom LAN and WAN
- ability to display and view information over the Eskom LAN and WAN
- a suite of standard reports and ability to create custom reports
- interface with other Eskom systems e.g. SAP, MS office, Wonderware, etc.

3.1.6 Fundamental features

- The system shall be based on open industry standards that meet Eskom's IM standards.
- The system shall comprise modular components.
- The system shall appear as a single system combining software and databases and for all condition monitoring techniques.

3.1.7 DATABASE

The database stores all acquired condition data and associated information such as alarms, bitmaps, pictures, any references to the data, etc. The information for all CM techniques is contained in a single database. The system needs to provide a comprehensive database management system and interface for the system administrator to view, optimise, add to, delete and organise configuration data. The database editor to be provided needs to be of the latest technology. The database also stores historical data with provisions for archiving and retrieval of archived data. Data exchange is via Open Database Management Systems, viz. OPC – link with process control systems, ODBC or SQL – link with analysis and or collaboration tools. Database technology allows data access over LAN and WAN. Eskom architectural standards apply.

This database/s shall be completely open and conform to all the required Eskom Information Management architectural standards.

a) Data exchange via Open Database Management Systems:
   - OPC – link with process control systems.
   - ODBC or SQL – link with analysis and or collaboration tools.
b) Database is accessible over LAN and WAN.
c) Data importing and exporting
d) User defined database labels
e) Image storage and retrieval
f) Data archive and retrieval from archive directory

3.2 REMOTE VIEWING

All functionality must operate across the Eskom LAN/WAN, and include detailed views of all of the monitored parameters and systems. Views need to be updatable at the update input rate. It must be possible to add equipment views with associated data and trend any combination of parameters together. It needs to be possible to save and retrieve any combination of collected views. As a minimum the following screens shall be included in the viewer:

3.3 ALARMING AND TRENDING

The software must identify and indicate any non-conformance. Non-conformances can be derived by computations of any combination of baseline signals, threshold levels and threshold ranges, trends,

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group of trends, etc. Alarming must be intelligent and widely configurable by end users. If it becomes necessary to change alarms during the life of equipment, each previous alarm and dates that alarms were applicable must be recorded.

3.4 FAULT DIAGNOSTICS

The software may include fault diagnostic algorithm engines to identify developing faults or provide enough information to allow the early identification of developing non-conforming conditions. The associated conditions and diagnosed faults must be linked and stored in the database. If the software does not provide such algorithms, relevant information must be made available so that an analyst can make such diagnosis.

3.5 SYSTEM INTERFACE WITH THE ESKOM LAN/WAN

The system needs to interface with Eskom LAN/WAN to allow remote operation, viewing and access to data. Such interfacing must conform to all Eskom IM architectural requirements.

3.6 MOUNTING OF INPUT MODULES

Not Applicable.

3.7 CONNECTIVITY OF THE SYSTEM

Figure 2 provides a high level connection diagram interfaces with related Eskom information systems.

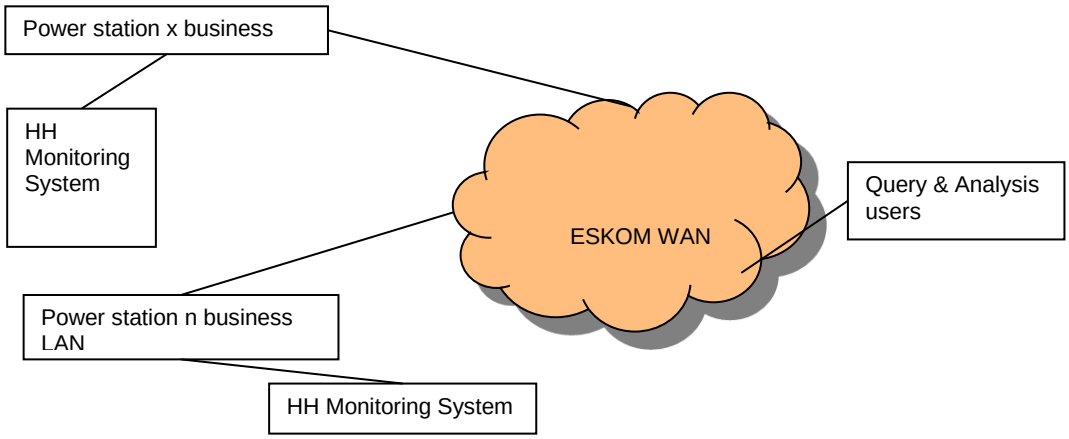

Figure 2: System interconnection diagram

3.8 POWER SUPPLY TO THE SYSTEM

All sensors, analysers, data collectors must be self or battery powered. The software system and database system can be powered by 220V AC.

3.9 ANALOGUE AND BINARY INPUTS

Not applicable to the Balance of Plant system.

3.10 MONITORING ABILITY

The system must be capable of monitoring and handling data associated with physical parameters that indicate condition of critical components. Parameters relevant to BoP components and techniques are indicated in Table 1.

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Table 1: List of Condition Monitoring Techniques

Techniques used routinely
Vibration
Thermography
Oil Analysis
Special testing techniques
Motor current analysis
Phase measurements
Natural frequency determination
Run-up and coast down
Synchronous time averaging
Order tracking
Operating deflection shape (ODS)
Modal analysis
Acoustic ultrasonics
Finite element analysis

3.11 SOURCES OF DATA

Data are sourced via sensors and data collectors referred to in 6.3. The required data is only collected in the duration that the data collection devices are connected. The system must also make provision to receive data from other plant data storage systems and manual inputs.

3.12 REMOVAL/ADDING/CHANGING OF ADDITIONAL SYSTEMS

Removal/adding/changing components need to be done on a “plug and play” basis. The system needs to be designed to include all Eskom Corporate architectural standards. The system needs to recognise a new component and add its functionality to the existing software environment.

3.13 ANALYSING ABILITY

3.13.1 Data manipulation

The software must have data manipulation capabilities to process all the signals received from the sensors, analysers, and or data collectors. Manipulation may include:

- signal pre-processing in preparation for data transfer between database and data collection devices,
- signal pre-processing in preparation for data analysis
- data transfer between database and any analysis or reporting software.

3.13.2 Health assessment

Equipment health will be determined by assessing the combined results of all techniques applied to the equipment. The combined results must be presented as a consolidated view that is printable and saveable. The software may include modules for health assessment. If the software does not provide such algorithms, relevant information must be made available so that an analyst can make such health assessments.

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3.13.3 Prognostic Assessment

The software may include algorithm engines to determine when corrective action should be taken on each developing fault to prevent the non-conformance deteriorating into a fault. The associated prognosis must be linked with the conditions and diagnosed non-conformances, and must be stored in the database. If the software does not provide such algorithms, relevant information must be made available so that an analyst can make such prognosis.

3.13.4 Corrective action recommendation

The software may include algorithm engines to determine what corrective action should be taken on each developing fault to prevent the non-conformance deteriorating into a fault. The associated recommended action must be linked with the conditions, diagnosed non-conformances and prognosis, and must be stored in the database. If the software does not provide such algorithms, relevant information must be made available so that an analyst can make such corrective action recommendations.

3.13.5 Reporting

Reporting capabilities must include functionality to create custom reports in addition to any set of standard reports. All reports must be viewable, printable, saveable in the database and electronically exchangeable.

3.14 INTERVAL OF DETECTION

Monitoring is on demand. Hence the interval of detection is in the order of days, weeks, or months as specified in each equipment's maintenance plan.

3.15 COMPUTER CAPABILITY

It needs to be possible to view the data from the system remotely on a standard Eskom computer of the latest Information Management specification.

3.16 COMMUNICATION PROTOCOLS WITH OTHER SYSTEMS

The system needs to be OPC compliant and include all Eskom Corporate architectural standards.

3.17 EXPANDABILITY AND UPGRADEABILITY

The following requirements apply:

a) The system is expandable and upgradeable at "component" level. This means that it should be possible to upgrade individual items of hardware or software without having to perform major upgrades on the rest of the system.
b) The system also needs to be almost infinitely expandable and configurable in terms of the number of digital and analogue inputs.
c) Multi-vendor devices. Software should use industry standards (e.g. serial/USB, TCP/IP, ANSI, ISA, etc.) to connect with measuring instruments so that multiple vendor devices may be used if required.
d) Multi-user software. Multiple users should be able to operate the software concurrently.
e) System fully operational over Local Area Network (LAN) and Wide Area Network (WAN).
f) Network Transport Protocol - TCP/IP.
g) A common database for multiple techniques
h) Condition monitoring software handles data of multiple techniques uniformly and with a single login.
i) Condition monitoring software integrates with analysis software tools.
j) Number of hierarchies must scale in line with the data bus and or hardware.
k) Number of levels within a hierarchy must scale in line with the data bus and or hardware.
l) Number of measurement points must scale in line with the data bus and or hardware.

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m) Measurements data per measurement point must scale in line with the data bus and or hardware.

3.18 TECHNICAL SCALABILITY

a) Multi-vendor devices shall be supported. Software shall use open industry standards (e.g. serial/ USB, TCP/IP, ANSI, ISA, etc.) to connect with measuring instruments so that multiple vendor devices may be used if required.
b) Multi-user software licences. Multiple users shall be able to operate the software concurrently.
c) System fully operational over Local Area Network (LAN) and Wide Area Network (WAN).
d) Network Transport Protocol - TCP/IP.
e) A common, Eskom IM approved database for multiple techniques
f) Condition monitoring software handles data of multiple techniques uniformly and with a single login.
g) Condition monitoring software integrates seamlessly with analysis software tools.
h) Number of hierarchies shall be unlimited.
i) Number of levels within a hierarchy shall be unlimited.
j) Number of measurement points shall be unlimited.
k) Measurements data per measurement point shall be unlimited.

3.19 INTEROPERABILITY

- The system shall use Eskom IM approved industry standard interfacing and integration technologies so that instruments can be inter-changed where appropriate.
- The system shall use Eskom IM approved industry standard interfacing and integration technologies to ensure interaction and exchange data with other Eskom information systems, e.g. SAP, MS office, email, etc.
- Relevant Eskom IM standards also apply.

3.20 STANDARDISATION

The concept design and where possible, equipment, needs to be standardised across all installations of the system.

3.21 PARAMETERS TO BE MONITORED

The Balance of Plant condition monitoring system is required to cater for the data from equipment types listed in Table 2 and applied as specified in Eskom standards listed in Table 7.2. Complete list of equipment to be monitored per power station appears in Appendix B.

Table 2: Monitoring techniques for equipment

Equipment type	Applicable, Acceptable techniques
Motors	Vibration Flux Coil Motor current analysis
Pumps	Vibration, Thermography
Gearboxes	Vibration, Thermography, Lubricant analysis
Compressors	Vibration, Thermography, Lubricant analysis
Fans	Vibration, Thermography
Electrical panels	Thermography
Transformers	Thermography
Piping	Thickness

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Table 3: Eskom standards for condition monitoring techniques

Technique	Eskom Standard
Vibration	36 – 1095
Thermography,	36 – 511
Lubricant analysis	36 – 53

Parameters for relevant routine condition monitoring techniques are listed. Routine monitoring techniques are: vibration, IR thermography, and lubricant analysis.

3.22 MEASUREMENT PARAMETERS, LOCATIONS AND ALARMS FOR VIBRATION

When vibration technique is applied, the parameters to be measured and alarms per equipment type apply as stated in Table 4.

Table 4: Measurement parameters and alarms per equipment type for vibration technique

	Measurements at					Alarms for each point		
Equipment	DE	NDE	body	footing	Coupling	Overall	Spectral	Narrow band
Motor (includes fan motor)	Y	Y	Y	Y	Y	Y	Y	Y
Pump	Y	Y	Y	Y	Y	Y	Y	Y
Gearbox	Y	Y	Y	Y	Y	Y	Y	Y
Fan	Y	Y	Y	Y	Y	Y	Y	Y
Compressor	Y	Y	Y	Y	Y	Y	Y	Y

3.23 MEASUREMENT PARAMETERS, LOCATIONS AND ALARMS FOR THERMOGRAPHY

Temperature images are taken using Infra-red cameras and must be applied as per Table 5.

Table 5: Measurement parameters and alarms per equipment type for thermography

Equipment	Measurement parameters	Locations	Alarms
Electrical connections on panels, motors, transformers	Visual & IR images	Facing measurements points	Temperature deviations
Pumps	Visual & IR images	Facing measurements points	Temperature deviations
Motor	Visual & IR images	Facing measurements points	Temperature deviations

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3.24 MEASUREMENT PARAMETERS FOR OIL ANALYSIS

Lubricant samples are taken from applicable lubricant tanks of the equipment. A selection of tests from Table A.3 are conducted on the samples.

4. EQUIPMENT TYPES AND CONDITION MONITORING TECHNIQUES

Rotating equipment shall be analysed with vibration measurements at least on drive and non-drive end, and any other appropriate key points. Electromechanical equipment may be additionally analysed with thermography. Electrical equipment such as transformers, electrical panels, and junction boxes shall be assessed with thermography. Lubricating fluids shall undergo lubricant analysis. Appendix A details parameters to be monitored per equipment type per technique. Example lists of equipment per condition monitoring technique appears in Appendices E, F, and G. Equipment lists and plant areas are illustrative only as these vary between power stations.

4.1 VIBRATION - FUNCTIONAL & TECHNICAL SPECIFICATIONS

The Vibration technique is used to detect failure mechanisms and modes in rotating equipment such as fans, motors, pumps, and gearboxes. A list of basic failure mechanisms and modes is indicated in Table 4.1 only as examples.

Table 6: Minimum failure mechanisms and modes to be detected with vibration

Component	Failure mode
Bearings	Worn, incorrect/insufficient lubrication
Belt tensions	Incorrect tension
Foundation, footings	Worn, loose, broken
Fans & Impellers	Imbalance, Cavitations
Coupling	Misalignment
Rotor	Imbalance
Stator	Imbalance

4.2 VIBRATION PROBES OR SENSORS

Vibration measurement probes shall have the following functions and features.

a) Sensors shall be self-adhering, e.g. magnetic attachment, no hand held probes are allowed for safety and accuracy reasons.
b) Triaxial probes are preferred.
c) Probe and sensor Dynamic Range minimum of 96 dB
d) Probe sensitivities in relation to machine speed are shown in Table 4.2.

Table 7: Probe sensitivities per machine speeds (Source Eskom Standard)

Machine speed	Sensitivity
< 600 RPM	500mV/g
600RPM to 20 000RPM	100mV/g
> 20 000RPM	10mV/g

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4.3 SPECIFICATIONS FOR VIBRATION ANALYSIS

Specifications relevant to data collection and analysis have been combined as there is no preference for location of the analysis software. Either simple or sophisticated collector/analyser combinations can be used but all data shall be stored in the condition monitoring database component. The following are minimum functional and technical specifications for data collection, display and analysis:

a) Measure velocity, displacement, acceleration, or any combination.
b) Units: Metric System
c) Display previous readings with current readings
d) Alarm capabilities
    i. Overall alarm levels
    ii. Spectral alarm bands
    iii. Narrowband envelopes
e) Minimum frequency analysis capabilities:
    i. High Frequency,
    ii. Low Frequency,
    iii. Order Tracking.
f) Advanced functions:
    i. Normal Averaging,
    ii. Exponential,
    iii. Peak Hold,
    iv. Synchronous Time, and
    v. Negative Averaging
g) Dynamic analysis of:
    i. Overall spectra and waveforms,
    ii. Phase
h) Output: Communication with host computer on USB, serial or Ethernet.
i) A/D Converter shall be minimum 16 bits
j) Frequency Range: minimum DC- 40 kHz.

4.4 ESKOM STANDARDS FOR VIBRATION

Eskom standard for vibration: 36 - 1095 Vibration based condition monitoring of rotating auxiliary plant.

4.5 THERMOGRAPHY - FUNCTIONAL & TECHNICAL SPECIFICATIONS

Infrared cameras and associated software are required to conduct condition monitoring on equipment. Thermography shall be used (not necessarily exclusively) to identify faults or malfunctions on categories of equipment shown in Table 5.1.

Table 8: Equipment monitored with IR Thermography

Mechanical Equipment	***Electrical Equipment***	***Piping and Valves***
Pumps	Switchboards	Cooling pipes
Motors	Panel boards/boxes	Steam pipes
Shaft couplings	Control panels	Water pipes
Vent cooling	Transformers (air and oil)	
Air/PF duct blockages	Power cables	
Oil cooling channels	Batteries	
Gearboxes	Switch disconnects	
	Fuse disconnects/holders	

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4.6 FAILURE MODES DETECTED WITH THERMOGRAPHY

Thermography tools shall be able to detect at minimum the types of failures listed in Table 5.2.

Table 9: Minimum Types of failures to be detected with Thermography

Failure
Overheating
Electrical Insulation breakdown
Electrical connections – looseness
Power inefficiency

4.7 FUNCTIONAL REQUIREMENTS FOR THERMOGRAPHY

IR cameras shall have the following minimum functions:

a) Include a visual camera
b) Provide for reflected background temperature (emissivity) compensation and or adjustments.
c) Adjustments when transmission medium is other than air.
d) Auto Hot/Cold Spot Recognition (temperature alarms)
e) Perform image averaging.
f) Digitally adjust the level, span, zoom and pan on images.
g) Provide a range of different colour palettes.
h) Allow for both visual and infrared images on reports.
i) Transfer image descriptions automatically into the report.
j) Export IR and visible images in file formats recognisable by MS Office products.
k) Data transfer to host computer system via serial, USB, or Ethernet

4.8 TECHNICAL SPECS FOR IR CAMERAS

IR cameras shall have the following minimum technical specifications:

a) Temperature shall be in °C with range -20°C to +300°C (Additional temperature ranges may be facilitated by lens changes)
b) Measurement precision shall be ±2°C or 2% of full scale.
c) Minimum resolvable temperature (MRT)-temperature sensitivity shall be ≤ 0.1 °C at 30 °C.
d) Spectral range for high temperature applications: 3-5µm
e) Spectral range for lower temperature applications: 8-12µm
f) Operating environment:
   - Temperature -10°C to 50°C
   - humidity of 10% to 90%
g) Storage temperature: -20°C to 50°C.

4.9 ESKOM STANDARDS FOR THERMOGRAPHY

Eskom 36 - 511 Infrared Thermography Standard applies. Key requirements presented here are extracted from the standard.

4.10 OIL ANALYSIS - FUNCTIONAL AND TECHNICAL SPECIFICATIONS

The Eskom standard for a laboratory information system (LIMS) is Sample Manager. Table 6 lists the tests that are required for lubricating oils.

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4.11 LUBRICATING FLUIDS RESULTS DATA

Data and results for tests shown in Table 6.1 are stored in Sample Manager.

Table 10: Tests to be done on lubricating fluids

Test (Test methods shown are preferred)
1. Appearance and smell (odour)
2. Particle Quantification (PQ)
3. Cleanliness -(ISO 4406: 1999).
4. Total acid number (TAN) -ASTM D974.
5. Total base number -(ASTM D974, ASTM 2896, ASTM D 664).
6. Viscosity -(ASTM D445).
7. Crackle test for free water.
8. Water content -(ASTM D1533-Karl Fischer Reaction Method).
9. Water Content -(ASTMD1744-Karl Fischer Reagent).
10. Demulsibility and water separability (IP 19, ASTM D1401, ASTM D2711)
11. Wear debris analysis (WDA) or Ferrography.
12. Additive content and wear metals -(ASTM D5185-ICP) or FTIR or RDE (ASTM D6595)
13. Rust inhibitor -(ASTM D665)
14. Flash point -(ASTM D92-Cleveland open cup, ASTM D93-Pensky-Martens closed cup)
15. Volume resistivity -(ASTM D1169 -Fire resistant fluids (FRFs only)).
16. Density -(ASTM D1298 (FRFs))
17. Air release value -(ASTM D3427)
18. Foaming characteristics -(ASTM D892)
19. Insolubles, pentane and toluene -(ASTM D893 procedures A and B, ASTM D4055)
20. Oxidation stability -(ASTM D2272 (RBOT))
21. Blotter Spot test for soot and remaining oil dispersion

4.12 ESKOM STANDARDS FOR LUBRICANT ANALYSIS

Eskom 36 - 53: "In-Service Monitoring of lubricating oils and hydraulic fluids"

5. PORTABLE TOOLS GENERAL TECHNICAL SPECIFICATIONS

Any portable data tools shall comply with these additional requirements.

5.1 TECHNICAL SPECIFICATIONS FOR PORTABLE TOOLS

The power station environment is both indoors and outdoors. The environment is categorised as harsh because of the dusty conditions, noise and vibrations. Hence the following specifications apply:

a) Minimum IP-65. The air can be dusty and instruments shall be protected against dust ingress. Moisture levels could be high and instruments shall be sealed from moisture.
b) Ambient operating temperatures shall range from -10°C to 50°C.

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c) Battery powered instruments shall be at able to operate for at least 8 hours or be achieved with a spare battery changed with no loss of data.
d) Instruments shall be used both indoors and outdoors. Display screens shall be readable both indoors and outdoors.
e) The manufacturer shall specify the how often instruments shall be calibrated and who is an acceptable calibration authority.

5.2 FEATURES REQUIRED FOR DATA TOOLS (ANALYSERS, ETC.)

The data tools have the following requirement:

a) Capability to transfer the output into a Eskom IM accepted, common database,
b) interface with each other if needed,
c) use non-proprietary Industry best practice standards to interface with other devices and software,
d) have common open, industry best practice generic user interfaces,
e) perform as many data gathering functions as possible to minimise the total number of tools required for data gathering.

6. FUNCTIONAL REQUIREMENTS - CONDITION MONITORING SOFTWARE

Functional requirements for condition monitoring software described.

6.1 DATA HANDLING

An initial step in condition determination is collecting relevant data. This includes tasks such as conducting tests, taking measurements, reading monitoring indicators, making sensory observations, etc. Functions in the condition monitoring software are required to:

a) Using Eskom accepted open industry standards, interface with data collection devices such as: sensors, loggers, analysers, infrared cameras, etc. as required by various condition monitoring techniques.
b) Using Eskom accepted open industry standards, transfer data between data collection devices and the condition database.
c) Prepare or process the raw data for use by the condition monitoring software.
d) Support shall be provided for the techniques listed in Table 1. However the system shall have the capability to include other special techniques that may be required for advanced testing.

6.2 CONDITION DIAGNOSIS

After preparation, the condition data shall be processed to detect presence of faults or degraded states. Thereafter the causes of faults or degraded states shall be determined. Condition of the equipment shall be determined by combing results of condition monitoring techniques where they are available.

6.2.1 Condition detection

The condition monitoring data shall be processed to determine presence of anomalies. Typical functions to be executed for condition detection include:

a) Process available data for each technique listed in Table 3.1.
b) Automatically assess all measured parameters against relevant limits/alarms or diagnostic algorithms.
c) Automatically detect points in alarms.
d) Indicate points in alarm.

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6.2.2 Faults or degraded state diagnosis

Fault causes shall be determined from the data for each technique.

a) Diagnosis shall be assisted by diagnostic algorithms and or threshold and range alarms.
b) Diagnosis shall be conducted taking into account results from all condition monitoring techniques used on the equipment.
c) Further investigation may be required to confirm or determine underlying causes of some faults and non-conformities.
d) Consolidate faults and non-conforming conditions to determine the equipment overall condition.
e) Append condition results to equipment's condition history database.
f) Append diagnosis relative to each fault or non-conformity in the data base.

6.2.3 Diagnostic algorithms and alarms

Diagnosis shall be assisted with use of diagnostic algorithms and or threshold and range alarms.

Alarm Configuration

a) It shall be possible to set alarms per measurement parameter per measurement point.
b) Alarms are required to be indicated by thresholds, ranges, or rate of change as applicable to the measurement point and measurement parameter.
c) Alarms shall be calculated from analysis of historical data.

Alarm Management

a) As alarm levels shall be adjusted for equipment age, operating conditions, change of structural form, etc., full alarm history shall be recorded for each monitoring point.

6.3 ALARMS FOR VIBRATION

Alarms types and operations on alarms for vibration are specified below.

6.3.1 Alarm types required

The following alarms for vibration are required:

a) Overall alarm levels with up to four levels per measurement point
b) Peak Band Alarms
c) Power Band Alarms
d) Narrow band alarm envelopes
e) Phase Angle Alarm
f) Statistical Alarms
g) User defined alarm frequencies

6.3.2 Operations on alarms

a) User defined alarm frequencies
b) Set and display baselines
c) Add Alarms
d) Edit Alarms
e) View all points in alarm within a selection (e.g. hierarchy, group, route, workspace, or item of equipment, etc.)
f) Trend all alarms
g) Edit alarms individually and or in groups
h) Detection of outlier alarms and erroneous data
i) Compare alarm between item of equipment

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6.4 ALARMS FOR THERMOGRAPHY

Alarms should be raised when temperature measurements are outside expected norms for the specific equipment under test. The alarm can be visually highlighted in a suitable way on screen and in a report.

6.5 ALARMS FOR LUBRICATING FLUIDS

Alarms should be raised when measurements are outside expected norms for the specific parameter under test. The alarm can be visually highlighted in a suitable way on screen and in a report.

6.6 CONDITION PROGNOSIS

After diagnosing the condition it shall be required to determine when intervention is required to prevent equipment breakdown.

a) Reports of condition and work history shall be accessed together with equipment technical specifications, operating specifications, assembly drawings, bills of materials, etc. These documents shall be retrieved electronically.
b) Condition prognosis shall also be supported with intelligent software algorithms.

6.7 CORRECTIVE ACTION RECOMMENDATION AND REPORTING

6.7.1 Determine and specify corrective actions

The reporting module shall provide necessary reports so that all results from data gathering, measurements, or condition monitoring activities can be used together with the diagnosis and prognosis to specify what shall be fixed and when. Each monitoring technique shall uncover unique faults to be corrected. Corrective action shall be recommended based on the equipment's condition and prognosis. Corrective action recommendations can be software assisted.

Each diagnosis shall have remedial work specified for it and be stored in the Eskom IM approved work database against the equipment and the results that substantiate the work specification.

Any interface with SAP PM shall be via the Eskom approved SAP integration layer.

6.8 SPECIFIC REQUIREMENTS WHEN USING PORTABLE INSTRUMENTS

Software aspects specific to portable instruments are specified below.

6.8.1 Route management

Initially work shall be arranged into suitable routes taking into account location of equipment, measurements that shall be taken, etc., for convenience and to fit in with operating schedules. The software shall provide comprehensive route management functionality such as develop and modify routes and schedules.

6.8.2 Support for Portable instruments

- The software shall provide interfaces for portable data collectors or analysers to exchange measurements and routes information for all monitoring techniques. Interfaces shall be Eskom approved open Industry standards such as Serial, USB, Ethernet, etc.
- All changes in equipment identity, specification, and or route entered in portable instruments shall be transferred to the master Eskom IM approved database with options to accept or reject changes.
- Provision shall be made to transfer any ad-hoc measurements taken that are not be part of the route.

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6.9 REPORTING

In addition to standard reports, the software shall provide capabilities to design and create custom reports. These reports shall be easily and simply user configurable within the host software environment. These reports cannot be created with the use of “macros” or any other programming type language.

6.10 EQUIPMENT MASTER RECORDS

a) Master records for all equipment to be monitored shall be as stipulated in the Eskom document “Manual for Condition Monitoring balance of plant using hand held technology”. Information includes: equipment identity, technical specifications, location of equipment in the plant, operating conditions, measurement parameters, frequency of measurements, parameter limits or ranges, and measurement orientations.
b) Master records shall be synchronised if they are be contained in more than one system.
c) Provision shall be made for a minimum name length of 32 mixed alphanumeric characters.

6.11 EQUIPMENT MODEL ADMINISTRATION

Each monitored item of equipment shall be modelled in the software database. Standard functionality shall enable the following standard operations on models:

a) Create, edit, copy, delete
b) Add measurement points
c) Add photo images to an item of equipment
d) Add notes to an item of equipment
e) Apply different rotational speeds across an item of equipment

6.12 GENERAL SOFTWARE FEATURES

The following general software features shall be provided as a minimum:

a) User Preferences for customised look and feel
b) Context sensitive help
c) Windows based design
d) Management of User accounts
e) Profile based security
f) Diagnostics for troubleshooting software installation.

7. REQUIREMENTS FOR PRESENTATION AND ANALYSIS

The software shall have the capability to be present, graphically, for purposes of viewing or accessed for analysis.

7.1 PRESENTATION

Functionality and features for presentation are listed below.

7.1.1 Data presentation features

a) Items of equipment are linked into plant areas as listed in Appendix B.
b) All plant areas shall be presented on the system.
c) All plant areas shall be visible to users per user profile.
d) Current information as well as history shall be available simultaneously (at least 6 months).
e) Views of cluster of sites shall be provided to allow cross checking to be performed
f) View per plant area
g) View per equipment category

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h) Views shall be linked in a hierarchical structure with the ability to step through the hierarchy in either direction.
i) Status is indicated by at least five levels with colour as per Table 9.1.

Table 11: Colour codes indicating condition

Green	Acceptable
Yellow	Unsatisfactory
Red	Unacceptable

7.1.2 Data viewing

In addition to local viewing, data shall be accessed and presented over the Eskom LAN and WAN. Remote access shall be through an Eskom IM approved web browser or thick client. Views shall be dynamically updated where required. The following views are required per equipment per plant area:

a) Overall condition status
b) Condition, alarms, faults, degraded states, prognosis
c) History: Condition, alarms, faults, degraded states, prognosis
d) Trends: faults and degraded conditions
e) Work recommended per non-conformance
f) Maintenance work/work history/work status

7.1.3 Overall condition status

A consolidated view fear each item of equipment is required. The consolidation combines as appropriate, results of, vibration, oil, thermography, flux coil, visual inspections, etc. that include all failure mechanisms monitored. Any non-conformance shall be indicated in the equipment's overall condition with the ability to "drill down" to the point of non-conformance when equipment is selected or when it appears in any view. Green indicates that all checks were passed. Yellow indicates that condition is unsatisfactory, i.e. although the status does not constitute a functional failure a problem is developing, red shall indicate an unacceptable state. It shall be possible to drill down from this overall level to at least the point of the fault, and drill up again. Viewing details are presented in Appendix C.

7.1.4 Condition, alarms, faults, degraded states, prognosis

A measurement point or observed parameter shall be selected. The condition status (good, problem developing, problem present, etc.) of each selected point shall be indicated. Acceptable conditions shall be justified against stated equipment specific baselines or alarm levels. Further drilling down shall indicate the violated alarm or condition anomaly and technique that identified the problem. Viewing details are presented in Appendix C.

7.1.5 History: Condition, alarms, faults, degraded states, prognosis

It is required to start with current (last test/assessment) and “drill down” into historical data as required and indicated for Overall Condition Status, and Condition, alarms, faults, degraded states, prognosis.

7.1.6 View fault and work status

This view displays work status of remedial work linked to each fault on equipment. See Appendix C for structure of the view.

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7.1.7 View maintenance/work history/work status

Work (planned and done); work status (approved, scheduled, complete, etc.) per item of equipment per date shall be listed. The system shall interface with SAP PM using the Eskom approved SAP integration layer.

7.1.8 Data Visualisation requirements for vibration

Vibration signals can be represented in the time domain and frequency domain.

a) Basic visualisation requirements for this data include:

- Display
- Plot
- Save Views
- Print

b) Detailed visualisation functions include:

- Zoom and pan
- Use of cursors
- Plot multiple signals on the same plot
- Annotate results
- Customising Scales of graphs
- Alternating between views e.g. time waveforms, frequency spectrums, etc.
- Save any view
- View plots from different equipment on one display

c) Views Required

- Overall Trends
- Time Waveforms
- Fault frequencies
- Spectrums
- Phase Displays
- Spectrum post processing
- Combination views, e.g.
  - Trend/Spectrum
  - Trend/Spectrum/ Time Waveform
  - Waterfall/Extracted Trend/ Spectrum
  - Waterfall/Extracted Band Trend
  - Trend/Time Waveform
  - Spectrum/Band Trend
  - Defect Frequency Overlay
  - Running Speed Overlay
  - Spectral Band Alarm Overlay
  - Spectral Envelope Alarm Overlay
- Alternating between views for Velocity, Acceleration or Displacement

7.1.9 Data Visualisation requirements for Thermography

a) Images are to be retrieved from the database for on screen viewing.
b) Digital adjustment shall be provided for level, span, zoom and pan on images.

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7.1.10 Data visualisation requirements for Lubricating fluids

These can be presented as numeric or by way of graphs, etc. as appropriate to particular tests.

7.2 ANALYSIS

The systems database shall be arranged to incorporate base data to facilitate typical analyses such as:

a) Trends of equipment condition
b) Failure analysis

7.2.1 Trend equipment condition

a) All faults and degraded conditions per equipment shall be graphed or tabulated over time against the affected piece of equipment.
b) Equipment shall also be compared to other equipment based on
   - Similar models
   - Similar models across manufacturers
   - Similar applications

7.2.2 Failure analysis

Equipment condition data, condition reports, work and failure histories are required as input to analysis and investigations. Data shall be assimilated, analysed and trended as relevant to determine:

a) Failure modes
b) Failure causes
c) Failure effects
d) Timing of failure
e) Compare similar equipment types, applications, etc., for both common and unusual trends and failures, as well as root cause determination and analysis.

7.2.3 Data requirements for analysis and investigations

Required data for analysis and investigations are:

a) History of the results for each measurement point per equipment.
b) History of the alarms thresholds for each measurement point.
c) Faults history.
d) Work history.
e) Parts replaced, repaired, refurbished, etc.

7.2.4 Data analysis requirements for Vibration

The software shall provide the following post processing of vibration data:

a) Time Waveform analysis
b) Vibration spectrum analysis
c) High Frequency, Low Frequency, Order Tracking
d) Orbit Plots
e) Bode Plots
f) Trending Data
g) Converting Waveforms to Spectra
h) Normal Averaging, Exponential, Peak Hold, Order Tracking, Synchronous Time, and Negative Averaging

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7.2.5 Data analysis for Thermography

Present state of the art analysis for thermography will be acceptable.

7.2.6 Data analysis for lubricating fluids

Present state of the art analysis for oil analysis will be acceptable.

8. REPORTS REQUIREMENTS

The software's reporting capability shall provide the following functionality:

a) Reports shall be viewable on the screen
b) All reports shall be printable.
c) All reports shall be available electronically for data interchange with other information systems, convertible to HTML, MS Office or PDF files.
d) Reports and data are required electronically in both editable and non-editable formats.
e) All reports shall be saveable and retrievable within the software
f) Avail reports based on Users profile
g) Allow for customisable report content

8.1 REPORTS FOR VIBRATION

The format of the report shall be consistent and as a minimum include the following:

a) Date and time of inspection.
b) The manufacturer, model and date of calibration of the instrument used.
c) Operating condition when measurements were taken.
d) All identified problems.
e) Recommendations with a timeframe for action.
f) Standard reports required include:
    i. Alarm Report
    ii. Exception Report
    iii. Last Measurements
    iv. Item of equipment Assessment Reports
    v. Equipment Summary Report

8.2 REPORTS FOR THERMOGRAPHY

The format of the report shall be consistent and as a minimum include the following:

a) Date and time of inspection
b) The manufacturer, model and date of calibration of the instrument used
c) Operating and environmental conditions for each item of equipment at the time of inspection
d) Specific details of anomalies detected
e) Corrective action recommended
f) Severity of the problem and urgency of corrective action
g) Visible photograph
h) Infrared photograph
i) The name, qualification and signature of thermographer

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8.3 SCOPE OF WORK REPORT DETAILS

Scope of work reports shall give an overview of work done in the period under consideration and cover the following:

a) List and indicate the current condition of equipment.
b) All equipment that shall have been tested shall be reported. If any equipment was not tested the reason that prevented testing shall be given
c) Include changes made to software in the period – e.g. alarm level, etc.

9. COLLABORATION, COMMUNICATION, PUBLICATION

The condition monitoring software shall have features, functionality to cater for collaboration, communication, and publication of information. These shall be based on Eskom approved open industry standards

9.1 COLLABORATION

The condition monitoring system shall use Eskom approved open industry standard interfacing. It is envisaged that the system shall be accessed as:

a) Input data to a collaborative engineering portal that brings together all types of information regarding a piece of equipment to aid investigation of problems using drill down functionality for further details.
b) Input to any knowledge sharing system.

9.2 COMMUNICATION

Information from the system shall be communicated in several forms.

a) Reports and information shall be electronic to facilitate it being ported onto various required platforms.
b) The software shall provide Eskom IM approved interfacing with communications systems such as email systems and MS Office products.

9.3 PUBLICATION

Reports shall be published on various electronic systems such as intranet. The software shall provide Eskom IM approved interfaces to forms of electronic publication.

10. PROCESS INTEGRITY

The system shall provide all relevant data, records and reports to indicate that the required processes have been followed. The minimum requirement is listed below. It is noted that the information is contained in multiple systems. The proposed condition management solution shall provide for access to any relevant information contained therein.

10.1 MONITORING AND CONTROLLING PROCESS & SERVICE EXECUTION

As a minimum the following reports are required:

a) List equipment checked against equipment on the schedule.
b) Report the overall condition of each item of equipment that was checked in the period under review.

10.2 PROCESS EFFICIENCY, ACCURACY, CONSISTENCY

The following indicators shall be monitored to track service effectiveness.

a) Number of correct predictions
b) Number of incorrect predictions

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c) Number of unplanned work orders arising out of issues that could have been identified by condition monitoring.
d) Calibration certificates for all instruments used in the review period.
e) List of employees and qualifications that worked on the plant in the review period.

10.3 MONITORING AND CONTROLLING PROCESS EFFECTIVENESS

The following information is required to assess process effectiveness.

a) Failed parts and root causes of the failures shall be tracked.
b) List of failures that were not detected by condition monitoring but should have been.
c) The number of unnecessary, intrusive maintenance tasks.
d) Savings from PM's that are revised or eliminated by Condition Monitoring techniques.
e) Mean Time Between Failures (MTBF).
f) Mean Time to failure.
g) Total hours worked on emergency jobs to be measured as a percentage of total hours worked.

11. AUTHORISATION

This document has been seen and accepted by:

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12. REVISIONS

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February 2014	0.1	E. Stephen	Draft Document
February 2014	0.2	E. Stephen	Draft Document for Comments Review
April 2014	1	E. Stephen	Final Document for Authorisation and Publication

13. DEVELOPMENT TEAM

The following people were involved in the development of this document:

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- Errol Stephen

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APPENDIX A: EQUIPMENT DATABASE

In addition to measurement parameters and measurement points the equipment database shall hold the following categories of data:

a) Identity and specifications
b) Function and Operating conditions
c) Alarm thresholds

The minimum data fields for each category are described in tables.

A.1 IDENTITY AND SPECIFICATIONS

Table A1 Equipment identity data fields

Item	Description	Example
Equipment ID	(SAP No.)	3894834AZ
Description	Simple but descriptive as possible name	Motor1
Serial No.	Serial no. as assigned by manufacturer	735356222EX
Manufacturer	Name of Manufacturer	GEC
Model	Model no. as assigned by manufacturer	XR6
Voltage	Specified Operating voltage rating	380
Power	Specified operating power rating	3KW
Current	Specified operating current rating	15A
Rotating speed	Specified operating speed rating or speed range	4500 RPM
plus key technical specifications as related to type of equipment motor, gearbox, fan, etc.	Parameters that describe each type of equipment.	Motor: coupling type, etc. Fan: blow rate, etc. Gearbox: no. of gears, etc.

A.2 FUNCTION AND OPERATING CONDITIONS

Table A2 Equipment function and operating data fields

Item: Motor1		
Function	Description function in plant	Drive for slurry pump1
Criticality	Designated criticality	Critical
Physical location	The physical location in the plant to assist in finding and identifying the equipment	Behind pump house at waste water works.
KKS no. / AKZ	Designated KKs No.	389283293828
Operating Conditions	Temperature, pressure, speed, etc.	Normal speed 36000 rpm

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