

# Contents

---

**Preface..... VIII**

**Abbreviations/Acronyms used in this Guide ..... IX**

**1 Introduction..... 1**

    1.1 Purpose ..... 1

    1.2 Scope..... 2

**2 General management of ageing assets ..... 3**

    2.1 Usual references/resources..... 3

    2.2 Benefits of replacement and updating ..... 3

    2.3 Other considerations ..... 4

    2.4 Obsolescence..... 4

**3 Uninterruptable Power Supplies and Battery Systems ..... 5**

    3.1 Technology introduction ..... 5

    3.2 Typical Failure modes..... 6

        3.2.1 UPS..... 6

        3.2.2 Batteries..... 6

    3.3 Condition monitoring techniques..... 7

        3.3.1 Temperature measurement..... 7

        3.3.2 Battery cell voltage measurement..... 7

        3.3.3 Ripple current measurement..... 8

        3.3.4 Connection resistance measurement..... 8

        3.3.5 Capacity test..... 8

        3.3.6 Battery impedance measurement ..... 8

    3.4 Expected/accepted values ..... 8

    3.5 Assessing risk of failure ..... 9

    3.6 Life extension methods..... 9

        3.6.1 UPS..... 9

        3.6.2 Batteries..... 9

    3.7 Equipment specific useful extras/examples..... 10

- 4 Electrical drives ..... 11**
  - 4.1 Technology introduction ..... 11
  - 4.2 Typical Failure modes..... 11
  - 4.3 Condition monitoring techniques..... 12
  - 4.4 Expected/accepted values..... 12
  - 4.5 Assessing risk of failure..... 13
  - 4.6 Life extension methods..... 13
  - 4.7 Equipment specific useful extras/examples..... 13
- 5 Electrical protection devices ..... 14**
  - 5.1 Technology introduction ..... 14
  - 5.2 Typical Failure modes..... 14
  - 5.3 Condition monitoring techniques..... 15
  - 5.4 Expected/accepted values..... 15
  - 5.5 Assessing risk of failure..... 15
  - 5.6 Life extension methods..... 15
- 6 Power cables..... 17**
  - 6.1 Technology introduction ..... 17
  - 6.2 Typical Failure modes..... 17
    - 6.2.1 Cabling environment ..... 17
    - 6.2.2 Cable UV degradation..... 18
    - 6.2.3 Degradations associated with cable trays ..... 18
    - 6.2.4 Moisture ingress ..... 18
    - 6.2.5 Placticizer migration..... 19
    - 6.2.6 Oxygen degradation..... 19
    - 6.2.7 Water Treeing..... 19
    - 6.2.8 Electrical treeing..... 19
  - 6.3 Condition monitoring techniques..... 19
  - 6.4 Expected/accepted values..... 20
  - 6.5 Assessing risk of failure..... 20
  - 6.6 Life extension methods..... 20

<b>7 Switchgear (HV and LV)</b> .....	<b>21</b>
7.1 Technology introduction .....	21
7.2 Typical Failure modes.....	21
7.3 Condition monitoring techniques.....	21
7.4 Expected/accepted values .....	22
7.5 Assessing risk of failure .....	22
7.6 Life extension methods.....	22
7.7 Equipment specific useful extras.....	22
<b>8 Transformers</b> .....	<b>23</b>
8.1 Technology introduction .....	23
8.2 Typical Failure modes.....	23
8.3 Condition monitoring techniques.....	24
8.3.1 On Line Testing.....	24
8.3.2 Other On-Line Tests.....	25
8.3.3 Off-line tests.....	25
8.4 Expected/accepted values .....	26
8.5 Assessing risk of failure .....	26
8.6 Life extension methods.....	27
8.7 Equipment specific useful extras/examples.....	28
<b>9 Generators and motors</b> .....	<b>29</b>
9.1 Technology introduction .....	29
9.2 Typical Failure modes.....	29
9.3 Condition monitoring techniques.....	30
9.3.1 Stator Winding Off-Line Tests.....	31
9.3.2 Stator Winding Insulation Resistance and Polarisation Index .....	31
9.3.3 Loss Angle and Winding Capacitance .....	31
9.3.4 Partial Discharge Testing from Machine Terminals.....	32
9.3.5 Partial Discharge Location Detection.....	32
9.3.6 Winding DC Resistance .....	32
9.3.7 Winding AC Impedance.....	32
9.3.8 Generator Stator Core Tests.....	33
9.3.9 Remote robotic inspection .....	35

9.4 Expected/accepted values ..... 35

9.5 Assessing risk of failure ..... 35

9.6 Life extension methods..... 36

**Appendix A Example inspection templates..... 37**

**Appendix B Equipment Assessment Process..... 56**

**Appendix C Examples of ageing-related failures ..... 62**

**References ..... 63**

**Bibliography..... 65**

**EEMUA Publication: Feedback Form ..... 66**

**Tables**

Table 1: Vented lead acid (VLA) battery – common causes of failure .....6

Table 2: Valve regulated lead acid (VRLA) battery – common causes of failure.....6

Table 3: Nickel cadmium battery – common causes of failure .....6

Table 4: Battery degradation.....7

Table 5: Battery design life by type .....9

Table 6: Frequency of UPS maintenance.....9

Table 7: Frequency of battery maintenance..... 10

Table 8: Transformer life expectation ..... 26