RECOMMENDATIONS FOR ON-SITE TESTING OF MV CABLES

NIVASHNEE RAMPARSAD
AGENDA

• Introduction
• Available Test Methods
• Cable Test Suggestions
• Withstand and Condition Monitoring
• Drum Handling and Installation Practices
• Failure Mechanisms in MV Cables
• Sheath Failures
• Accredited Installers
• Record Keeping
TRICKS OF THE TRADE
INTRODUCTION

Q: Why is there a need to do on site cable testing?
A: To determine the actual condition of the cable system as well as its future performance. Applies to new or cables already in service.

Factors to consider prior to cable testing:-

- How old is the cable system?
- Type of insulation?
- Current load and voltage rating?
- Cable history?
- Environmental conditions?
Q: What are the conditions for testing on site?

1. Testing shall be conducted under the following conditions:
   a) after apparatus has been installed (or re-installed) but before energizing for the first time;
   b) after work has been performed on the insulation of the cable system;
   c) after any cable has been intentionally left de-energized for more than one month unless otherwise specified; and
   d) as and when required for diagnostic testing.

2. For new and re-commissioned equipment, the interval between testing and energizing from the system shall be the minimum practical (no more than 24 h).
METHOD 1: DC HIPOT TEST

- Recommended as suitable test method for LV cables (*SANS 10198-13:2015 Ed 2*).
- Has since been removed as a recommended test method in *SANS 10198-13:2015 Ed 2*).

**Advantages:**
- Relatively simple and inexpensive test equipment
- Other tests methods are recommended for aged MV XLPE cables with even testing on PILC cables being contested these days

**Disadvantages:**
- Unable to detect certain defects
- May lead to space charge accumulation, especially at accessory-to-cable interface.
- May adversely affect future performance of water-tree-affected XLPE cables
IEEE 400-2001 provides a cautionary note regarding the DC Hipot test: “Testing of cables that have service aged in a wet environment (specifically XLPE) with DC at the currently recommended DC voltage levels may cause the cables to fail after they are returned to service. The failures would not have occurred at that point in time if the cables had remained in service and not been tested with DC. Furthermore, massive insulation defects in extruded dielectric insulation cannot be detected with DC at the recommended voltage levels.”
METHOD 2: VLF Testing

• **Advantages:**
  – No space charge accumulation
  – Can be tested with ac voltage up to $3 \times U_0$
  – Simulates cable defects without jeopardizing the cable system integrity
  – Confidence once the 0.1 Hz test is passed.

• **Disadvantages:**
  – Expensive test equipment
  – Longer testing times
  – Inconclusive results are obtained on cables with extensive water-tree damage or ionization of the insulation.
METHOD 2: VLF TEST DURATIONS

• When newly installed individually screened MV cables are being commissioned, ensure that each core is overvoltage tested at the appropriate test voltage given in table 1 for 60 min. Multiple cores can be tested simultaneously if the test equipment rating permits.

• When cables are overvoltage tested after maintenance or repair, ensure that they are tested for a duration of 60 min at the test voltages given in table 7, for individually screened MV cables, and table 8, for belted MV cables.

• Ensure that the test voltage is applied on each conductor and that the non-tested conductors, earthed metallic screen and armouring (where employed) are all connected together and earthed.
### Table 1: Commission test voltages for newly installed individually-screened MV cables

<table>
<thead>
<tr>
<th>Cable operating voltage $\alpha$ (kV)</th>
<th>VLF test voltage sine $\alpha$ (kV)</th>
<th>VLF test voltage cosine/rectangular $\alpha$ (kV)</th>
<th>Power frequency test voltage $\alpha$ (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6 $\alpha$</td>
<td>11 $\alpha$</td>
<td>16 $\alpha$</td>
<td>8 $\alpha$</td>
</tr>
<tr>
<td>11 $\alpha$</td>
<td>19 $\alpha$</td>
<td>27 $\alpha$</td>
<td>13 $\alpha$</td>
</tr>
<tr>
<td>22 $\alpha$</td>
<td>38 $\alpha$</td>
<td>54 $\alpha$</td>
<td>25 $\alpha$</td>
</tr>
<tr>
<td>33 $\alpha$</td>
<td>57 $\alpha$</td>
<td>80 $\alpha$</td>
<td>38 $\alpha$</td>
</tr>
</tbody>
</table>

**NOTE** $^1$ The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine/rectangular voltage is equal to the peak voltage.

**NOTE** $^2$ Where the test levels cannot be achieved or where limitations are placed on the maximum test voltage by the equipment (for example, switchgear) connected to the cable, a reduced voltage for an extended duration may need to be considered and agreed to.
# VLF Testing Voltage Levels

## Table 2 — Commission Test Voltages for Newly Installed Belted (Non-Radial Field) Paper-Insulated MV Cables

<table>
<thead>
<tr>
<th>Cable Operating Voltage kV</th>
<th>Test Voltage Between Conductors</th>
<th>Test Voltage From Conductor to Sheath</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VLF Test Voltage Sine (kV)</td>
<td>VLF Test Voltage Cosine Rectangular (kV)</td>
</tr>
<tr>
<td></td>
<td>VLF Test Voltage Cosine Rectangular (kV)</td>
<td>Power Frequency Test Voltage (kV)</td>
</tr>
<tr>
<td></td>
<td>VLF Test Voltage Sine (kV)</td>
<td>VLF Test Voltage Cosine Rectangular (kV)</td>
</tr>
<tr>
<td>3,3/3,3</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>3,8/6,6</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>6,6/6,6</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>6,35/11</td>
<td>27</td>
<td>38</td>
</tr>
<tr>
<td>11/11</td>
<td>33</td>
<td>47</td>
</tr>
</tbody>
</table>

**NOTE 1** The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine rectangular voltage is equal to the peak voltage.

**NOTE 2** Where the test levels cannot be achieved or where limitations are placed on the maximum test voltage by the equipment (for example, switchgear) connected to the cable, a reduced voltage for an extended duration may need to be considered and agreed to.

**NOTE 3** Single phase test voltages used on-site dictate that during the test on each core, the other cores, metallic screen and armouring must all be earthed. The test voltage will therefore be applied between the tested phase and the other phases, and at the same time between the tested phase and the metallic screen. Consequently, the between conductors and from conductor to sheath test voltages...
Table 7 — Maintenance test voltages for individually screened MV cables

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable operating voltage</td>
<td></td>
<td>VLF test voltage sine</td>
<td>VLF test voltage cosine rectangular</td>
<td>Power frequency test voltage</td>
</tr>
<tr>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kV</td>
</tr>
<tr>
<td>6.6</td>
<td>8</td>
<td>11</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>18</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>25</td>
<td>35</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>38</td>
<td>54</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 1 The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine rectangular voltage is equal to the peak voltage.

NOTE 2 Where the test levels cannot be achieved or where limitations are placed on the maximum test voltage by the equipment (for example, switchgear) connected to the cable, a reduced voltage for an extended duration may need to be considered and agreed to.

NOTE 3 The test used for maintenance are two thirds (2/3) of the test voltages for newly installed cables.
### Table 8 — Maintenance test voltages for belted (non-radial feed) paper-insulated MV cables

<table>
<thead>
<tr>
<th>Cable operating voltage</th>
<th>Between conductors</th>
<th>Power frequency test voltage</th>
<th>From conductor to sheath</th>
<th>Power frequency test voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VLF test voltage sine</td>
<td>VLF test voltage cosine rectangular</td>
<td>VLF test voltage sine</td>
<td>VLF test voltage cosine rectangular</td>
</tr>
<tr>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kV</td>
<td>kV</td>
</tr>
<tr>
<td>3,3/3,3</td>
<td>7</td>
<td>9</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>3,8/6,6</td>
<td>11</td>
<td>15</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>6,6/6,6</td>
<td>13</td>
<td>18</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>6,35/11</td>
<td>18</td>
<td>26</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>11/11</td>
<td>22</td>
<td>31</td>
<td>15</td>
<td>22</td>
</tr>
</tbody>
</table>

**NOTE 1** The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine rectangular voltage is equal to the peak voltage.

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METHOD 3: TAN-DELTA

- **Advantages:**
  - Tested at AC voltage up to 3xU0
  - Regular measurements will establish deterioration history of cable
  - Tests are performed at operating or lower frequencies.

- **Disadvantages:**
  - A breakdown test is still required to identify any large defects.
### Method 3: Tan-Delta for XLPE

#### Table 3 — Guidelines for the condition assessment of cables based on 0.1 Hz VLF TD, DTD and TDS for newly installed XLPE cables

<table>
<thead>
<tr>
<th>Condition Assessment</th>
<th>TD at $U_0$ [10^{-2}]</th>
<th>DTD [10^{-2}]</th>
<th>TDS at $U_0$ [10^{-2}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No action required</td>
<td>&lt; 2.5</td>
<td>&lt; 0.6</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Further study advised</td>
<td>2.5 to 5</td>
<td>0.6 to 1</td>
<td>0.2 to 0.5</td>
</tr>
<tr>
<td>Action required</td>
<td>&gt; 5</td>
<td>&gt; 1</td>
<td>&gt; 0.5</td>
</tr>
</tbody>
</table>

*XLPE cables in operation for less than five years.

#### Table 4 — Guidelines for the condition assessment of cables based on 0.1 Hz VLF TD, DTD and TDS for aged (in service cables) XLPE cables

<table>
<thead>
<tr>
<th>Condition Assessment</th>
<th>TD at $U_0$ [10^{-2}]</th>
<th>DTD [10^{-2}]</th>
<th>TDS at $U_0$ [10^{-2}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No action required</td>
<td>&lt; 2.5</td>
<td>&lt; 3</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Further study advised</td>
<td>2.5 to 25</td>
<td>3 to 30</td>
<td>0.2 to 0.5</td>
</tr>
<tr>
<td>Action required</td>
<td>&gt; 25</td>
<td>&gt; 30</td>
<td>&gt; 0.5</td>
</tr>
</tbody>
</table>
METHOD 3: TAN-DELTA FOR PILC

Table 5 — Guidelines for the condition assessment of cables based on 0.1 Hz VLF TD, DTD and TDS for newly installed PILC cables

<table>
<thead>
<tr>
<th>Condition assessment</th>
<th>TD at $U_0$ [10^{-3}]</th>
<th>DTD [10^{-3}]</th>
<th>TDS at $U_0$ [10^{-3}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No action required</td>
<td>&lt; 25</td>
<td>-20 to 20</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Further study advised</td>
<td>25 to 50</td>
<td>-20 to -50</td>
<td>or 20 to 50</td>
</tr>
<tr>
<td>Action required</td>
<td>&gt; 50</td>
<td>&lt; -50 or &gt; 50</td>
<td>&gt; 1</td>
</tr>
</tbody>
</table>

* PILC cables in operation for less than five years.

Table 6 — Guidelines for the condition assessment of cables based on 0.1 Hz VLF TD, DTD and TDS for aged PILC cables

<table>
<thead>
<tr>
<th>Condition assessment</th>
<th>TD at $U_0$ [10^{-3}]</th>
<th>DTD [10^{-3}]</th>
<th>TDS at $U_0$ [10^{-3}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No action required</td>
<td>&lt; 50</td>
<td>-35 to 10</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Further study advised</td>
<td>50 to 200</td>
<td>-35 to -50</td>
<td>or 10 to 50</td>
</tr>
<tr>
<td>Action required</td>
<td>&gt; 200</td>
<td>&lt; -50 or &gt; 50</td>
<td>&gt; 1</td>
</tr>
</tbody>
</table>
METHOD 4: PARTIAL DISCHARGE TESTING

• Advantages:
  – Measures and pinpoints defects
  – Useful for both PILC and XLPE cables
• Disadvantages:
  – Trained operators required
  – One large PD site may mask others
OUTERSHEATH TEST

• To verify the integrity of the outer sheath of the cable after installation, subject a cable to outer sheath testing. Where applicable, apply a DC sheath test voltage of 5 kV for 1 min, with a maximum leakage current of 1 mA/km being regarded as acceptable.

• This test is applied between the armouring (which has been disconnected from earth) and earth. Damage to the outer sheath will cause a current to flow back to the DC test set through the ground (earth). These faults can be detected with a sheath fault locating test set.
WITHSTAND vs CONDITION MONITORING

**Withstand Tests**

- Categorized as a “Pass/Fail” test
- Causes the cable system to fail at defects so that they can be identified.
- The cable is then replaced or repaired
- Over-voltage test implies applying a voltage higher than the operating voltage of the cable system
- Weighs the cost of failure during testing as opposed to unplanned outages.
- Remaining life of the cable could be reduced using withstand cable testing
**Condition Monitoring**

- Produces test data without causing defective areas to fail
- The cable is then replaced or repaired
- Referred to as diagnostic test methods
- Unique problem associated to new cables that have been joined to existing cables that have already been in service.

**WITHSTAND vs CONDITION MONITORING**
Transportation of drums

Utmost care must be taken when handling & transporting cable drums

- Drums of electric cable are bulky, expensive and difficult to handle.
- Use of a ‘low bed’ vehicle is preferred if the drums are to be transported a long distance.
- The drums should be tightly packed and secured with chains to prevent movement while in transit.
- Do not lay drums flat.
- The driver(s) should be asked to stop frequently during transportation to check if the load remains secure.
Cables drums not secured correctly
DRUM HANDLING

Unloading of drums

- Ensure lifting equipment is rated for the load to be lifted.
- Select correct spindle slings for the drum size and mass and ensure that these are in order.
- Ensure that a spreader bar is used.
- Do not drop drum, lower gently onto firm level surface.
DRUM HANDLING

Unloading of drums

Method 1: Hole excavated (maximum slope 1 in 10) to receive truck.

Method 2: Ramp constructed (maximum slope 1 in 4)
Cable Unloaded Incorrectly
Incorrect Cable Storage Practices
Incorrect Storage Practices
Incorrect Cable Storage and Effects
Before installation can occur, it is important to determine whether the cable used is the correct cable. Markings on drum flanges should be clear, stencilled or burned into the wood and should include:

- Manufacturer’s name or trade mark
- Rated voltage, rated area, number of cores and specification
- Length of the cable in metres
- Year of manufacture
- Gross mass in kilograms
- Serial number or other identification
- The instruction “NOT TO BE LAID FLAT”
- On each flange an arrow with the words ‘ROLL THIS WAY’
- SABS Mark
Cable Installations

- Normally, cables are buried direct into the ground. They can also be installed in ducts, tunnels or in air suspended between poles or on cable ladders.

- Always try to cause as little inconvenience as possible to the general public.
Trenching

- The **bottom** of the trench should be **level** and free from loose rocks or stones.
- If water is present, or thunderstorms possible, then **sump holes** should be dug **along the route** to allow removal of water.
- Wherever possible a **300mm walkway** should be provided at each side of the trench to avoid dislodging excavated material into the trench.
Cables installed directly underground

- Unarmoured cables may be buried if they are insulated and sheathed.

- If unarmoured insulated cables are buried at a depth of:
  
  a) less than 0.5 m, they shall be enclosed in conduit or otherwise mechanically protected (for example, in the case of paving or concrete), or protected by an earth leakage protection device with a rated earth leakage tripping current (rated residual current) not exceeding 30 mA.

  b) at least 0.5 m, the backfill around them shall not contain sharp objects and there shall be a marker tape that runs above the route of the cable, at a depth of between 0.3 m and 0.4 m.

(SANS 10142-1 Clause 6.4.4)
Incorrect

Excavated Backfill material

Correct

150mm Consolidated Backfill

75mm Bedding Hand compacted
Always ensure that trenches are enclosed to prevent harm to the general public – this can be attained by using shuttering, barricades, fencing or marker tape as required by regulation.
The drum should be positioned at the head of the trench.
Collars must be fitted between the drum flange and the cable jacks in order to keep the drum flanges clear of the jacks during installation.
Timber packing may be used to prevent the jacks from sinking into soft soil.
The cable must be pulled off over the top of the drum.
The drum should be raised approximately 50mm clear of the ground.
The outside end of the cable should be untied from the securing rope.
The pulling sock puts tension on the cable outer layers
Pulling eyes put tension directly on the conductors (preferred for larger cables or longer pulling lengths)
A combination between both types of pulling systems is often used.
Cable rollers

- **Support** the cable during pulling in.
- Must be placed so as to avoid **over-bending** of the cable.
- Special attention should be paid to the placement of these rollers at points where a change of direction is made (Corner Rollers).
## Minimum bending radii

<table>
<thead>
<tr>
<th>Cable type</th>
<th>Bending radius up to and including 11kV</th>
<th>22kV &amp; 33kV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Paper insulated cables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Single core</td>
<td>20 x d*</td>
<td>25 x d*</td>
</tr>
<tr>
<td>• Multi-core</td>
<td>12 x d*</td>
<td>15 x d*</td>
</tr>
<tr>
<td><strong>PVC insulated cables 1000 Volt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Multi &amp; single core 16.5 mm(^2)</td>
<td>8 x d*</td>
<td>-</td>
</tr>
<tr>
<td>• Armoured multi &amp; single core 70mm(^2) and greater</td>
<td>10 x d*</td>
<td>-</td>
</tr>
<tr>
<td><strong>XLPE insulated cables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Single core</td>
<td>17 x d*</td>
<td>17 x d*</td>
</tr>
<tr>
<td>• Multi-core</td>
<td>15 x d*</td>
<td>15 x d*</td>
</tr>
</tbody>
</table>
• Water trees in MV XLPE Cables
• Aged insulation materials
• Defects caused by high operating temperatures of the conductor
• Defects caused by overvoltages resulting from lightning strikes, switching or short-circuit currents.
FAILURE MECHANISMS IN MV CABLES
MECHANICAL DAMAGE IN NEW CABLES

• Involves cuts, scrapes excessive sidewall force damage
• Damage to outersheath may allow water to permeate between the insulation and the sheath.
• Damage to the insulation of the cable causing the cable to fail under operation
BAD INSTALLATION
OVERALL SHEATH DAMAGE

Typically when cables aren’t installed correctly, the serving (overall weather, chemical & electrical protection of the cable) becomes damaged.
OVERALL SHEATH DAMAGE
Figure 8-ing of Cable from drum

- When the length to be installed is very long, or the route is difficult, i.e. many bends etc.
CABLE INSTALLATIONS

Mount the drum directly over the duct entrance
ACCREDITATED INSTALLERS

South African Qualifications Authority

PURPOSE AND RATIONALE OF THE QUALIFICATION

Purpose:

• Terminate, joint, upgrade and install medium voltage cables.
• Work effectively and efficiently, optimising the use of resources.
• Observe all applicable regulations and legislative requirements.

These capabilities require an understanding of:

• Factors which affect the quality of cable joints and terminations.
• Work practices which promote and maintain safety and quality, while minimising risks, by identifying and eliminating hazards and potentially dangerous situations.
• Controlling environmental impacts and working in adverse climatic conditions.
• The relevant standards, statutory requirements and jointing or terminating procedures.
• Managing resources, time and the jointing team.
• Liaising with sub-contractors.
RECORD KEEPING

In 30 years time will you know where your cables are?

**Record:**
- “As laid” details
- Location of joint bays
- Depth of burial
- Position of cable ducts
- Date of installation etc.
Technical Helpdesk
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helpdesk@aberdare.co.za
www.aberdare.co.za