Outlines

1. Power cable
2. Pre-molded Joint
3. Outdoor Termination
4. GIS Termination
5. Development test
6. Type Test
7. Future plan
8. Conclusion

1. Power Cable

- ✓ **Conductor : Copper, 2,500mm2, 6 segments**
- Conductor Screen
- ✓ **Insulation Layer (XLPE), 30mm**
- Insulation Screen
- Bedding layer
- ✓ **Corrugated & Seamless Aluminum sheath**
- Anti-corrosion layer : Bitumen
- Extruded PE or PVC over-sheath with graphite

- **Overall Diameter : 172 mm**
- **Weight : Approx.42 kg/m**

➢ Development target performance

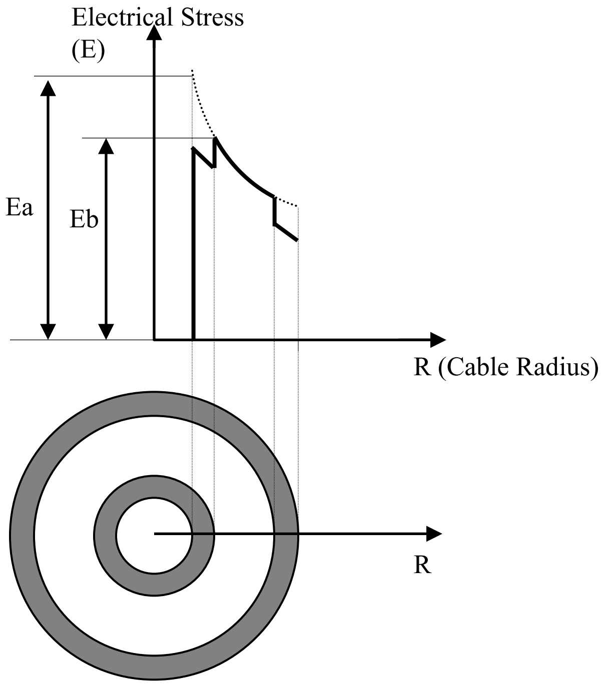
$$t_{AC} = \frac{U_m / \sqrt{3} \times k_1 \times k_2 \times k_3}{E_{L,AC}}$$

Where, Um = the highest r.m.s line to line voltage of the system(550kV)
k1 = degradation coefficient(1.2)
k2 = temperature coefficient(2.3)
k3 = indeterminate fator(1.1)
$E_{L,AC}$ = minimum breakdown strength for AC voltage

$$t_{Imp.} = \frac{BIL \times k_4 \times k_5 \times k_6}{E_{L,Imp.}}$$

Where, BIL = Basic Impulse Insulation Level
k4 = degradation coefficient(1.0)
k5 = temperature coefficient(1.25)
k6 = indeterminate fator(1.1)
$E_{L,Imp}$ = minimum breakdown strength for lightning impulse voltage

➢ Electrical Stress



$$E_{max.} = \frac{2 \times V}{d \times \left(\ln \frac{D}{d} \right)} \quad \left[{kV}/{mm} \right]$$

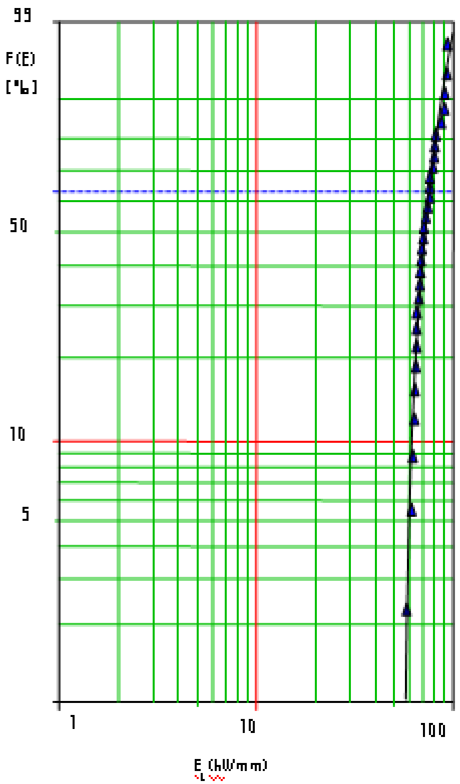
$$E_{min.} = \frac{2 \times V}{D \times \left(\ln \frac{D}{d} \right)} \quad \left[{kV}/{mm} \right]$$

V = Voltage to ground [kV]

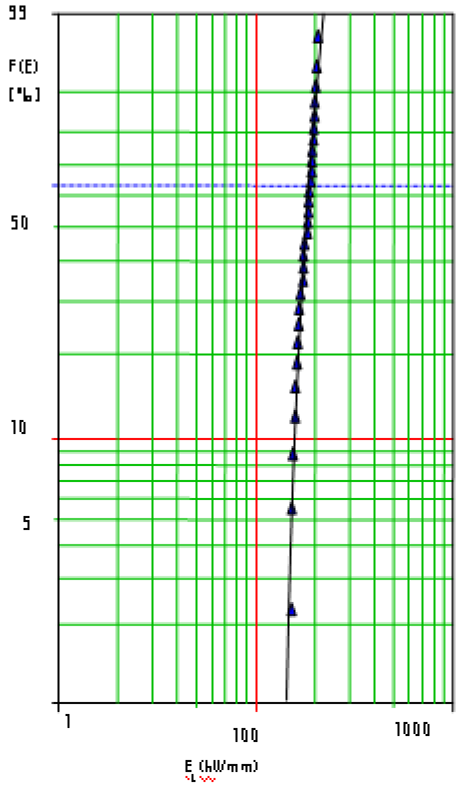
d = Inner diameter of the Insulation

D = Outer diameter of the Insulation

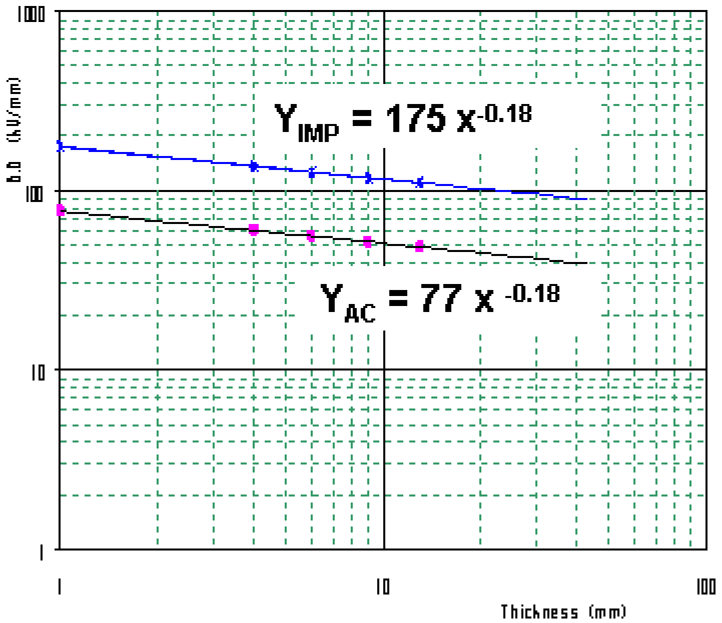
- **E_L,AC**



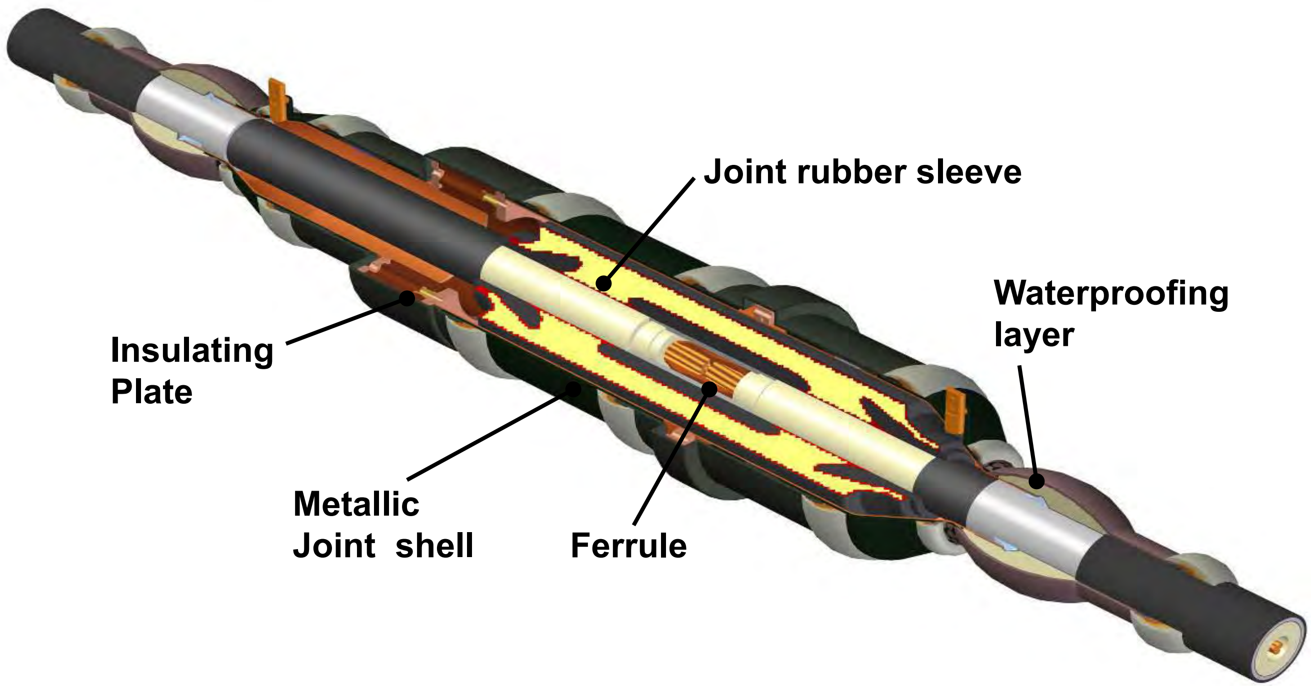
- **E_L, Imp**



- **Effects of insulation thickness**



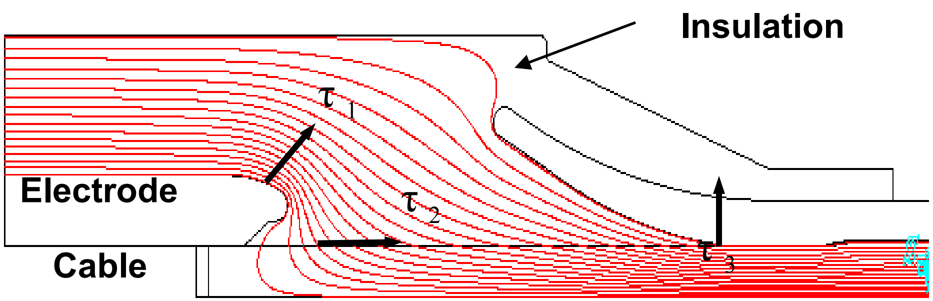
2. Pre-molded Joint



- ▣ Single piece Silicone rubber sleeve
- ▣ Interface pressure is safely maintained with elastic retention of material itself
- ▣ Cost-efficient and optimized design with easy & fast installation

➢ Electrical design

- ❑ Essential to control radial and longitudinal direction of electrical stress.
- ❑ Radial direction of stress depends on the shape of metal or semi-conductive electrode and dielectric strength of insulation material.
- ❑ Longitudinal direction of stress is dependent on the length between deflector/semi-conductive part of stress relief cone and triple junction point and interface pressure.
- ❑ Radial and longitudinal stress determine insulation thickness and joint length, respectively.



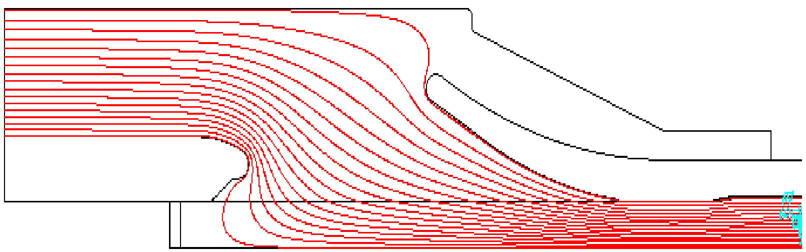
Pre-molded Joint (PMJ)

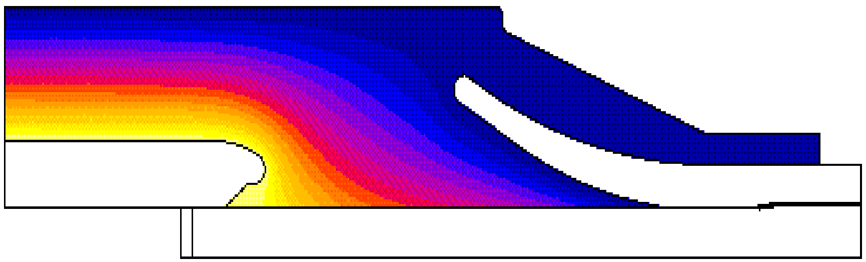
➢ Thermal design

- ❑ Prevention of local hot spots, especially where conductors are connected.
- ❑ Easy emission of heat and avoiding of local heat concentration

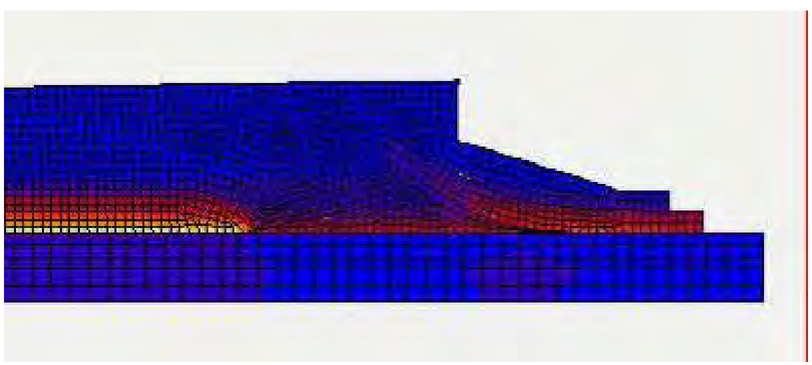
➢ Optimized Electrical & Mechanical designs by Computer Aided simulation

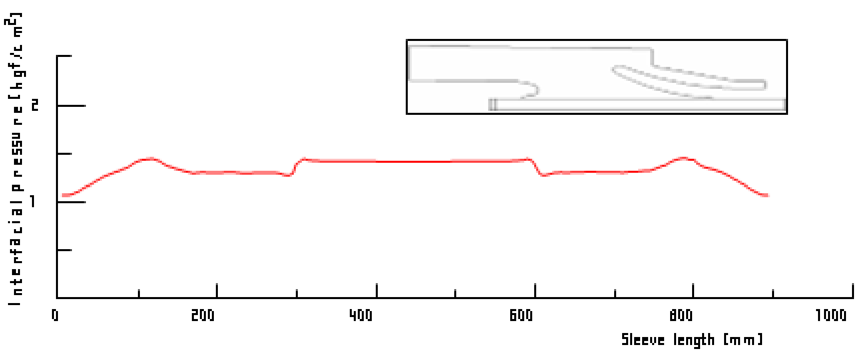
Electric field distribution



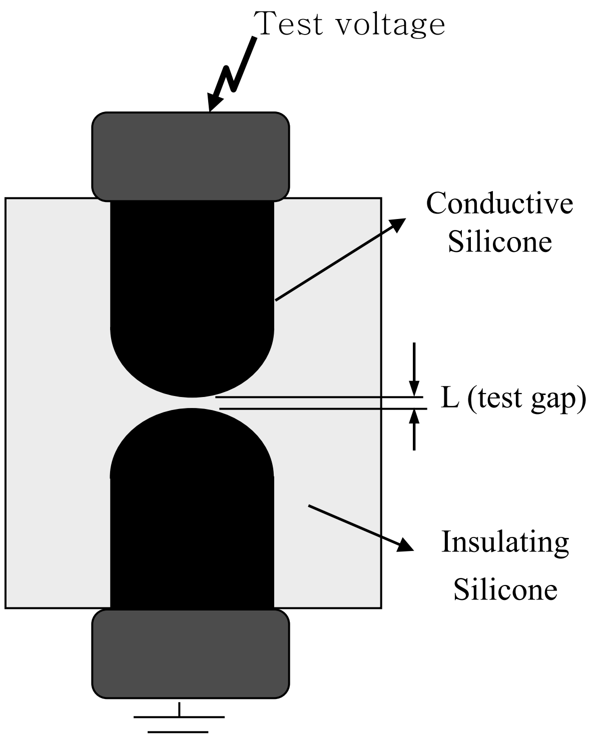


Interface pressure distribution

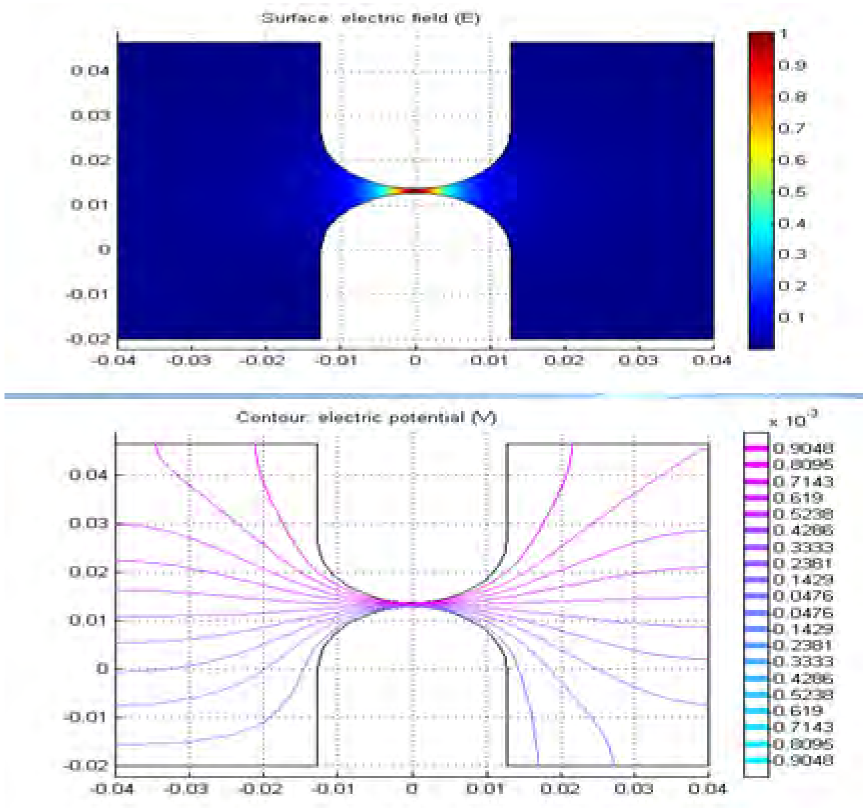




➢ Dielectric strength of Silicone rubber



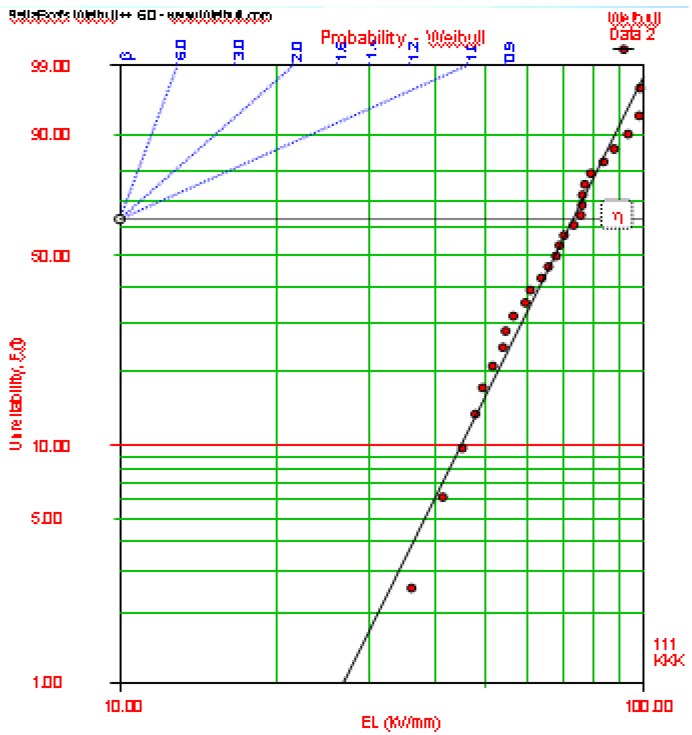
Test Method



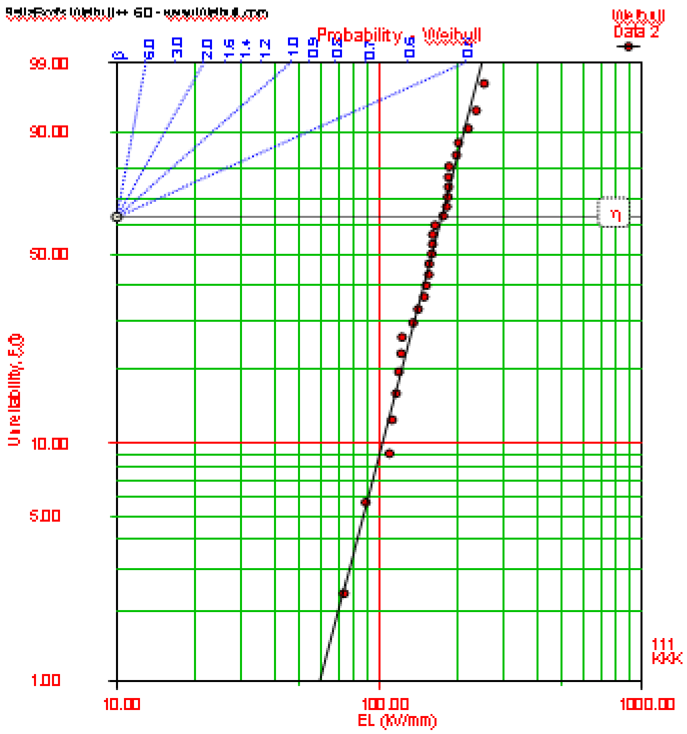
Electric Field

Weibull distribution - Accessory

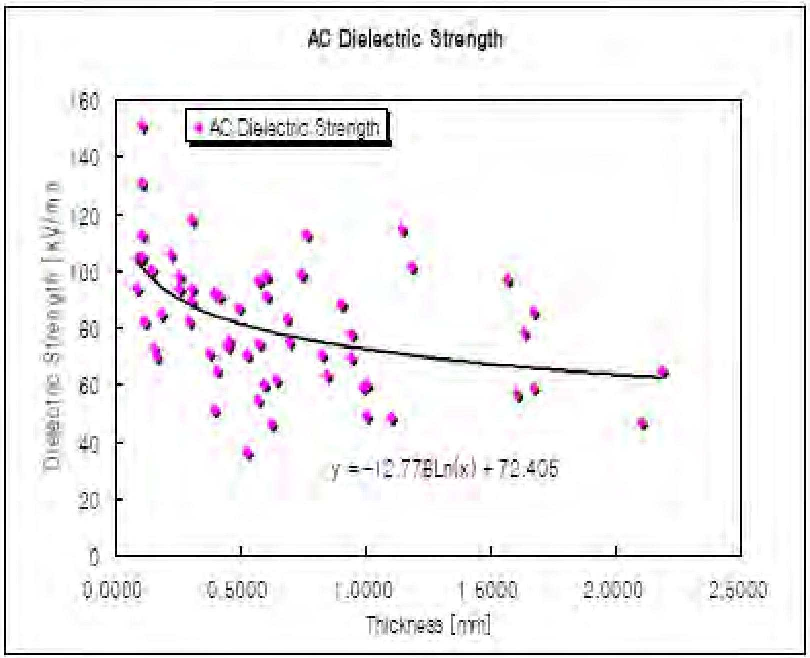
➢ E_L,AC

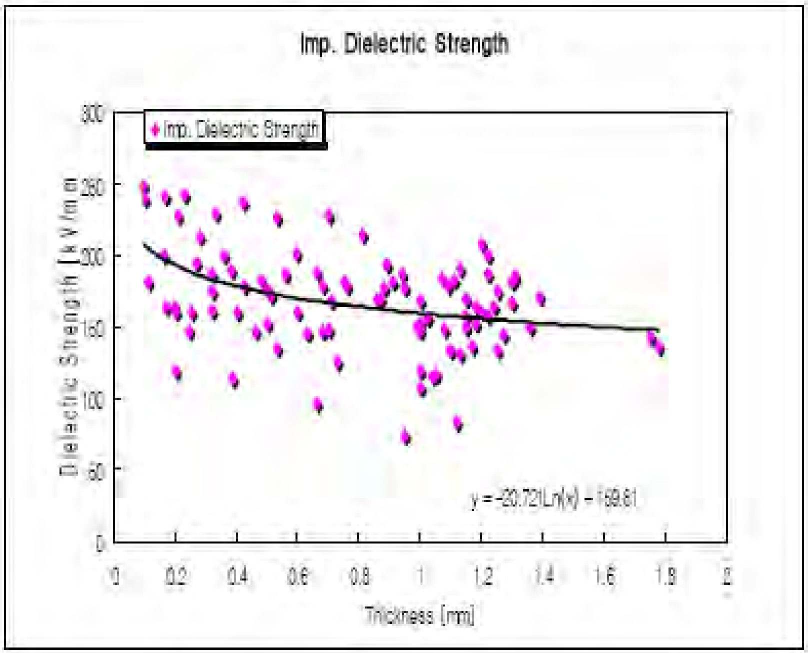


➢ E_L,Imp

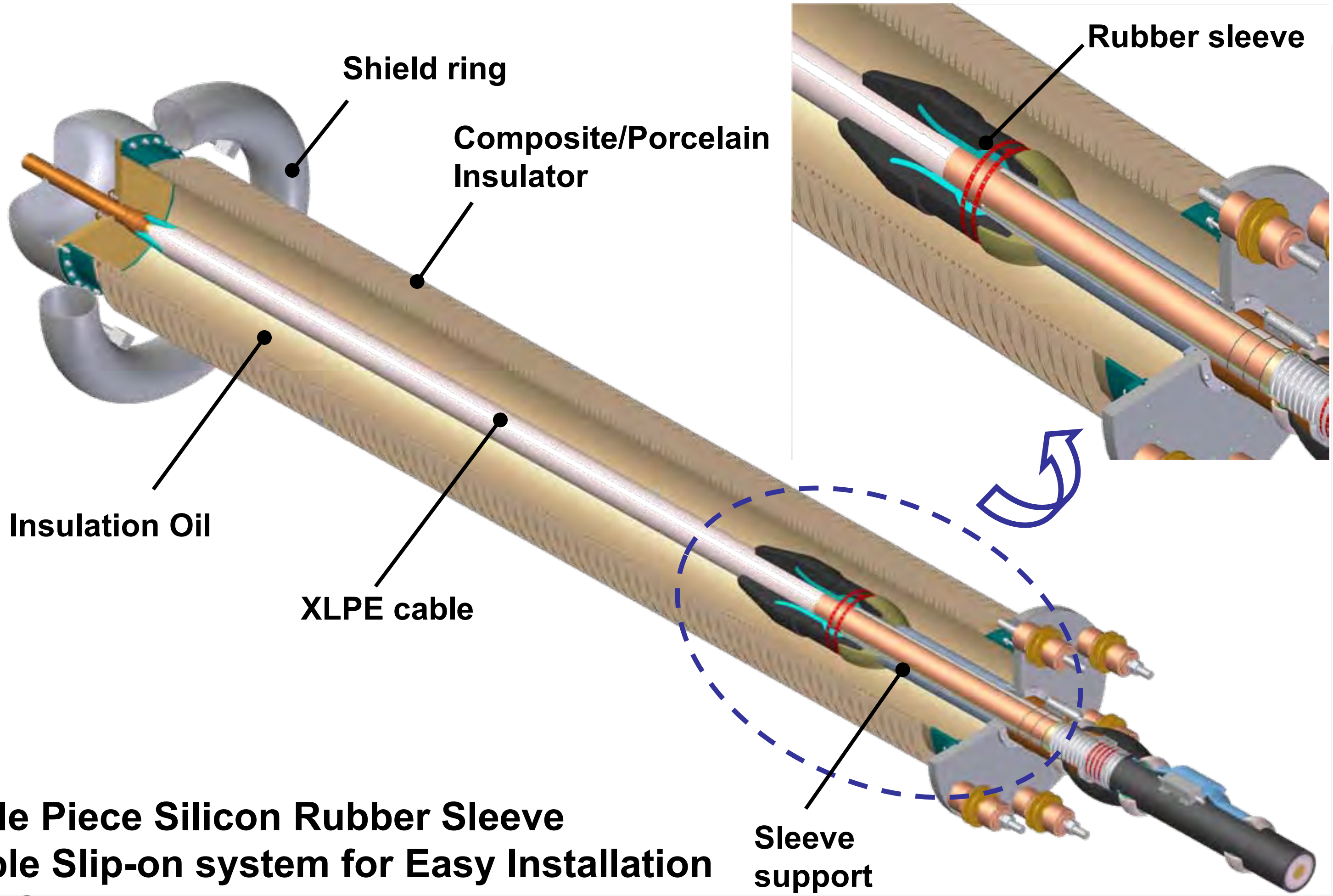


➢ <u>Effects of Silicone rubber thickness</u>



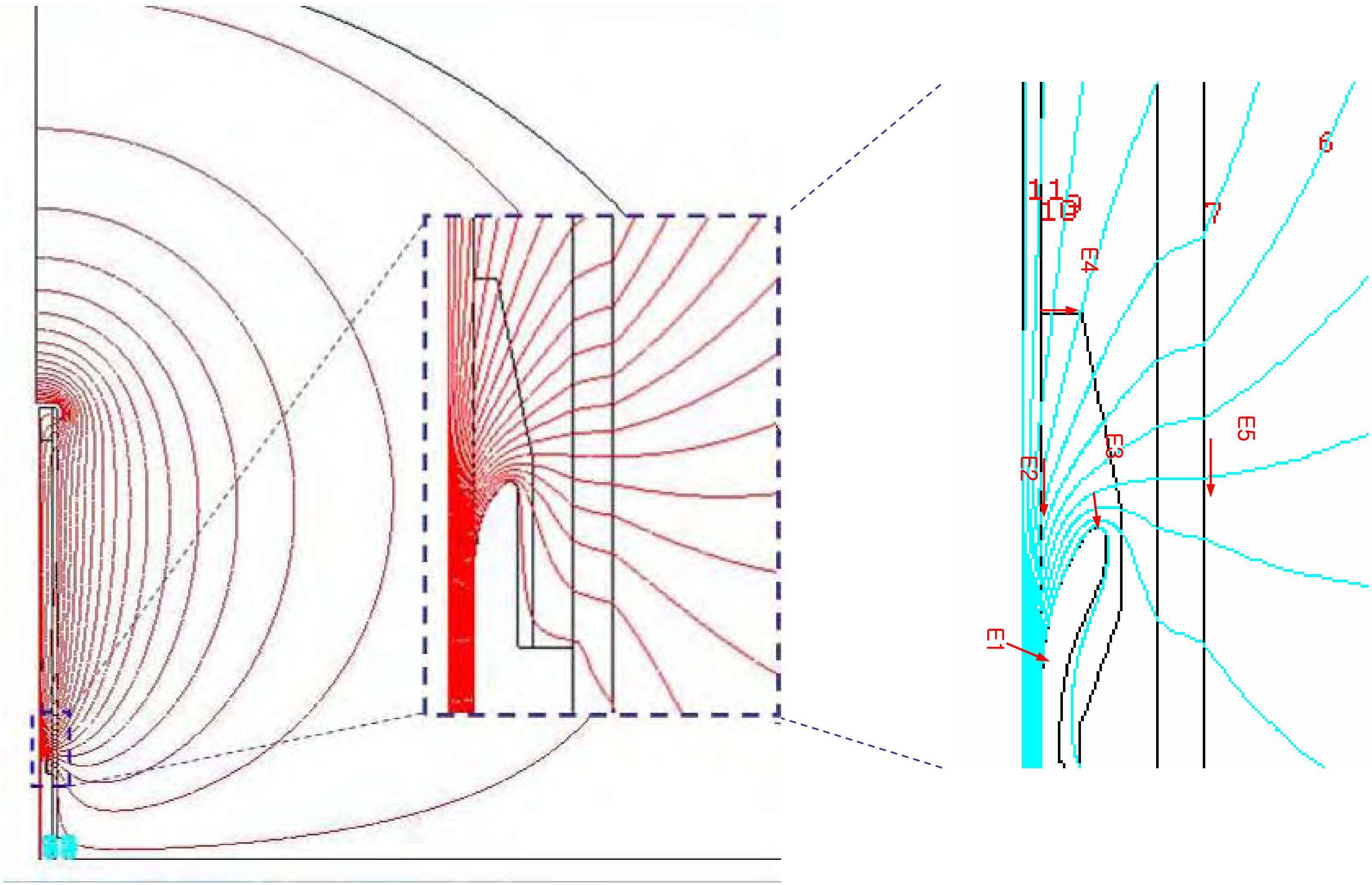


3. Outdoor Termination

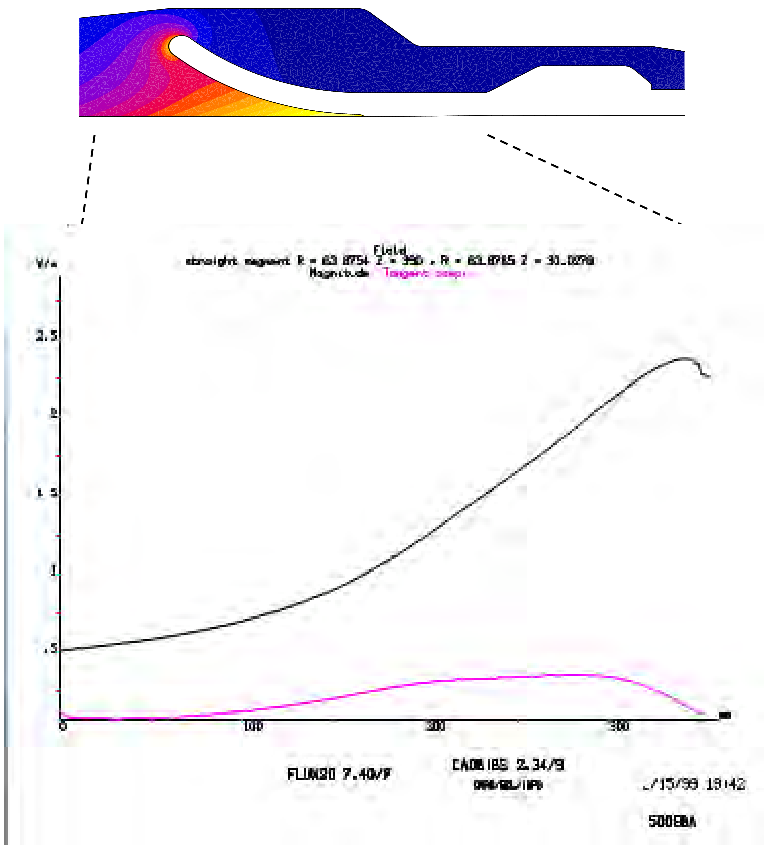


- ▣ Single Piece Silicon Rubber Sleeve
- ▣ Simple Slip-on system for Easy Installation
- ▣ Both Composite and Porcelain Insulators are available

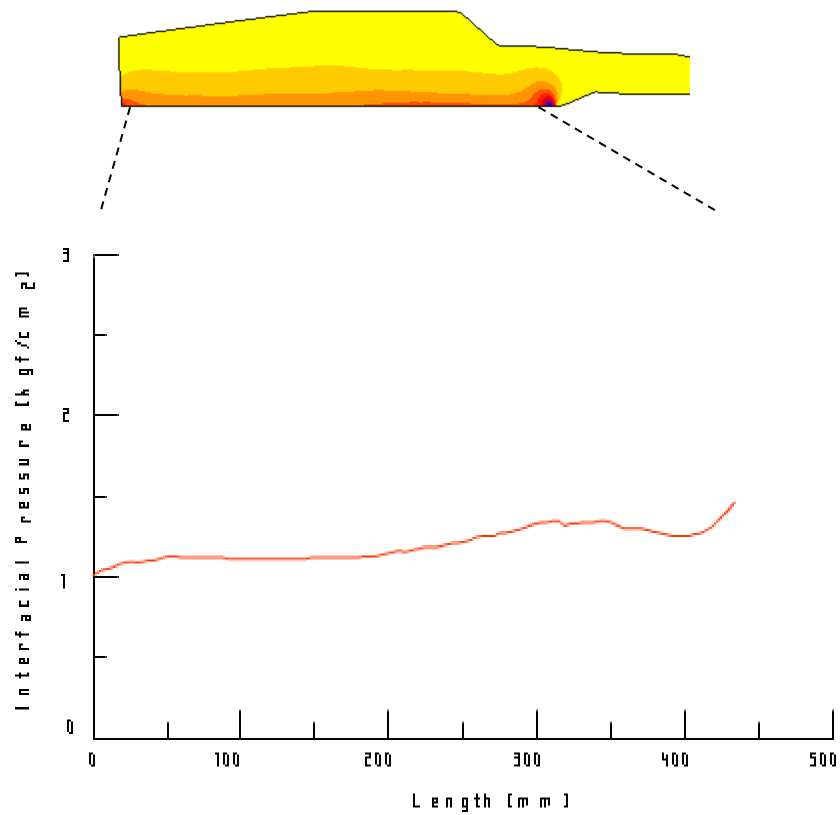
➤ **<u>Optimized Electrical designs by Computer Aided simulation</u>**



➢ Mechanical and Electrical Simulation along interface of cable/rubber



Cable/Sleeve interfacial electrical field



Cable/Sleeve interfacial pressure

➢ Optimized Mechanical designs for Insulator by calculations

▣ Wind velocity

$$q_z = 0.613 K_z K_{zt} V^2 I (N/m^2)$$ --------- Using Bernoulli equation, velocity pressure

Where q_z = Velocity pressure in height z above ground (N/m²)

K_z = Velocity pressure exposure coefficient

K_{zt} = Topographic factor = $(1+K_1K_2K_3)^2$ (Annex 3, Fig.6-2)

V = Window velocity (m/s) = 15.2 m/s

I = Importance factor = 1.15

▣ Tensile force

$$BM = (F_W \times h) + (T \times L) + (F_c \times H) + (F_S \times h)$$ --------- Bending Moment

$$SF = F_W + T + F_C + F_S$$ --------- Shear force

▣ Electromagnetic force

$$F_c = \frac{20.4KL}{S} I^2 \times 10^{-2} (kgf)$$ --------- Short circuit force

▣ Seismic intensity 0.8g

$$F_S = m \times a = \frac{\alpha}{g} \times W$$ --------- Earthquake external force

where, m = Weight of outdoor termination (kg)

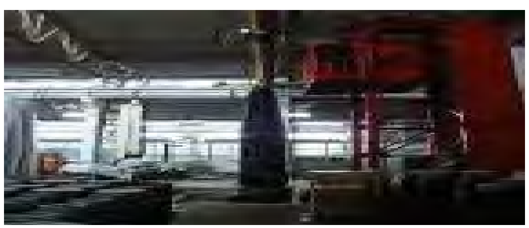
g = Acceleration of gravity = 9.8 (m/s2)

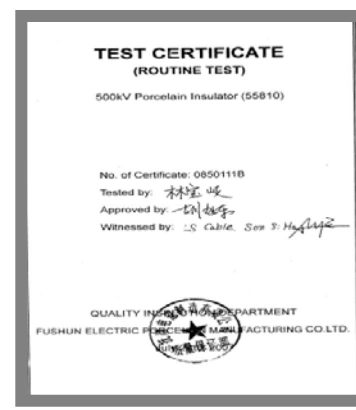
α = Maximum acceleration of seismic wave = 0.8g

Insulator test

➢ Composite Insulator

➢ Porcelain Insulator



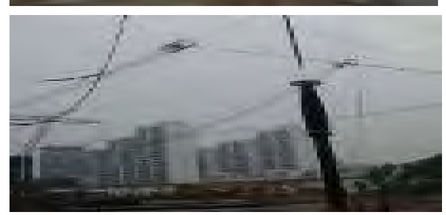


TEST CERTIFICATE
(ROUTINE TEST)

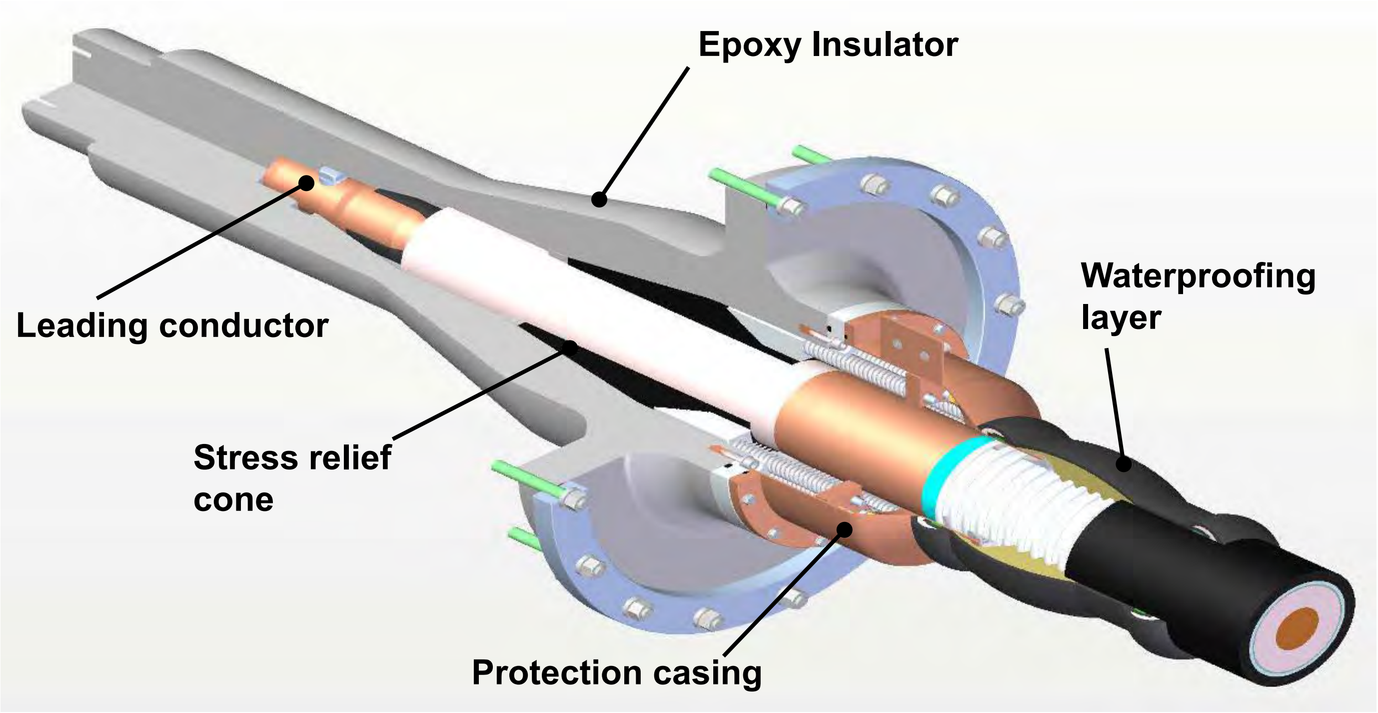
500kV Porcelain Insulator (55810)

No. of Certificate: 0850111B
Tested by:
Approved by:
Witnessed by:

QUALITY INSPECTION DEPARTMENT
FUSHUN ELECTRIC PORCELAIN MANUFACTURING CO.LTD.

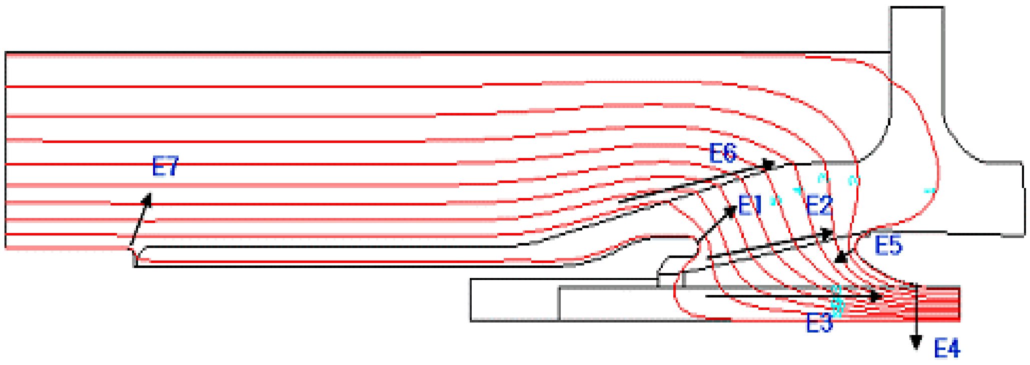


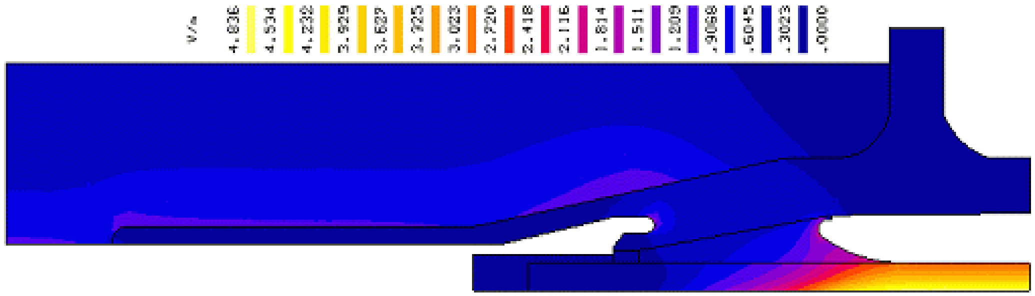
4. GIS Termination

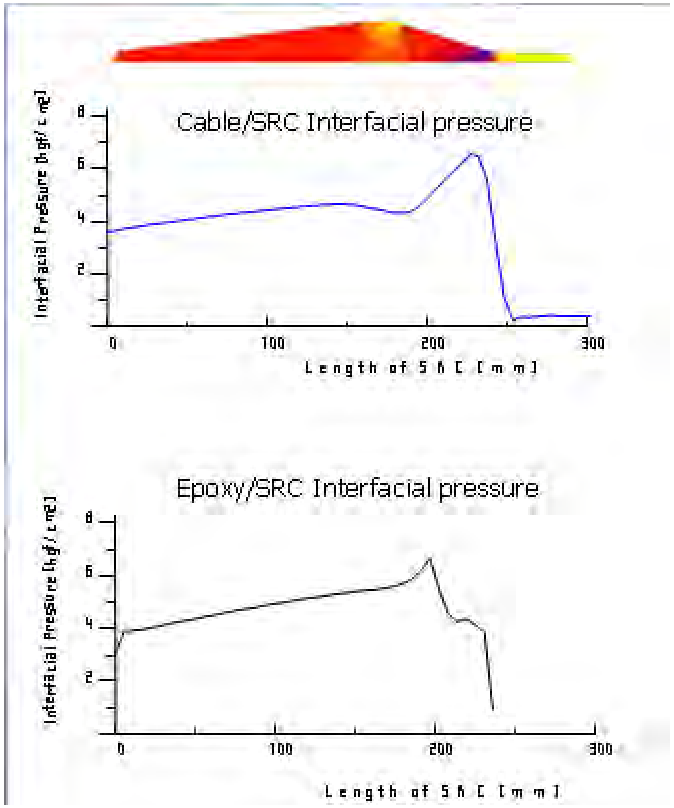


- ▣ Plug-in dry type termination (available normal dry type)
- ▣ Complying with IEC 60859 / IEC62271-209
- ▣ SIR based SRC and epoxy insulator
- ▣ Interface pressure is maintained by mechanical device

➢ Electrical and Mechanical Simulation along interface of cable/SRC



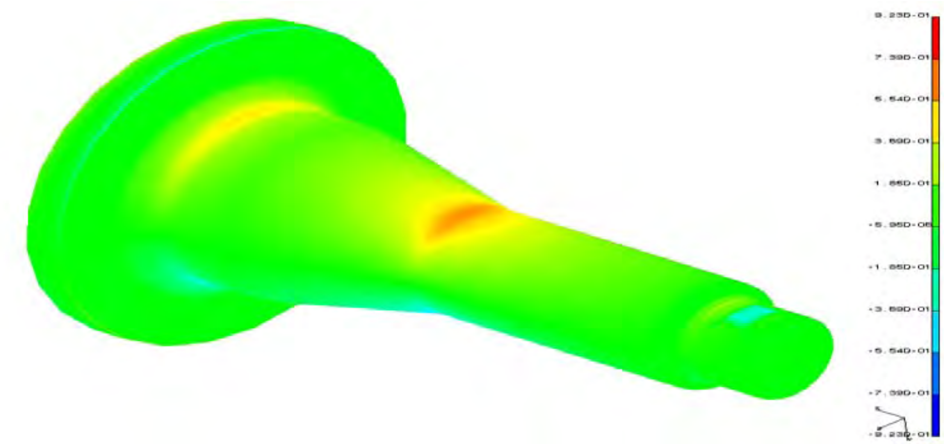


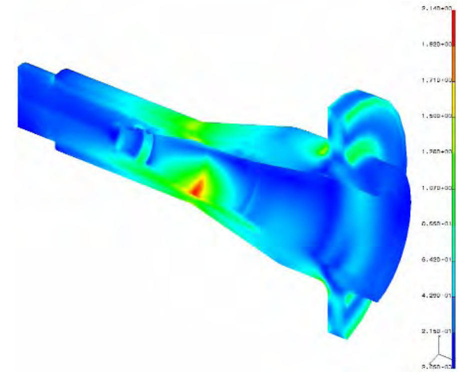


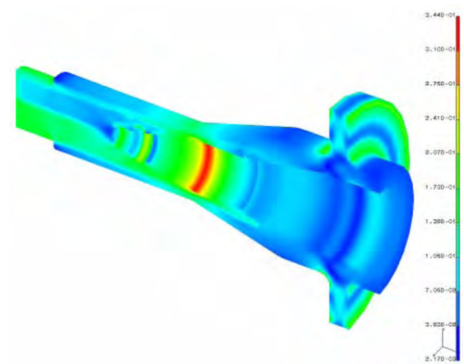
Electrical analysis

Interfacial pressure analysis

➢ Optimized Mechanical and Thermal designs by simulation and tests







Mechanical analysis and Tests

Thermal analysis

5. Development test

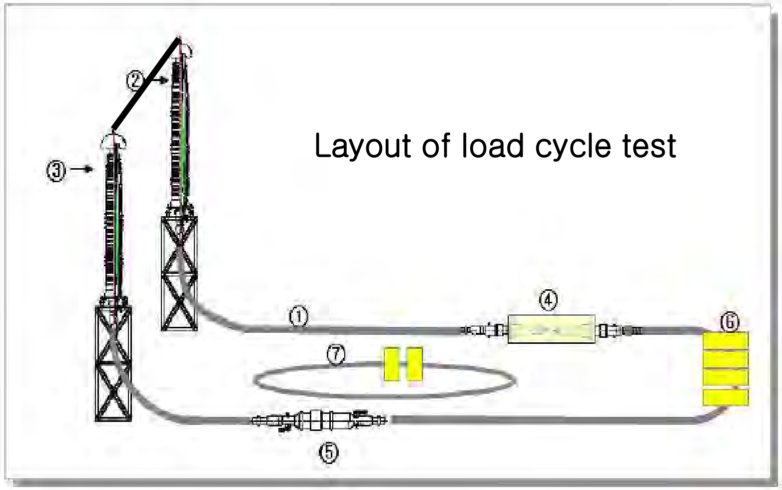
Sample tests have been conducted for proving design performance in accordance with IEC 62067.

➢ <u>Sample tests result</u>

	Test spec.	Sample A	Sample B	Sample C	Sample D
Partial discharge	Below 5pC/435kV	2pC (back noise)	2pC (back noise)	2pC (back noise)	2pC (back noise)
AC voltage test	580kV /1hr	Withstood	Withstood	Withstood	Withstood
AC voltage breakdown test	50kV/1hr step up	1050kV No B.D	930kV F.O	1050kV No B.D	1050kV No B.D
Switching impulse test	±1175kV/10shots	Withstood	Withstood	Withstood	Withstood
Lightning impulse test	±1550kV/10shots	Withstood	Withstood	Withstood	Withstood
Lightning impulse breakdown test	-50kV/3shot step up	-2200kV No B.D	-2050kV F.O	-2200kV No B.D	-2200kV No B.D

Load cycle test

This tests have been undergone the heat cycle test in accordance with IEC 62067.



① 500kV XLPE 2500SQMM Cable,
② Outdoor (Porcelain) Termination (Slip-On Type)
③ Outdoor (Polymer) Termination (Slip-On Type)
④ GIS Termination (Plug-in Dry / Dry type)
⑤ Pre-molded Joint (Sheath breaker type)
⑥ CT ⑦ Dummy cable

Load cycle test

Tests have been proved to possess the performance of 500kV Cable systems.

➢ **Test result**

	Test Spec.	Test Result
Bending test	25(d+D)+5%	O.K.
Partial discharge test	Below 5pC/435kV (room temp.)	2pC (back noise)
Tanδ measurement	0.1%/290kV, 95~100°C	0.06%
Heating cycle	580kV/30cycles Conductor temp. 95°C : 20days 105°C : 10days 8hr On, 16hr Off	No failure
Partial discharge test	Below 5pC/435kV (high temp.)	2pC (back noise)
Switching impulse test	±1175kV/10shots, 95~100°C	Withstood
Lightning impulse test	±1550kV/10shots, 95~100°C	Withstood
AC Voltage test	580kV/15min	Withstood
Disassemble check	Dimension and appearance	No sign of deterioration

6. Type test

3rd Party test

Type test have been successfully completed 500kV XLPE system in accordance with IEC 62067 witnessed by KEMA & WUHAN Lab.

➢ Type test result

	Test Spec.	Test Result
Bending test	25(d+D)+5%	O.K.
Partial discharge test	Below 5pC/435kV (room temp.)	2pC (back noise)
Tanδ measurement	0.1% /290kV, 95~100°C	0.055%
Heating cycle	580kV/20cycles Conductor temp. 95~100°C : 20days 8hr On, 16hr Off	No failure
Partial discharge test	Below 5pC/435kV (high temp.)	2pC (back noise)
Switching impulse test	±1175kV/10shots, 95~100°C	Withstood
Lightning impulse test	±1550kV/10shots, 95~100°C	Withstood
AC Voltage test	580kV/15min	Withstood
Disassemble check	Dimension and appearance	No sign of deterioration

① 500kV XLPE 2500SQMM Cable,
② Outdoor (Porcelain) Termination (Slip-On Type)
③ Outdoor (Polymer) Termination (Slip-On Type)
④ GIS Termination (Plug-in Dry type)
⑤ GIS Termination (Dry type)
⑥ Pre-mold Joint (Sheath breaker type)

Examination of specimen

➢ Cable Parts

➢ Accessory Parts

The official Type test reports will be soon issued certified by KEMA & WUHAN Lab

KEMA

KEMA T&D TESTING

SUMMARY No 70950250-TDT 09-@A

CLIENT	LS Cable Ltd 190, Gongdan-dong, Gumi-si, Gyeongbuk 730-706, Korea
SUMMARY OF REPORT No.	70950250-TDT 09-@A
MATERIAL DATA	500 kV High voltage cable and accessories

For the data of the cable and the accessories reference is made to page 2

DATE AND PLACE OF TESTS	September 22 till November 25, 2009 Gumi, Korea

REQUIREMENTS
The requirements of Chinese standard GB/T 22078.1. (2008) and the standards IEC 62067 (2001-10) and IEC 60229 (1982)

TEST PROGRAMME
The programme was specified by the client and comprised the type tests mentioned in standards GB 22078.1 (2008), IEC 62067 (2001-10) and IEC 60229 (1982).
For the programme reference is made to page 3 and 4.

SUMMARY AND CONCLUSION
The results obtained relate only to the work ordered and the material inspected.
For a detailed description of the material and the test results reference is made to test report 70950250-TDT 09-@A.
The tests were passed successfully.

KEMA Nederland B.V.

J.W. [illegible]
KEMA T&D Power

This summary consists of
4 pages
0 annexes

Arnhem, November 25, 2009

KEMA

MATERIAL DATA

A EXTRUDED SOLID DIELECTRIC INSULATED POWER CABLE

Type	XLPE 1x2500 mm^2 Cu 290/500 (550) kV
Manufacturer	LS Cable Ltd, Gumi, Korea

B OUTDOOR SEALING-END WITH PORCELAIN INSULATOR FOR POLYMERIC EXTRUDED POWER CABLE

Manufacturer:	LS Cable Ltd, Gumi, Korea
Drawing number	UEMA500Q006

C OUTDOOR SEALING-END WITH COMPOSITE INSULATOR FOR POLYMERIC EXTRUDED POWER CABLE

Manufacturer:	LS Cable Ltd, Gumi, Korea
Drawing number	UEMA500Q002

D METAL-ENCLOSED TERMINATION FOR POLYMERIC EXTRUDED POWER CABLE

Manufacturer:	LS Cable Ltd, Gumi, Korea
Type	Prefabricated dry type for Gas Insulated Switchgear
Drawing number	UEPG500Q001

E METAL-ENCLOSED TERMINATION FOR POLYMERIC EXTRUDED POWER CABLE

Manufacturer:	LS Cable Ltd, Gumi, Korea
Type	Prefabricated dry and plug-in type for Gas Insulated Switchgear
Drawing number	UEPG500Q003

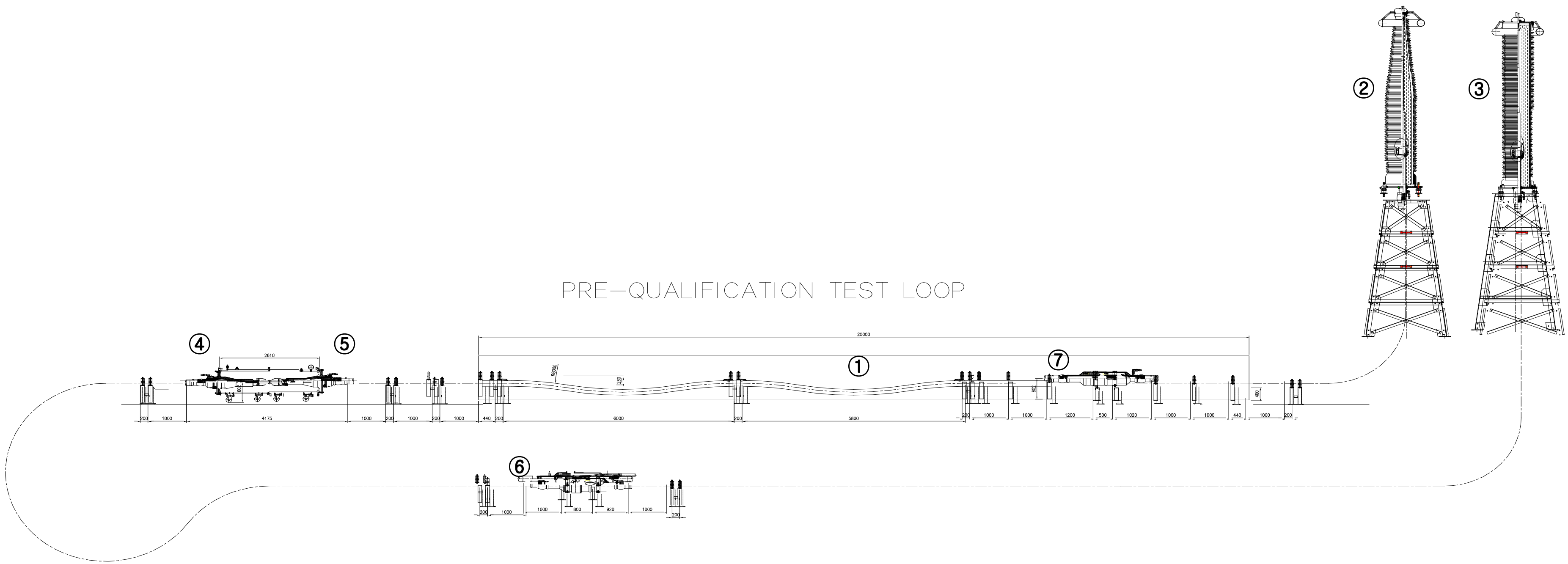
F INSULATING JOINT FOR POLYMERIC EXTRUDED POWER CABLE

Manufacturer:	LS Cable Ltd, Gumi, Korea
Type	Premoulded
Drawing number	UEMK500Q003

7. Future plan

Prequalification test

Prequalification test of 500kV XLPE system will be started May.`10 at 3rd party Laboratory in accordance with IEC 62067

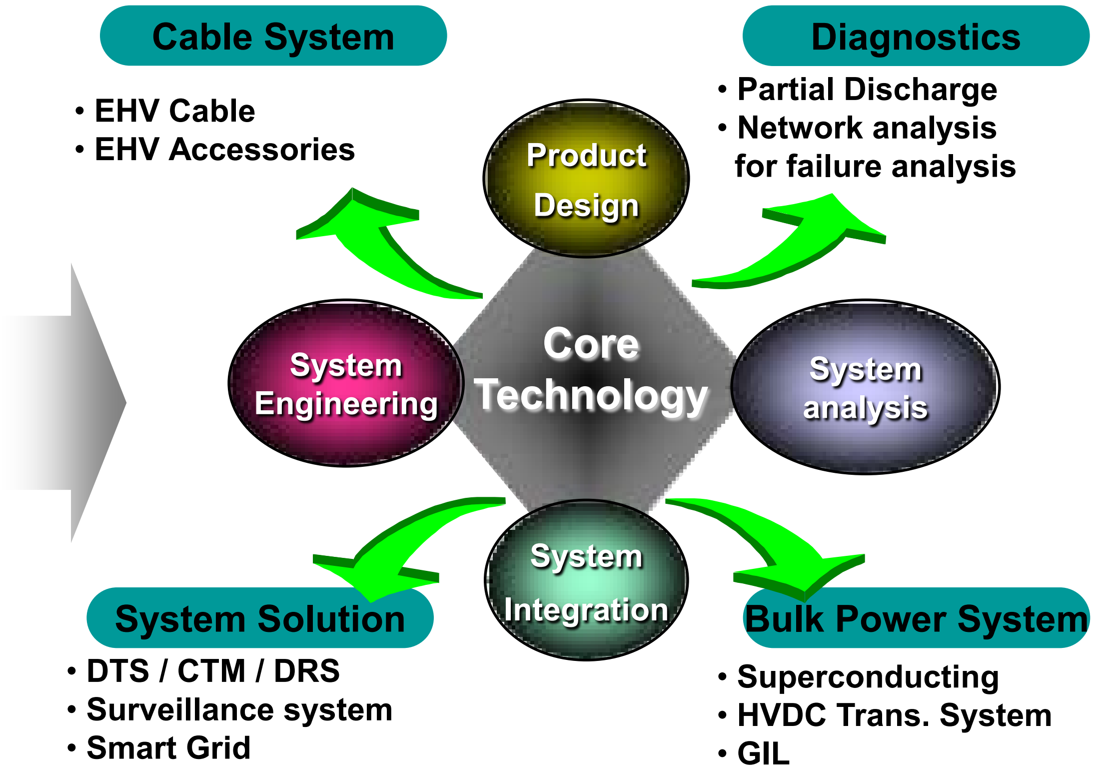


① 500kV XLPE 2500SQMM Cable,
② Outdoor (Porcelain) Termination (Slip-On Type)
③ Outdoor (Polymer) Termination (Slip-On Type)
④ GIS Termination (Plug-in Dry type)
⑤ GIS Termination (Dry type)
⑥ Pre-molded Joint (Sheath breaker type)
⑦ Pre-molded Joint (Non Sheath breaker type)

8. Conculsion

LS Cable have already completed Type & PQ tests for 400kV EHV system according to IEC 62067. Since 2005, all of our products supplied to domestic and overseas market have been successfully energized and operated without any problem.
Through this result of 500kV system development, we believe it will be milestone of the new technology not only for EHV transmission line but also for total solution of energy cable application business.

The Development of 500kV EHV System



Thank You !