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400 kV 2500mm² XLPE CABLE SYSTEM PREQUALIFICATION AND TYPE TEST FOR MIDDLE EAST ENVIRONMENT

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ABSTRACT

The IEC 62067 prequalification test is a test made before supplying on a general commercial basis a type of cable system.
In the very case of the 400kV interconnection of the Abu Dhabi Islands, the cable system was subjected to the prequalification test and a type test in view of its use for this contract.
The authors describe the cable system components and how they are designed to match a warm and wet environment.
They discuss the AC resistance of the conductor.
They describe the test installation conditions and how they replicate the middle east environment characteristics.
They report about the completion of the type test and the prequalification test.
They describe the 400kV interconnection of the Abu Dhabi Islands project that consists of 2 circuits of 420kV cable systems (Nexans being responsible for one circuit), involving 37.5 km cable, 75 joints and 12 GIS.

KEYWORDS

Qualification tests – IEC 62067 - EHV cables– AC resistance – 420 kV cable systems.

INTRODUCTION

The IEC 62067 prequalification test is a test made before supplying on a general commercial basis a type of cable system [1].
In the very case of the 400kV interconnection of the Abu Dhabi Islands, the cable system was subjected to both the type test and the prequalification test in view of its use for this project.
Moreover, the AC resistance of the 2500mm² copper conductor with insulated wires was measured.
During the prequalification test, the installation conditions were designed to match a wet environment to replicate the middle east environment characteristics.
The authors report about the completion of the type test and the prequalification test and describe the 400kV interconnection of the Abu Dhabi Islands project that consists of 2 circuits of 420kV cable systems (Nexans being responsible for one circuit), involving 37.5 km of cable, 75 joints and 12 GIS terminations.

DESCRIPTION OF THE SYSTEM UNDER TEST

The test concerns a 230/400(420) kV cable system with:

- A 2500 mm² Milliken Copper cable with insulated wires, XLPE insulated 230/400(420) kV,
- A 230/400(420) kV outdoor oil filled composite termination with an EPDM stress cone,
- A 230/400(420) kV oil filled GIS termination with an EPDM stress cone,
- A 230/400(420) kV one-piece premoulded cross bonding EPDM joint, with integrated partial discharge sensor
- A 230/400(420) kV one-piece premoulded straight EPDM joint, with integrated partial discharge sensor.

Cable

The cable is composed of :

- A 2500 mm² Milliken water-tight conductor with enamelled copper wires,
- Semi-conducting tapes on conductor,
- XLPE insulation system : conductor semi-conducting screen - insulation - insulation semi-conducting screen,
- A copper wire screen between swelling semi-conducting tapes,
    - A water-swellable semi-conducting bedding,
    - A helical copper wire screen,
    - A water-swellable semi-conducting bedding,
- A lead alloy sheath,
- A HDPE sheath covered by an extruded semi-conducting layer.

Figure 1 : Design of the 400 kV cable

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Accessories

400 kV outdoor oil filled composite termination

The composite termination consists of :

- An EPDM stress cone,
- A gasket,
- A screen connection system,
- A sheath shrinkage retention system,
- An epoxy/glass fibre composite tube with silicone sheds,
- An anti-explosion device.

Figure 2 Oudoor composite termination

400 kV oil filled GIS termination

The GIS termination is composed of :

- An EPDM stress cone,
- A gasket,
- A screen connection system and a sheath shrinkage retention system,
- A epoxy/glass fibre composite tube with silicone sheds,
- An epoxy insulator in accordance with the technical specification IEC 60859 table 2,

Figure 3 : GIS termination and outdoor bushing

Premoulded straight joint

The joint consists of :

- A crimped/welded copper connection,
- An electrode,
- A one piece premoulded EPDM body,
- A screen connection system and a sheath shrinkage retention system,
- A water-tight copper sleeve covered by a HDPE sheath,
- A silicone gel filling,
- An earthing cable,
- A capacitive partial discharge sensor,
- A steel supporting frame.

Premoulded cross bonding joint

It is designed as follows :

- A crimped/welded copper connection,
- An electrode,
- A premoulded cross bonding EPDM body, i.e including a shield break,
- A screen connection system and a sheath shrinkage retention system,
- A water-tight copper sleeve covered by a HDPE sheath,
- A silicone gel filling,
- A screen connection coaxial cable,
- A capacitive connection coaxial cable,
- A capacitive partial discharge sensor,
- A steel supporting frame,

Figure 4 : Cross bonding joint with embedded capacitive PD sensor

Test arrangements conditions

The various installation conditions of the loops described on the following diagrams are in accordance with :

- The international standard IEC 62067 for both type and prequalification tests,

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- The contractual installation conditions requested by the client for the Abu Dhabi project and which are replicated in the frame of the prequalification test.

Conditions for type test set up

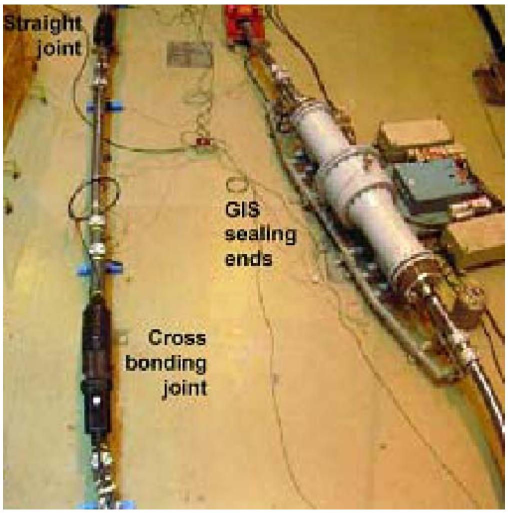

Figure 5 :Type test loop

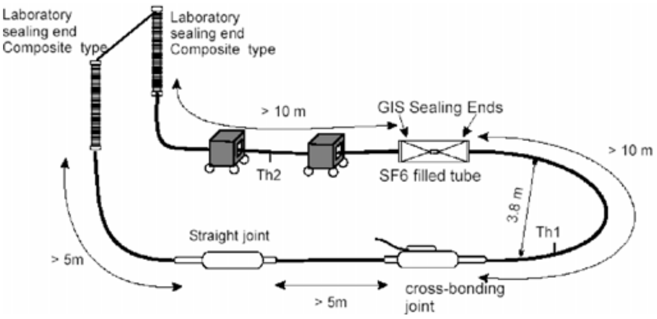

Figure 6 : Type test loop design

Distances between accessories

- >10 m between laboratory sealing end and GIS sealing ends,
- >10 m between GIS sealing end and cross bounding joint,
- >5 m between cross bounding joint and straight one,
- >5 m between straight joint and laboratory sealing end,
- The maximum U turn diameter is 3.80 m.

Conditions for prequalification test set up :

Figure 7 : Prequalification test loop

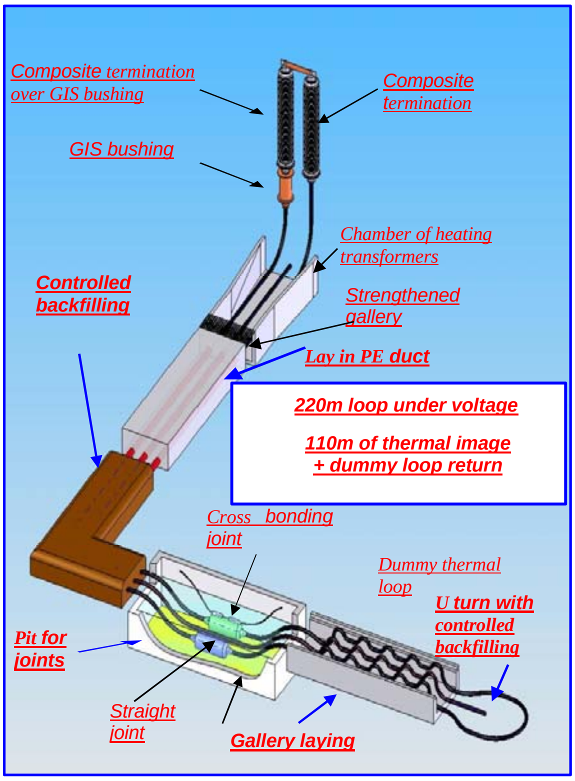

Figure 8 : Long term test loop design

Outdoor and GIS terminations

Both terminations are erected on a metallic structure fixed on a concrete slab.

The height of the structure is determined to comply with the bending radius of the cable and with the termination installation conditions.

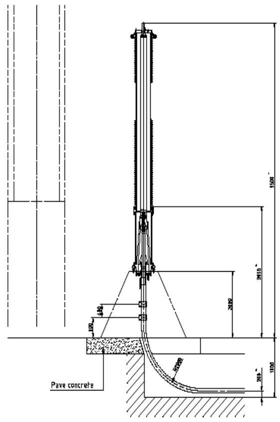

Figure 9 : GIS termination and outdoor bushing installation

Laying in ducts

The cables are installed in PE ducts 210/250 mm in diameter and 22 m long. After pulling the cable, the three ducts were sealed and filled with Bentonite®.

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Figure 10 : Ducts area before bentonite® filling

Controlled backfill

The controlled backfill area is 20 m long. The gap between each cable is 700 mm

The backfilling height above the cables is 1.20 m.

Figure 11 : Controlled backfill area before backfilling

Joints installation conditions

Figure 12 : Joint bay during salted water filling

The joint bay is 8 m (L) x 2.5 m (l) x 2.2 (h). It is made of concrete. The openings for the cables are plugged with plaster around each cable. The joints are installed on steel frames ; the cables are held on each side of the frame by two clamps. The joint bay is filled up to 10 cm above the highest point of the joints with a mixture of water, sand (granularity 0.2) and sea salt, with a concentration of 4 g/l. A tarpaulin cover is laid on the filling to enable the backfilling of the chamber with 20 m^3 of earth. The water level in the joint bay is adjusted every month.

Figure 13 : Joint bay filled with sand saturated with salted water

Gallery

The gallery is 22 m (L) x 2 m (l) x 1.45 m (h). It is made of concrete. A “snaking” area is arranged in the gallery by means of 4 cable holders spaced out 5 m from each other and fixed on the walls of the gallery.

To keep the spacing between the cables, free intermediate supports are placed 2.5 m from the snaking supports.

The gallery is closed by a wooden roof, covered and backfilled with earth.

Figure 14 : Gallery with vertical cable snaking

Loop U turn

The cable is installed in a trench to form a U turn of maximum 4.4 m diameter, covered with controlled backfill.

Figure 15 : loop U turn before backfilling

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TESTS SEQUENCES

Type test sequence

List of non electrical tests

- checking of cable construction and dimensions
- measurement of insulation purity
- measurement of moisture content in extruded insulation and screens
- hot set test on XLPE insulation
- shrinkage test on XLPE insulation and on HDPE outer covering
- measurement of the resistivity of semi-conducting screens
- measurement of screen protusions
- determination of the mechanical properties of the insulation and the non metallic sheath
- ageing tests on pieces of completed cable to check compatibility of materials – insulation and non metallic sheath
- impact test on metallic sheath
- water penetration test
- measurement of crosslinking by-product concentration in XLPE cables
- XLPE material characterization
- pressure test at high temperature on oversheath
- measurement of carbon black content of HDPE oversheath

List of electrical tests

- bending test of cable
- checking of insulation thickness
- partial discharge test at ambient and high temperature
- measurement of tangent delta
- partial discharge test at ambient and high temperature
- heating cycle voltage test
- partial discharge test after 5, 10, 15 and 20 cycles at ambient temperature
- partial discharge test at high temp
- switching and lightning Impulse voltage test (2h at 95/100°C conductor temperature)
- AC voltage test
- partial discharge test at ambient and high temperature
- test of outer protection for buried joints
- dismantling and examination
- AC resistance of the conductor.

Type test results

All non electrical and electrical type tests were carried out successfully in accordance with the relevant IEC Publication 62067 – first edition, 2001-10 and additional requirements according to the Technical Specifications of the ABU DHABI client contract.

AC conductor resistance

The cable samples are 12m long. All conductor wires are connected together at each end, the distance between voltage probes is 8m.

The a.c. resistance for 90 °C was measured to be 9.45 $\pm$ 0.30 µOhm/m.

The skin effect is then **1.065.**

Prequalification test sequence

These tests are performed in accordance with IEC 62067 §13.2 :

- Checking of the insulation thickness of the cable
- Heating cycle voltage test
- Lightning impulse voltage test on cable samples
- Examination of the cable system after tests

prequalification test results

A heating cycle voltage test was carried out on the cable system according to the requirements of the IEC 62067 standard. The specified and recorded values are given in the table 1 below.

The applied voltage is 400 kV.

Test conditions :	Standard IEC 62067 § 13.2.3	Recorded value		
Conductor temperature	90°C – 95°C	Total	Between 90.0°C and 95,0 °C	Between 91.1°C and 93,9 °C
Heating time	$\geq$ 8 hours		$\geq$ 8 hours	$\geq$ 8 hours
Temperature holding time	$\geq$ 2 hours		$\geq$ 2 hours	$\geq$ 2 hours
Cooling time	$\geq$ 16 hours		$\geq$ 16 hours	$\geq$ 16 hours
Number of cycles	$\geq$ 180	265	187	180
Voltage	1,7Uo,(374kv)	400 kV		
Hours under voltage	$\geq$ 8760 hours	8776 hours		

Table 1 : Prequalification voltage test under load cycles result

The typical temperature profile of a cycle is given on the following graph :

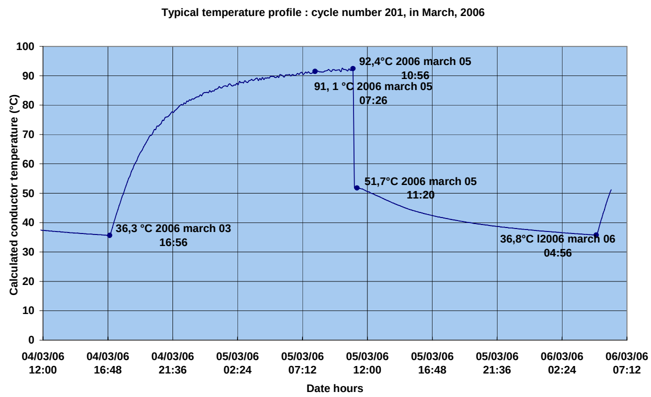

Figure 16 : Load cycle temperature pattern

The heating current was adjusted to take into account the variations of ambient temperature.

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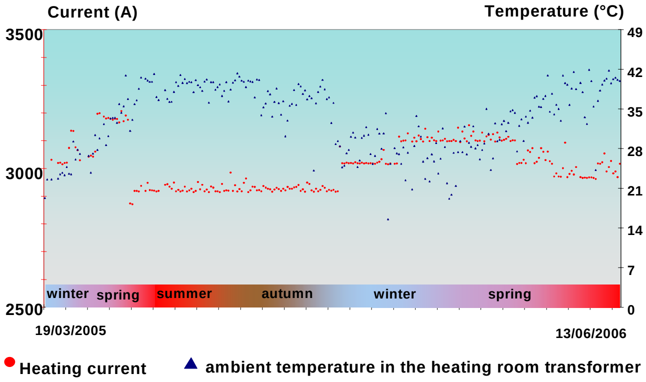

Figure 17 : Heating current vs. ambient temperature

The tested cable system was submitted to the test voltage at 400 kV during more than 180 cycles and 8,776 hours.

Lightning impulse voltage test on a cable sample after load cycles

For this test, after the load cycle sequence, a 40 m long cable sample was picked out of the loop and fitted with 2 SF6 composite termination.
The cable was heated during 2 hours between 90 and 95°C and submitted to the lightning voltage test under 1425 kV, and then to the 1550 kV level, according to the testing conditions for a 500 kV cable.

Figure 18 : Lightning impulse tests on a sample taken after load cycling tests

Examination of cable and accessories did not reveal any sign of wear.

AFTER LAYING TESTS

The after laying tests 260kV in accordance with IEC 62067 (1 hour 260kV) were performed on April 26, 27, 29 – 2007 as well as partial discharge measurements on each joint and termination. They were successfully passed and no partial discharges arising from the cable system were pointed out.

Figure 19 : arrangement for after laying tests at the GIS terminations

CONCLUSION

The 420 kV XLPE cable system including a 2500mm² Cu Milliken conductor with insulated wires successfully passed the IEC 62067 type and prequalification tests. In addition, after laying test were carried out without any trouble.

REFERENCES

[1] IEC 62067 ; first edition ; October 2001