Insulated Cables for Energy Transmission at UHVAC Level

Pierre Argaut
SCB1

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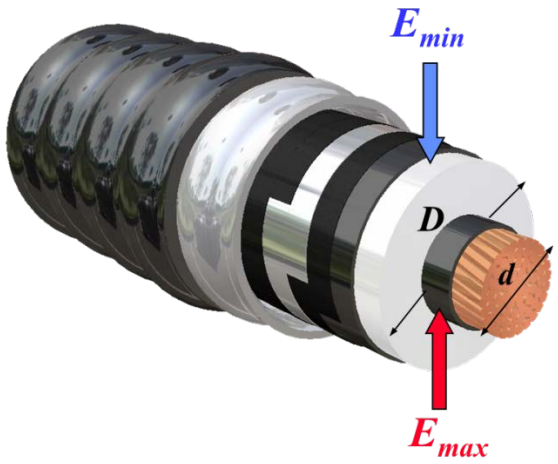
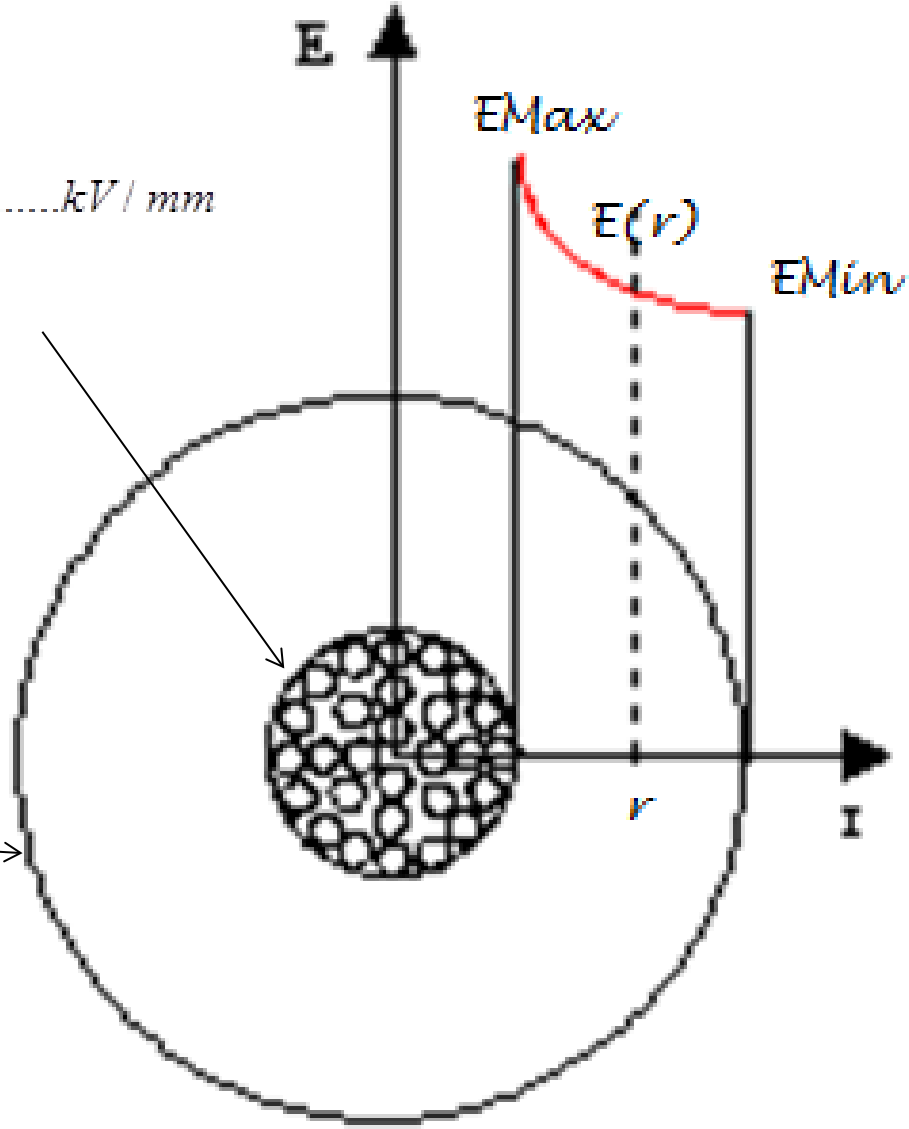
Electrical Field in a Cable

$$E_{max} = \frac{2.U_0}{d.\ln\left(\frac{D}{d}\right)} \text{.....} kV/mm$$



$$E_{min} = \frac{2.U_0}{D.\ln\left(\frac{D}{d}\right)} \text{.....} kV/mm$$



Lapped Cables

- The Use of Cables with Paper Insulation is limited due to discharge problems in butt-gap spaces at electrical fields of 5MV/m
- Emmanueli found a solution in 1920 by pioneering a fluid-filled cable where void formation is eliminated by maintaining a liquid impregnant at a positive pressure which, for this purpose, need not be very high.
- An alternative arrangement is to maintain the insulation under a high gas pressure:
  - If the sheath over insulation is reasonably flexible, gas pressure can be applied externally.
  - In other designs (Strong metal sheath), gas at a high internal pressure is admitted into direct contact with the insulation.

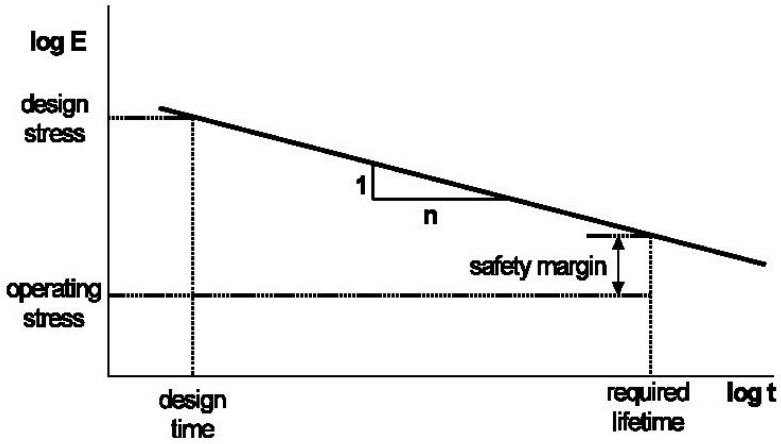
Today, pressurised cables are available up to 765 kV and even 1100 kV through the gradual development of the technology in terms of materials and manufacturing processes.

Low loss dielectric in the form of polypropylene paper laminate is now being utilised with a significant improvement in rating at the higher voltage levels compared to the conventional paper insulated cables. Operating stresses have been gradually increased over the years based on technological improvements and a sound service record.

Robert Rosevear, Cigré SC 21

IEE Conference, 1995

Lifetime Curves



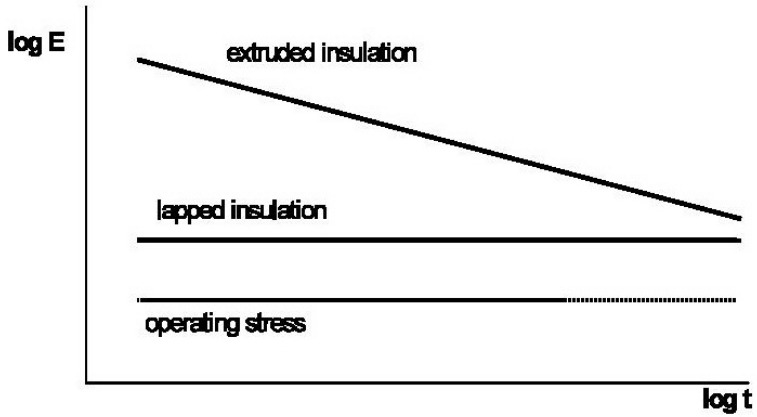
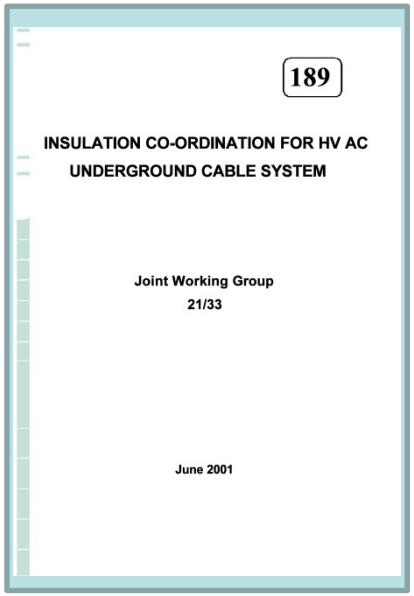


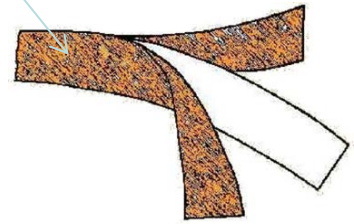
Figure 7 : Lifetime curve for extruded cable insulation

Design Stresses for Lapped Cables

	Low Pressure Oil-Filled Cables (LPOF)		High Pressure Oil-Filled Cables (HPOF)		High Pressure Gas-Filled Cables (HPGF)	
Voltage Class	**Up to Um=170 kV**	**Above Um=170 kV**	**Up to Um=170 kV**	**Above Um=170 kV**	**Up to Um=170 kV**	**Above Um=170 kV**
Stress	kV/mm	kV/mm	kV/mm	kV/mm	kV/mm	kV/mm
AC Voltage	**10**	**15**	**10**	**14**	**8**	**10**
Lightning Impulse (Design Criteria)	**85**	**95**	**80**	**90**	**60**	**80**
Switching Impulse	**75**	**85**	**70**	**80**	**50**	**70**



	PAPER	PPL
Dielectric Loss Angle at 90°C	2.4×10^{-3}	1.0×10^{-3}
Relative Permittivity	3.4	2.7
Dielectric Loss Factor at 90°C	0.0084	0.0027
Thermal Resistivity	5.0	5.5



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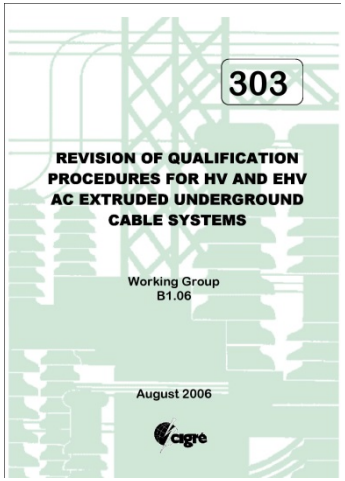
Design Stresses for Extruded Cables

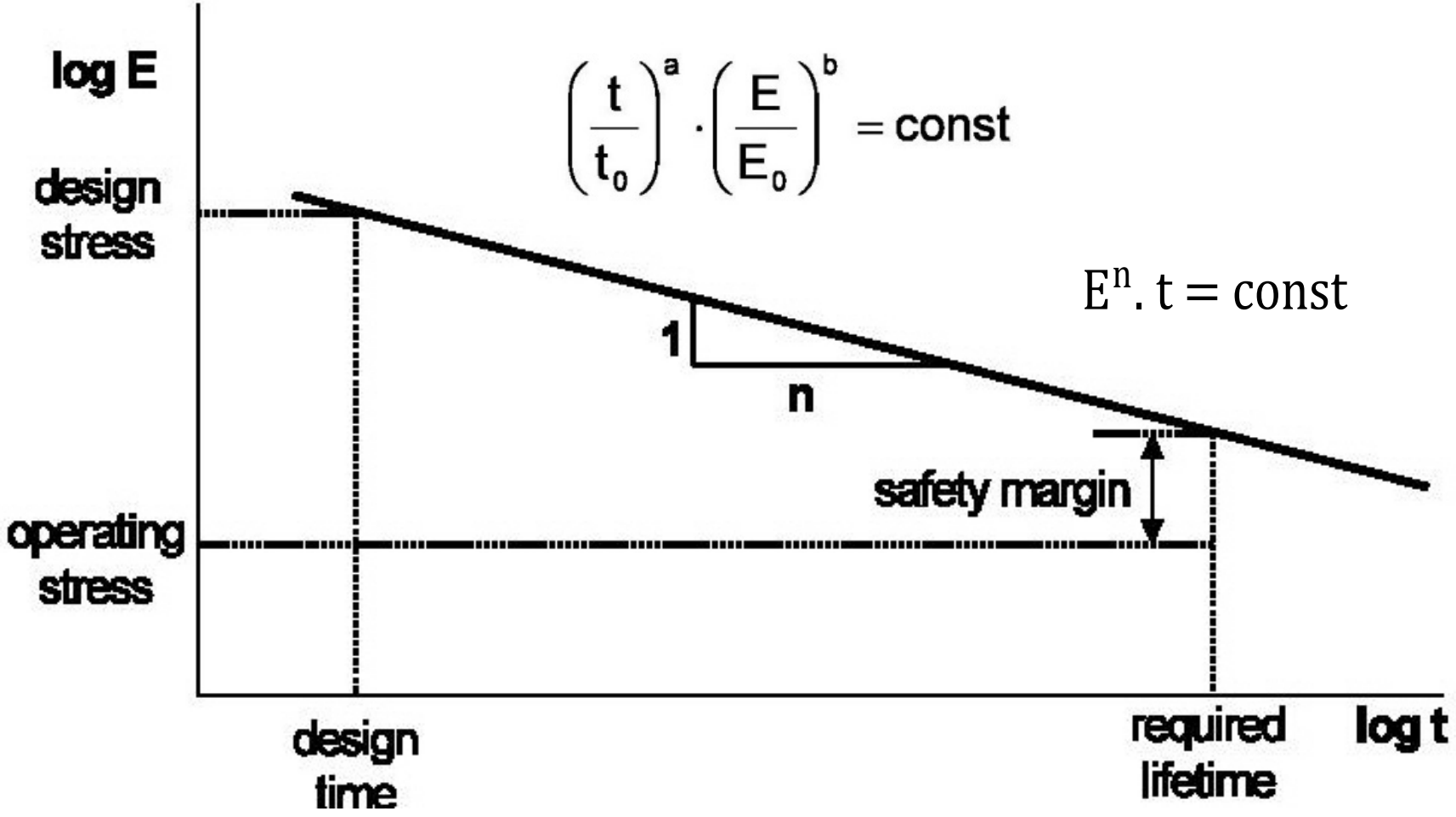
	Polyethylene (PE)			Cross-Linked Polyethylene (XLPE)		
Voltage Class	Um<170 kV	170<Um≤ 300 kV	Um>300 kV	Um<170 kV	170<Um≤ 300 kV	Um>300 kV
Stress	kV/mm	kV/mm	kV/mm	kV/mm	kV/mm	kV/mm
AC Voltage Design Stress	**7**	**11-12**	**16**	**7**	**11-12**	**16**
Lightning Impulse	**70**	**80**	**80**	**70**	**80**	**80**
Switching Impulse	**60**	**70**	**70**	**60**	**70**	**70**

400 kV PE Cable in 1986

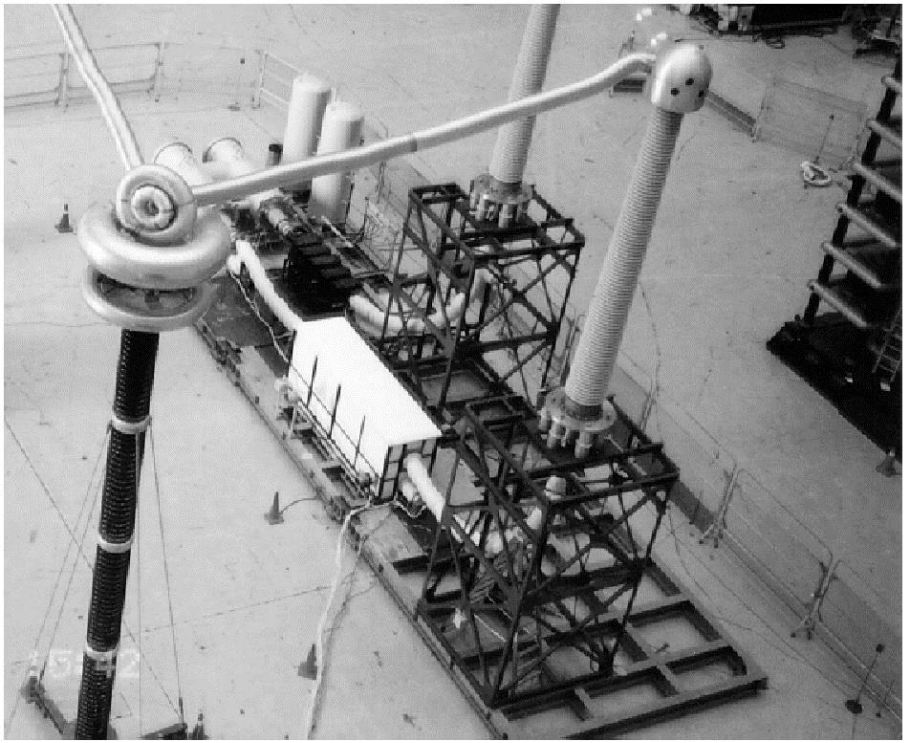
One must take also into account electrical stress Emin at the interface between cable and accessories



Lifetime for Extruded Cables



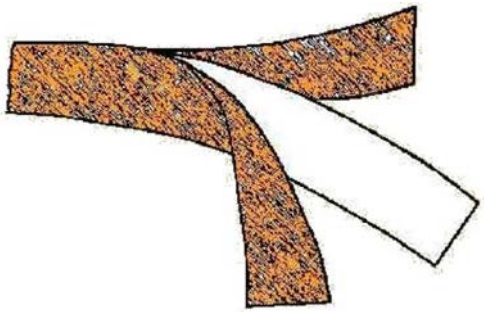
Test at IREQ 800kV SCFFCable (Report 21/22-04 at CIGRE Session 1996)



Item		Description
Oil passage diameter		Nom. 25 mm
Conductor	Size	2000 mm^2
	Shape	Milliken, 9 segments
Insulation	Material	PPLP
	Thickness	Min. 30 mm
Insulation fluid		Branched type DDB
Lead sheath thickness		Nom. 4.7 mm
PE jacket thickness		Nom. 7.0 mm
Overall cable diameter		Approx. 154 mm
Overall cable weight		Approx. 60 kg/m

1100 kV Lapped Cable

IEC/CIGRE UHV Symposium 2007



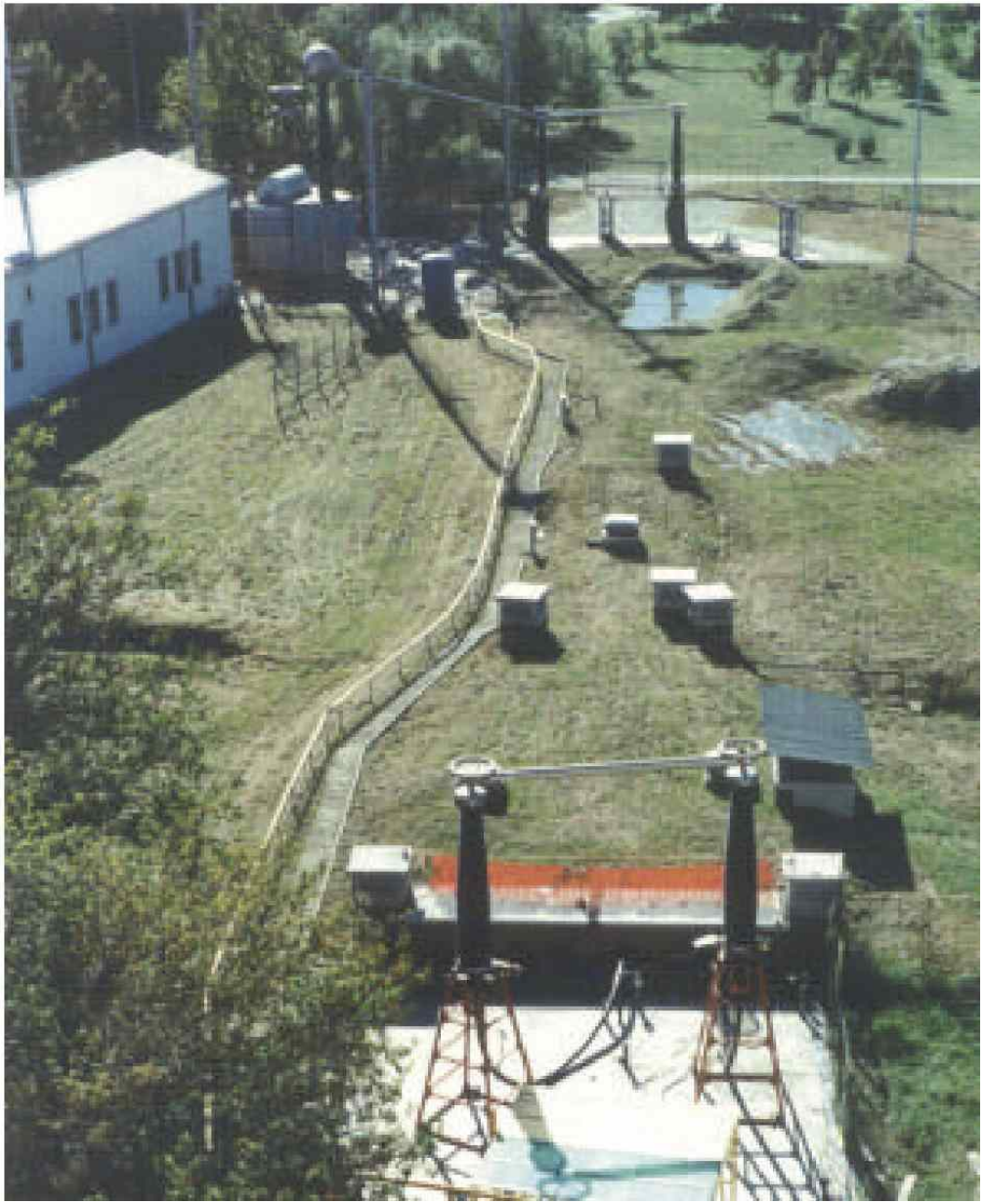
Oil Duct Diameter	24mm	
Conci Conductor	2000mm²	
Insulation thickness	35mm	
Lead sheath bitumen covered		
Hard drawn coper tape reinforcement		
PVC Outersheath		
Overall Diameter	152mm	
Weight	58kg/m	
Operating stress at conductor		30kV/mm
Operating oil pressure		1.4 Mpa
Operating temperature		90°C

Test at Cesi on Extruded Cables Report 21-104 at CIGRE Session 2002

Long term test at 500 kV has proved that Electrical Fields of 15 kV/mm and 8 kV/mm at service voltage (according to IEC 62067) could be adopted. for EHV/UHV

Successful Impulse tests at +_ 2350 kVp

Possibility to design 800 kV Cable with a outer diameter of 170 mm



Experience on extruded Cables example of shipping lengths Report 21-06 at CIGRE Session 2000

Item		Unit	Spec
Nominal Voltage		kV	**500**
Numb of Conductors			**1**
	Area	mm^2	**2500**
	Shape	**Sectoral / Compacted**	
	Outer D	mm	**61.2**
Inner Semicon		mm	**2.5**
Insulation Thickness		mm	**27.0**
Outer D on Insulation		mm	**120.2**
Outer Semicon		mm	**1.0**
Cushion Layer		mm	**3.5**
Aluminum Sheath		mm	**3.3**
Oversheath		mm	**6**
Outer Diameter		mm	**170**
Approximate Weight		Kg/m	**43.5**

Conclusion

- Lapped Cables are available and fully tested at 800 kV and 1100 kV
- PPL technology is offering better solutions with lower losses
- Extruded XLPE cables can be designed at 800 kV with a very small increase of Electrical fields at service voltage.
- Same Shipping lengths as current 500 kV extruded cables are possible.

THANK YOU FOR YOUR ATTENTION!!!

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