HV/EHV Extruded Cable Systems

Mohamed MAMMERI (General Cable)
Balza, Xabier (General Cable)

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HV-EHV UG Cable System

• A full range of cables and accessories from 63 up to 500 kV, based on synthetic insulation techniques
  – Cross sections up to 2500 mm² even more
  – Screening & sheathing systems tailored to needs
  – Optical fibers incorporation

• These cables and all their accessories are fully designed, manufactured, tested and Prequalified.
HV/EHV transmission systems

• Extruded synthetic insulation cables have been developed successfully throughout the world for use in HV and EHV AC links up 500 kV.

• The key design criteria is driven mainly by the electrical stress in the main insulation of the cable and accessories. At voltages up to and including 150 kV extruded insulation has largely superseded paper-insulated cables for the new installations.

• XLPE has only recently become the insulation of choice for many utilities for EHV (>220kV and above) transmission circuits. The introduction of XLPE for longer transmission circuits has been facilitated by the use of one-year heat cycle voltage test called the Prequalification (PQ) test which was recommended by CIGRE in 1993 and afterwards specified in IEC 62067.

• The development of HV EHV cable system involves the following design aspects:
  
  Electrical design:
  the control of the electrical stresses at the cable screen interruption
  the control of electrical stresses within the accessory, mainly at interfaces

  Mechanical design:
  the control of the mechanical stresses inside the accessory
  the control of stresses transferred to the accessory by the adjacent cable and environment

  Thermal design:
  avoid that the accessory, due to its generally larger dimensions becomes the hot spot for the cable system
Philosophy and design considerations

400 kV

- Electrical field on the conductor:
  - to establish the lifetime curve of the extruded insulation: **16 kV/mm max at the conductor shield**
  - to determine the B.I.L performance: **99 kVp/mm at the conductor shield**

- Electrical field over insulation: **7 kV/mm at the insulation shield**
  - to determine the interface between cable and accessory
TYPICAL DESIGNS – Examples

1- Conductor
Al / Cu
Circular / Milliken
Enamelled Cu

2- SMC/XLPE/SMC
Triple extrusion

3- Metallic screen
Cu wires + Al foil
Cu wires + PB extr.
Smooth Welded Al

4- Outersheath
HDPE / HFFR
Anti-rodent
Anti-termite
External smc layer
Mechanically robust!

But

- Transmission capacity reduced by air gap between the cable core and the screen
- Ecology (screen losses)
- Increased diameter
Screen design performance comparison

Corrugated aluminium sheath
- mechanical strength
- gap between S.C. and tube (poor heat transfer) (no longitudinal water tightness)
- large external diameter

Extruded corrugated Aluminium

Outer sheath

Extruded lead sheath
- well-known industrial process
- bending radius
- poor risk of corrosion
- connection to the accessories
- weight
- not environmentally friendly

Laminated aluminium foil
- weight
- good thermal behaviour
- compact cable

25/06/2007  French Experience in Aluminium Laminated Screens
Accessories - Electrical Design

- Finite element computer programs are used to calculate the stresses in the critical regions of the accessories i.e. over electrodes and at the interfaces between different components and materials.
EHV Prefabricated Terminations

- A full range of prefabricated outdoor and G.I.S terminations up to 500 kV with a stress cone profiled to control the electrical field
One Piece Premolded joint: TB 89 of CIGRE

- A single premoulded elastomeric sleeve forms the insulation as shown in figure 7, it is complete with insulation, connector screen, stress control profile screens, insulation screens and, where applicable, screen interruption. Interfacial pressure at the sleeve to cable core interface is maintained by the elastic memory of the sleeve.
GC HV-EHV Qualification

- PQ test on 400kV AC $2500^2$ Cu enameled
  - Overloading heat cycles at 105°C
  - Lightning impulse test performed at 105°C
HV-EHV U/G Cable system - A Unique Experience

- ±525kV DC
- ±320kV DC

Timeline:
- 500kV: 1st km of 500 kV
- 335kV to 400kV: 1st km of 400 kV
- 225kV: 1st km of 225 kV
- 70kV to 161kV: 1st km of 90 kV
- 63kV to 69kV: 1st km of 63 kV

Key Dates:
- 1902: First world-wide application
- 1968: 196 terminations, 2 joints
- 1969: 533 km, 795 terminations, 617 joints
- 1985: 1000th km of 225 kV
- 1990: 2000th km of 225 kV
- 2002: 4,286 km, 7,530 terminations, 6,820 joints
- 2014: 5,044 km, 8,562 terminations, 5,153 joints
- 2015: 5,123 km, 14,174 terminations, 6,668 joints
- 2018: 2020

Graphical Representation:
- Colored bars indicating different voltage levels and distances.
- Yellow circles marking significant milestones.
HV-EHV U/G Cable system-
References

A few examples of projects through the world...........
400kV Cable system for ELTRA(DK)

- Three underground sections in a transmission line 141 km long
  - 14 km * 3 Phase * 2 circuits = 84 km of Cable core (1200 mm²)
  - 36 terminations with composite insulators
  - 96 Joints
- Type tests performed in Silec Laboratories
- Installation started in April 2003 completed June 2004
Achievement examples

Project Tianjin (China)
300/500 kV - 1600 mm² copper conductor, aluminum screen (wire+laminated foil) XLPE insulation
- Total length : 2073 meters
- 6 GIS + 6 Terminations

Project Pubugou (China)
• 300/500 kV - 800 mm² copper conductor, aluminium screen (wire+laminated foil) cables XLPE insulation
- Total length : 9175 meters
- Length in vertical shaft : 4140 meters of single core cables
- 38 GIS Terminations
Long high power underground cable transmission lines

- Reinforcement to the unique 400 kV OHL to supply the South East of France area is made using 225 kV underground cables links

- 3 underground cable links are being implemented:
  - Boutre-Trans: 65 km (the number of joint bays is limited to 68, some drums weighting up to 50 T (≈1400 m of cable))
  - Biançon-Fréjus: 25 km
  - Biançon-La Bocca: 20 km

*Map of the underground 225kV links (green) and OHL (red)*
Elia, Belgium’s electricity transmission system operator, has launched the Stevin project to upgrade the Belgium electricity grid and address four major needs

- To connect offshore wind power to the grid
- To connect the “Nemo” Subsea interconnector between Belgium and the UK to the grid
- To improve the electricity supply for the West Flanders region.
- To enable the connection of additional generation (e.g. wind, solar) in the coastal region.

The project scope is the following:

- a 30-mile long double-circuit (2x3,000MVA) 380kV line;
- a new EHV substation in Zeebrugge

For 6.2 miles, the 380kV-line will run underground. Transition stations will be built in Bruges and Vivenkapelle.
380 kV UG Power Line
Stevin – Section

The underground section will be composed of 4 systems (2 circuits each with 2 cables/phase) performed by two suppliers

- **Cable type:**
  - 2,500mm² enameled copper, Milliken
  - Copper wire screen – one phase w/ integrated F.O. for temperature monitoring
  - Aluminum water barrier

- **Each circuit will be installed in “cross-bonding” with 4 main sections (12 short sections)**

- **Terminations: outdoor, composite type**

- **The cables will be laid direct in the ground in a 50ft.-wide trench except for**
  - Some HDD sections as required by the route (e.g. road crossings)
  - the crossing of the “Boudewijnkanaal”, for which two dedicated tunnels (one per circuit) will be built