HIGH VOLTAGE INSULATED CABLES

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HIGH VOLTAGE INSULATED CABLES – AN OVERVIEW

• What is defined as a High Voltage (HV) Insulated Cable
• Why the need for HV insulated cables
• Designs of HV Cables
• An HV cable system
• Issues to consider
• A new Flexible joint design
What is High Voltage?

- **LV** Low Voltage: Up to 1000V
- **IV** Intermediate Voltage: 3.3 kV
- **MV** Medium Voltage: From 6.6 kV to 33 kV
- **HV** High Voltage: From 44 kV up to 150 kV
- **EHV** Extra High Voltage: From 220 kV up to 500 kV
- **SHV** Super High Voltage: From 765 kV
THE NEED FOR HV CABLES

Why High Voltage?

- Power: \( P = V \times I \times \sqrt{3} \times \cos(\Theta) \)
- If voltage goes up by \( N \) times, then current comes down by \( 1/N \) times
- At lower voltage and higher currents, the conductors would have to be impossibly large
- A suburb of say 50 000 houses will draw 100 to 150 MVA
THE NEED FOR HV CABLES

Cable Load Capacity ($V*I*\sqrt{3}$) in MVA
MV vs HV

- 33 kV
  - 240 mm² Al
  - 630 mm² Al
  - 1000 mm² Al
  - 2000 mm² Al

- 132 kV
  - 240 mm² Al
  - 630 mm² Al
  - 1000 mm² Al
  - 2000 mm² Al
THE NEED FOR HV CABLES

What Why Cables and not conductors?

• Ground for servitudes is very expensive in cities
• Aesthetic – the cities often have the money to pay
• Cables are more immune to weather conditions, etc
• Near fields and fears of childhood leukemia

What influences the sizes?

• African city dwellers do not generally live in high-rise flats
• Our population densities are lower than Europe, North America and SE Asia
• Local maximums are generally 1000mm2 as opposed to 2500mm2
THE NEED FOR HV CABLES

Cable and Conductor use as an approximate percentage (value) in RSA

[Bar chart showing LV, MV, OH, HV Cable categories with LV at 80%, MV at 10%, OH at 10%, HV Cable at 5%]
THE NEED FOR HV CABLES

Findings from a survey of 19 member countries:

- Of over 860,000 km transmission circuits, **only 2% are undergrounded**
- At **higher voltage levels**, **less than 0.3%** are undergrounded
- **Environmental aspects** - magnetic fields, visual impact and depreciation of land values
- **Technical** – availability of right of way, power transmission capacity and repair times
- **Comparative costs** – mean cost ratio of underground cable to OH lines vary from 7 at the lower and up to 20 at the higher voltage levels
- **Overhead lines are the most economical and reliable** means of high voltage transmission

Source: Cigre joint JWG 21/22.1 Comparison of HV overhead lines and Underground cables of voltage levels equal to or higher than 110kV
DESIGNS OF HV CABLES

FUNCTIONS OF THE METAL SCREEN TYPES

ELECTRICAL FUNCTIONS
• Equipotential screen (radial electrical stress field)
• Capacitive current collection/draining
• Short circuit draining

PROTECTIVE FUNCTIONS
• Mechanical protection
• Water Barrier (water trees)

Sometimes one layer performs both functions (CD) and in others the functions are split between multiple layers (SD)
DESIGNS OF HV CABLES

EXTRUDED METAL SCREEN TYPES

LEAD - One component combines mechanical and electrical properties:
• Extruded Lead sheath
• Semi-conductive water swelling tapes to block the interface between the insulation system and the metal sheath
• Oversheath (usually MDPE or HDPE)

CORRUGATED ALUMINIUM SHEATH - separated mechanical and electrical properties:
• Extruded, corrugated Aluminium sheath
• Thick layer of semi-conductive water swelling tapes to block the interface between the insulation system and the metal sheath
• Oversheath (usually LLDPE)

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DESIGNS OF HV CABLES

Corrugated Seamless Aluminium extruded sheath design

- Conductor
- XLPE
- Water Blocking Tape
- CSA Sheath
  - Inner Semi-Conducting Screen
  - Outer Semi-Conducting Screen
  - Aluminium Tape
  - Water Blocking Tape
  - LLDPE

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METAL FOIL SCREEN TYPES

Combined Design (CD) - combined mechanical and electrical properties:

• Semi-conductive bedding (water swellable if required)
• Thick metal foil either welded or glued, that carries the full short circuit current coated and bonded to the outer sheath (usually HDPE)

The metal foil is mainly aluminium; copper can be used as well.
DESIGNS OF HV CABLES

METAL FOIL SCREEN TYPES

**Separate Design (SD)** - separated mechanical and electrical properties:

- Copper or aluminium wires
- Water swelling tapes to block the screen area
- Coated laminated metal foil i.e. for example Al 0,2 mm + 0,05 mm coating on one side.
- Oversheath (usually MDPE or HDPE)

Metal is mainly aluminium, copper or other metal laminated foils can be used.

[Image of HV cables]
DESIGNS OF HV CABLES

METAL FOIL SCREEN TYPES

Separate Semi-conductive Design (SscD) – separated electrical and water tightness properties with semi-conductive plastic coated foil.

- Round copper wires screen, non swelling semi-conductive tape below
- Thin lead or Al foil (0,05 mm typical) with glue on one side, inner side (screen side) coated with typically 0,05 mm thick semi-conductive plastic
- Over-sheath (usually PVC)
DESIGNS OF HV CABLES

MAIN FEATURES OF THE METAL SCREEN TYPES

EXTRUDED LEAD SHEATH
• Well know industrial process (√)
• Bending radius (√)
• Low risk of corrosion (√)
• Connection to accessories (√)
• Mass (x)
• Not environmentally friendly (x)

Source: JiCable 2007 Paper A1-4
French Experience in Aluminium Laminted Screens
DESIGNS OF HV CABLES

MAIN FEATURES OF THE METAL SCREEN TYPES

CORRUGATED ALUMINIUM SHEATH
• Mechanical strength (√)
• Gap between semi-conductive screen and Al tube
  - poor heat transfer (x)
  - poor longitudinal water tightness (x)
• Large external diameter (x)

Source: JICable 2007 Paper A1-4
French Experience in Aluminium Laminted Screens
DESIGNS OF HV CABLES

MAIN FEATURES OF THE METAL SCREEN TYPES

LAMINATED ALUMINIUM FOIL

• Mass (√)
• Good thermal behaviour (√)
• Compact cable (√)

Source: JICable 2007 Paper A1-4
French Experience in Aluminium Laminted Screens
DESIGNS OF HV CABLES

Installed lengths of cables with various metallic sheath designs (km)

Source Cigre 446
HV CABLE SYSTEMS

A typical system configuration is generally a combination of:

- Single or multiple circuit HV cable feeders that are single core 300 mm² to 2500 mm² Aluminium or copper conductors and XLPE insulated and ..
HV CABLE SYSTEMS

- Straight-through and/or sheath interrupting cable joints and ..
HV CABLE SYSTEMS

- Porcelain or silicone (dry or fluid filled) outdoor terminations or
- Plug-in terminations into GIS or transformers, and ..
HV CABLE SYSTEMS

- A special bonding system used to minimize or eliminate sheath circulating currents or standing voltages in single core cables in order to maximize power transfer capability of the feeder.
ISSUES TO CONSIDER

Causes of failure in HV Cables

Figure 20 - General failure causes for cables (from failure investigation studies)

Source: DNV-GL “Power Cable System Testing – Position Paper”
ISSUES TO CONSIDER

Causes of failure in HV Cable Accessories

Source: DNV-GL “Power Cable System Testing – Position Paper”
ISSUES TO CONSIDER

Corrosion of the metallic sheath in CAS designs

Metal Foil Types

In spite of the extensive used of the SD design since the 80’s in Germany and the CD design since the 90’s in France, no corrosion problem has been reported up to now.

Source Cigre 446
ISSUES TO CONSIDER

Metallic Foil Types

Outer sheath damage in metal foil designs
• the laminated coverings are very robust (requirement for bending, impact, abrasion and sidewall pressure tests) and
• repairing work is seldom needed when state of the art laying techniques are used

The global trend:
• is an increase of the market share of the laminated coverings, and
• a decrease of traditional screens extruded lead, and corrugated metal screens.

Source Cigre 446
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ISSUES TO CONSIDER

Workmanship

• It is of vital importance to manage the interface between the cables and the accessories in order to reduce the potential technical risk.

• The cables and accessories are made under well-defined factory conditions. Their quality and reliability are assured by adherence to well defined specifications.

• The accessories, however, are mounted on site, and notwithstanding that this job is done by skilled and trained jointers, it is often performed in more delicate and undefined conditions than in the factory.

Jointer skills are vital in ensuring the reliability of new links.

Source (Cigre TB 476)

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ISSUES TO CONSIDER

After installation testing

- **Commissioning tests – IEC 60840  76/132 kV (U_m=145 kV):**
  - 132 kV for 1 hr at 20 – 300Hz
  - (Factory test @ 190 kV for 30 min, 10 pC)

- **Typical Test unit Capability:**
  - 260 kV at 83A (34.8 MVA)
  - 20 - 300Hz ,10pC
A NEW FLEXIBLE MV/HV JOINT

A new flexible MV/HV joint developed for submarine cables to 220 kV (Tested to Cigre 490)

Source: Hengtong
# A NEW FLEXIBLE MV/HV JOINT

<table>
<thead>
<tr>
<th>Items</th>
<th>FMJ</th>
<th>Common joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure &amp; size</td>
<td>same as the cable</td>
<td>Different structure &amp; larger size</td>
</tr>
<tr>
<td>Process</td>
<td>Molding process</td>
<td>Assembly of prefabricated parts</td>
</tr>
<tr>
<td>Electrical performance</td>
<td>same as the cable</td>
<td>Reach use requirements</td>
</tr>
<tr>
<td>Mechanical property</td>
<td>same as the cable</td>
<td>Poor</td>
</tr>
<tr>
<td>Bending property</td>
<td>same as the cable</td>
<td>Poor</td>
</tr>
<tr>
<td>Service life</td>
<td>same as the cable</td>
<td>High failure rate</td>
</tr>
</tbody>
</table>

Source: Hengtong
THANK YOU!

Acknowledgement of Cigre source material