Extension of Qualification applied on a MV extruded submarine cable in France.

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ABSTRACT

The project called "BELLE ILE 4" consists in implementing a new MV submarine power link to feed a French island after partly removing the previous one. The length of the link is around 14.5 km with 30 m maximum depth. The study introduces the newest technology based on the development of coilable hybrid 3x150 mm² copper 20 kV cable, XLPE insulated with 48 optical fibers.
The authors will introduce a new "Extended Prequalification sequence" based on the recommendation of CIGRE TB 303 and the standard IEC 60840 that was applied on the MV submarine cable.

KEYWORDS

XLPE, Submarine Cables, CIGRE TB 303.

INTRODUCTION

Belle Ile is an island in the Atlantic Ocean of the Brittany coast in the western part of France, fed by 3 MV submarine cable systems connecting Belle Ile to the mainland. The link "BELLE ILE 2" is out of service and it was decided to replace it. The project called "BELLE ILE 4" consists in implementing in the same corridor a new MV submarine power link after partly removing the previous one. This choice was validated by the fishermen who prefer to keep the same cable laying zone than to enlarge it.

To guarantee the quality of supply in the island in the absence of "Belle Ile 2", generating sets were displayed, showing the need to quickly replace the missing cable. The length of the link is around 14.5 km and the maximum depth is 30 m. To minimize the cost, it was decided to lay the cable with fixed table vessel and to maximize the reliability, on board joints were forbidden and factory joints limited to one per phase. In addition, the regional representatives of the Ministry of Environment forbade the use of lead on this project. Therefore, a welded copper screen was specified.

Simultaneously, the local authorities were thinking to lay an optical fiber cable to provide high speed internet to the island. As a result, the DSO, ERDF, and the Conseil Général, the local Authority, agreed to build a common cable called hybrid providing at the same time electricity and telecommunications.

This hybrid cable should cope with the HN 33-S-26 [1] a company specification for MV submarine cables derived from the French standard NF C 33-226 [2] dealing with MV land cables and the UIT G 652 for the optical part.
This paper introduces the newest technology based on the development of coilable hybrid Cable design with copper laminated screen longitudinally applied and bonded to the outer sheath which demonstrates high reliability for currently envisioned Subsea systems.

The focus of the paper is to assess the reliability of XLPE insulation cable system subjected to extensive qualification program. This paper describes the development process of MV XLPE Cable systems and the results of the type tests qualification process.

Indeed, the cable system has been submitted to mechanical and electrical type tests qualifications mainly focus on, Coiling Tests, Traction Tests, Tensile and Bending Tests followed by Electrical Type Tests. The non-Electrical Type tests have been performed as well. Several European laboratories have been involved along the process of the qualification.

Even though successfully passed type tests need not to be repeated, the frequency of supply of distribution submarine cable is smaller than the rhythm of changes in cable design or manufacturing process which may lead to different performance characteristics and therefore recurring type testing.

CIGRE Technical Brochure 303 [3] led the way by introducing a guide for a functional analysis approach in the extension of validity of test of HV cables. The modification proposed by a supplier could be studied in order to detect which performance characteristics were affected and to select the tests that need to be repeated. The same methodology was applied for this MV submarine cable qualification.

The authors will introduce in the paper a new "Extended Prequalification sequence" based on the recommendation of CIGRE TB 303 and the standard CEI 60840 Ed 2004 that was applied on the MV submarine cable. Such a specific protocol adapted for the project was a pioneer methodology in the cable manufacturing industry for MV cable system.

CABLE DESIGN

The contract asked for a production of a coilable cable, XLPE insulated 15 kilometers long cf Fig 1. To the communication means on the island in, bringing Belle Ile habitants with internet network, it was asked by the local authorities to add 48 of optical fiber in Monomode type to the cable.
It is recommended that the cable design should have a minimum weight of 25 kg per meter in air. The cable system was provided without joints, even factory ones.

Fig. 1: 3x150 mm² copper 20 kV XLPE Submarine cable

The cable consist of 150 mm² Cu, 5,5 mm insulation. It was designed for 12/20 kV. The 150 mm² conductor is round, circular stranded, compacted and filled with longitudinally water blocking tapes. The tensile armor consists of two non-crossed armored layers of galvanized round steel wires. Indeed, this laying confers to the cable a good coilable behavior cf. Fig 2.

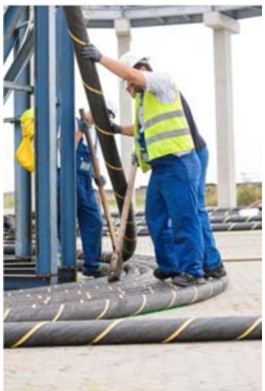

Fig. 2: Coiling test on 3x150 mm² copper MV XLPE Submarine cable

The manufacturing of this cable has been achieved by General Cable Group involving both plants in France and in Germany. GC France was in charge of the manufacturing of the single cores while the stranding process, armor, PP Yarns layers and Optical Fiber have been realized by NSW.

TESTING QUALIFICATION

The cable design has been developed and tested in accordance with the requirements of EDF standards HN 33 S 26 based on the French standard NF C 33 226 and UIT G652.
The tests scheme was performed according to the following protocol:
Each individual insulated core has been submitted to AC tests at 48 kV during 15 minutes and PD measurement at 21 kV AC. The individual jacket of the single core has been tested at 24 kV DC for 1 min. The OF attenuation measurement has been performed before and after stranding. Additionally such measurement has been repeated after coiling test.

<u>Traction and Tensile bending tests</u>:

The tensile bending test (cf. Fig 3) has been performed according to HN 33 S 26. A force of 63 kN was applied. The bending radius used was 2.2 m approximately.

Fig. 3: Traction and Tensile bending test on 3x150 mm² copper MV XLPE Submarine cable

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<u>Electrical tests:</u>

In order to assess whether this had any degrading effect on the cable system, electrical tests have been performed on the cable length previously subjected to coiling and bending tensile tests. The tests have been conducted with U_0= 12 kV

- Partial discharges test at ambient temperature 1,73 U_0
- Tan δ at cold and hot conditions at 0,5 U_0 to 2 U_0
- Three heating loaded cycles (at least 2 hours heating, at least 4 hours cooling) with maximum temperature on the conductor 100°C $\pm$ 3°C.
- Partial discharges test under hot temperature 95°C -100°C at 1,73 U_0
- Hot impulse test at 125 kV (10 positive and 10 negative impulses)
- Power frequency AC test at 4 U_0 during 4 hours.

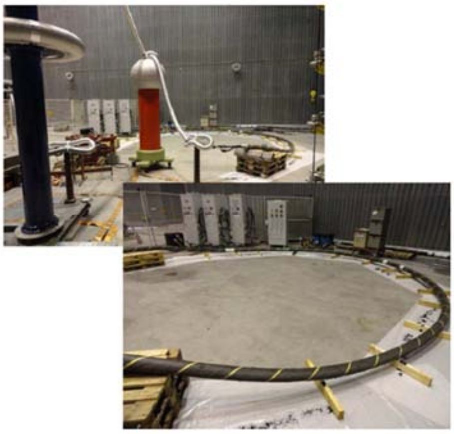

Fig. 3: Electrical type tests set up

It is noted that the non-Electrical Type tests have been performed as well. The tests program have completed successfully

Water-tightness test

A water penetration test was also conducted in order to demonstrate the good performance of the longitudinal water barrier despite the mechanical and thermo-mechanical stresses.

A 10m part of the cable was extracted and was subjected to a water-tightness test. At the middle of this length, the cable was stripped until the core layer on a distance between 10 and 20 mm. Then, the sample was introduced in a pressure tube of 6m maximum and pressurized with salty water at 10 bars during 100 hours.

The test has been passed successfully.

Methodology to assess the test that may not need to be repeated

French MV cable also require a long term performance test as described in NF C 33-226 which is included in EDF Submarine cable specification HN 33-S-26 as a long duration test and similar to HV cable prequalification tests according to IEC 60840 or IEC 62067.

The assessment of the tests that may not need to be repeated was conducted according with the Functional Analysis method and proposed table in CIGRE Technical Brochure 303 Annex 5.4.

First step was to identify the main changes of the proposed cable compared to the one previously prequalified. Both aspects were studied, the components and the manufacturing process.

The second step was to confront these changes with the functions tested in EDF standards (HN 33-S-26 and NF C 33-226).

For this project the changes in the cable design concerned mainly the metallic screen / outersheath complex. Such modification related to bonding material and process to jacket and metal screen. Outer semi-conductive screen was also concerned with a minor change.

Consequently dielectric characteristic of the insulation is not considered to be affected and does not require a long term endurance test. The thermo-mechanical aspect can be affected by the changes and therefore needs to be re-tested.

New "extended prequalification tests"

The philosophy adopted conducted to the introduction of an "extension of pre-qualification test" based on the proposed sequence in § 2.3.3 of the CIGRE Technical Brochure 303 and further described in IEC 60840 with some amendments.

The tests protocol is articulated according to the following sequence:

a) Bending Test on the metallic foil overlap 20 (d+D) ± 5 %
   d: diameter of conductor
   D: outer diameter of cable
b) Partial Discharge at ambient temperature 1,73 U_0
c) 60 Heating Cycles (4 hours heating, 4 hours cooling, conductor temperature 100°C)
d) Tan δ Measurement at U_0
e) 20 Heating Cycles under voltage (2,5 U_0)
f) Partial Discharge test at hot temperature
g) Lightning Impulse voltage tests
h) Power frequency voltage test
i) Examination of the cable system (visual inspection + metallic foil adherence tests)

The duration of the heating cycles was taken from the relevant MV French standard NF C 33-226 §B.5.2.5 with cycles 4 hours heating / 4 hours cooling.

On a dielectric point of view it was decided to proceed with 20 cycles heating cycles under 2,5 U_0 electrical stress in order to recreate, according to Weibull law, a stress equivalent to what is demanded in EDF specification : 210 cycles 8h/16h under 2 U_0 which would have led to 5000 hour test.

On a thermo-mechanical point of view, 80 cycles is indeed far from the 210 cycles demanded by the EDF specification which can highlight design issues with the bonding of the metallic foil. However the cable undergone mechanical conditioning with triple bending tests at 20 times the cable radius having particular care of having an alternation in the reeling/unreeling that alternates compression stress with traction stress on the metallic foil overlap.

Besides the electrical test sequence that will follow the thermo-mechanical cycles a visual analysis is thoroughly performed in order to detect any radial buckling that may deteriorate the radial water barrier and could reveal a gluing issue. This visual inspection completed with adherence test on the metallic foil with the oversheath and adherence test at the overlap.

INTEGRATION INTO EDF STANDARDS

The conclusion of this cable qualification process is being considered in the next revision of EDF HN 33-S-26 standard introducing this “Extension of pre-qualification test” for the purpose of thermo-mechanical testing when component affecting this performance is affected. The same approach can be adapted similarly to HV cable systems [4]

INSTALLATION ACHIEVEMENT

After the success completion of the development and the qualification process, the 15 km length of the full Cable system 3 x 150 mm² copper XLPE has been supplied and successfully installed in Brittany in April 2015. Fig 4 demonstrates the installation process.

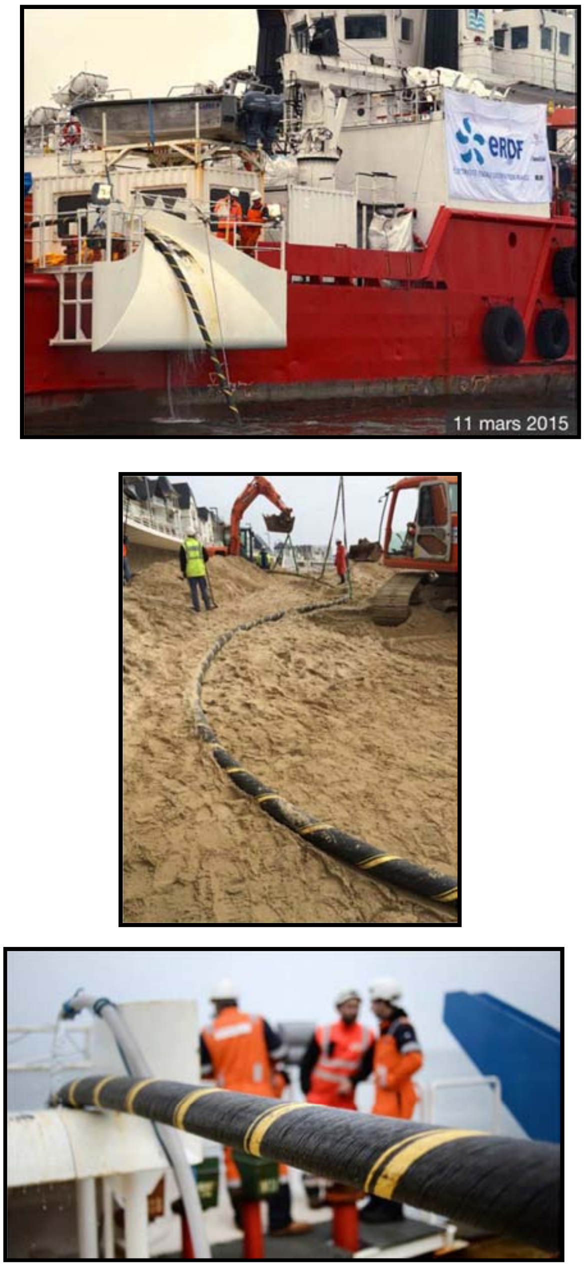

Fig. 4: Installation process of 3x150 mm² copper MV XLPE Submarine cable

CONCLUSION

The project called "BELLE ILE 4" consists in implementing a new MV submarine power link to feed a French island after partly removing the previous one.

A new “Extended Prequalification sequence” based on the recommendation of CIGRE TB 303 and the standard IEC 60840 has been introduced for MV submarine cable system. Such a specific protocol adapted for the project was a pioneer methodology in the cable manufacturing industry for MV link. This new sequence considers changes of the design previously prequalified. This allowed to the introduction of the new technology based on the development of coilable hybrid Cable design with copper laminated screen longitudinally applied and bonded to the outersheath.

The extensive qualification program was able to assess the reliability of MV XLPE insulation submarine cable system.

In addition, the cable system has been subjected to mechanical and electrical type tests qualifications mainly focus on, Coiling Tests, Traction Tests, Tensile and Bending Tests followed by Electrical Tests. Several European laboratories have been involved along the process of the qualification.

The full Cable system 3 x 150 mm² copper XLPE passed the qualification program and was successfully installed in Brittany in April 2015.

REFERENCES

[1] EDF specification HN-33-S-26 : Câbles sous-marins moyenne tension

[2] Norme NF C 33-226 : Câbles de tensions assignées comprises entre 6/10(12) kV et 18/30(36) kV, isolés au polyéthylène réticulé à gradient fixé, pour réseaux de distribution.

[3] CIGRE Technical Brochure 303: Revision of qualification procedures for HV and EHV AC Extruded Underground Cable Systems.

[4] E. Dorison and P. HONDAA 2011, “Working out extension of qualification procedures for HV and EHV cables systems”, JICABLE A.9.1