D.5.8 Report on insulated core testing after aging

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FLOTANT -Innovative, low cost, low weight and safe floating wind technology optimized for deep water wind sites, has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No.815289

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Abstract

Floating Offshore Wind (FOW) turbines will require MV/HV dynamic power cables to interconnect arrays and to connect to the long length static export power cables, which transmit the power from the offshore substations to the onshore grid, highlighting the need for cable solutions with high performance and reliability, yet cost effective.

Whilst copper is the conventional conductor choice due to its higher conductivity and mechanical strength, aluminum conductors cores are increasingly used for static power cables due to their benefit regarding overall cable weight and material cost and therefore similar cost and weight reduction benefits are expected to be realized for dynamic power cables with aluminum or aluminum alloy conductors.

***A** 3D rendering of the 66 kV dynamic power cable*

This deliverable will present the results of the two (2) year aging test of the insulated core according to Cigre Recommendations No.722 (Regime A). The assessment procedure comprises an accelerated aging protocol on sufficiently representative cable core samples followed by an assessment of the residual dielectric strength at the end of its design life. This testing procedure is recommended especially for dynamic cables with wet design, in order to demonstrate that the insulation system when saturated is capable of withstanding the electrical stresses during cable's lifetime.

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1 Introduction

A long-term water aging test of the insulated cable core, according to Cigre Recommendation TB 722, was performed to assess the feasibility of the wet cable design with aluminium conductors in sea environment (saline solution). This test is required in order to demonstrate that the insulation materials, when saturated, retain sufficient dielectric strength to operate at the intended design dielectric stress, E_{design}, of production cables when they are continuously immersed in sea water for the cable service life. It should also be noted that a successful aging test result for cores with aluminium conductors is applicable to cores with copper conductors but not the opposite.

The assessment procedure comprises an accelerated aging protocol on sufficiently representative cable samples followed by an assessment of the residual dielectric strength at the end of its design life. The most demanding and widely accepted wet aging protocol is the 50 Hz 2 years duration test.

Therefore, for the purposes of this Project, the procedure of the 2-year water aging test is chosen (Regime A, Cigre TB 722).

Details concerning the test objects and the test procedure can be found at the publicly available deliverable D3.3 "*Insulated core of dynamic 72.5kV cable for aging testing*".

The results are presented in the following Chapter through the attached official test report of the Hellenic Cables' submarine plant (Fulgor, Quality control department).

2 Test Report - Results

HELLENIC CABLES
Member of CENERGY HOLDINGS

FULGOR S.A.
HELLENIC CABLE INDUSTRY

TEST REPORT

No.	243 / 00
Issue date	25/08/2021

Manufacturer	FULGOR S.A
Test object	SINGLE CABLE CORE
Type	1x240 mm^2 – Al/XLPE/CWS
Rated voltage U_0/U (U_m)	38/66 (72.5) kV
Standard specifications	CIGRE TB 722 APRIL 2018
Test laboratories	FULGOR S.A., Soussaki, Greece
Range of tests performed	Report on insulated core testing after aging
Date of test	05 MAY 2019 - 05 AUGUST 2021
Test result	All tests foreseen were carried out satisfactory and all measured values were compared with those data and values given by the above standard specifications and found to meet the requirements.

FULGOR S.A.
Quality Control Engineer
V.Souglakos

FULGOR S.A.
Quality Control Manager
I. Ztoupis

The measured values apply only to tested objects. Contents of this test report may not be reproduced fully or partially, without permission of the CABLEL HELLENIC CABLES GROUP

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2.1 General description of the test object

The test object was a single cable core with aluminium round compacted conductor, XLPE insulation and Copper Wires Screen. More details are given in Annex 2 – Drawing 1. The cable core was manufactured at FULGOR plant and the test was performed by FULGOR S.A, in FULGOR premises.

Brief information for cable is presented below:

Test object: Cable core

Type	1x240 mm_2 AL/XLPE/CWS
Rated voltage U_0/U (U_m)	38/66 (72.5) kV
Standard specification	CIGRE Recommendations No. 722
Manufacturer	FULGOR S.A.

2.2 Tests

2.2.1 Pre-Conditioning of the test objects

A description of the cable system under investigation is presented below.

Start date: 05/05/2019

End date: 26/05/2019

Measuring equipment:

Code No.	Type	Calibration expiry date
070-140	Temperature / Pressure /Voltage data logger	30/12/2021

Test method: Cigre TB 722 § 3.6.2

Two samples of approximate 160m each, were immersed in the tank and submitted to the pre-conditioning test.

Test conditions	Unit	Applied value	Required value
Temperature of water	ºC	55 ± 5	55 ± 5
Salinity of water	%	~ 4.0	3 – 6
Duration	Hrs	>500	≥500
Hydrostatic Pressure	mbar	1000	900 - 1500

Test result: When the test time had elapsed for the preconditioning test the test objects proceeded to the accelerated ageing test.

Evaluation of test result: PASS

2.2.2 Accelerated ageing of dielectric

Start date: 20/06/2019

End date: 29/07/2021

Measuring equipment:

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Code No.	Type	Calibration expiry date
070-140	Temperature / Pressure /Voltage data logger	30/12/2021
070-008	AC Voltage test System 60kV	24/05/2023

Test method: Cigre TB 722 § 3.6.3, Regime A

At the end of the preconditioning, the two samples, approximate 160m each, proceeded to the accelerated ageing test. After the completion of 1st year of ageing, the remaining test object, approximate 160m, proceeded to the 2nd year of accelerated ageing test with the same test conditions.

Test conditions	Unit	Applied value	Required value
Voltage test	kV	54 ± 3%	54 ± 3%
Frequency	Hz	50	50
Temperature of water	ºC	40 ± 5	40 ± 5
Salinity of water	%	~ 4.0	~ 4.0
Duration of 1st year	Hrs	>8.750	>8.750
Duration of 2nd year	Hrs	>17.500	>17.500

Test result: After the completion of each year of accelerated ageing, test objects were removed from the tank to assess the residual dielectric strength. The first sample had been subjected to more than 8.750h ageing and the second to more than 17.500h ageing.

Evaluation of test result: PASS

2.2.3 Measurement of residual dielectric strength

Start date: 11/07/2020

End date: 05/08/2021

Measuring equipment:

Code No.	Type	Calibration expiry date
070-001	600kV AV voltage measuring system	23/05/2023
071-001	Optical measuring system	02/07/2022

Test method: Cigre TB 722 § 3.6.4 (Table 3.6) and HD 605 § 5.4.15.3.4.

After the completion of each year of accelerated ageing, the test objects were tested to smaller samples in order to assess the residual dielectric strength with AC voltage step breakdown test according to Cigre TB 722 §3.6.4.2 (Table 3.6) & HD 605 § 5.4.15.3.4.

Test conditions	Unit	Applied value	Required value
Voltage test	kV	54 ± 3%	54 ± 3%
Frequency	Hz	50	50
Temperature of water	ºC	40 ± 5	40 ± 5
Salinity of water	%	~ 4.0	~ 4.0

Test Result: The test results for step breakdown complied with the requirements given in the tables below.

- 1st year of accelerated ageing
    - Six (6) samples were tested and the residual dielectric strength exceeded 32.7 kV/mm in all.
- 2nd year of accelerated ageing
    - Six (6) samples were tested and the residual dielectric strength exceeded 32.7 kV/mm in all.

Evaluation of test result: PASS

3 Conclusions

This work has offered a summary of the main results regarding the performance of an insulated aluminium power core designed for dynamic applications, under applied electrical stresses and wet conditions. Based on the selected applied voltage level (54 ± 3% kV), the test results for step breakdown fully complied with the requirements of the Test Regime A. This is encouraging, as the proposed wet design for insulated dynamic power cores with aluminium conductors can be implemented for deep water floating wind applications. Taking into account that the proposed cable design is low weight and low cost compared to the conventional copper one, this deliverable contributes to the overall reduction of the LCoE for floating wind applications.

ANNEX 1. INSTRUMENTATION USED FOR TESTS

Code No.	Type	Required value
070-001	600 kV AC voltage measuring system	23/05/2023
070-008	AC voltage test system 60 kV	24/05/2023
070-140	Temperature / Pressure / Voltage data logger	30/12/2021
071-001	Optical measuring system	01/07/2022

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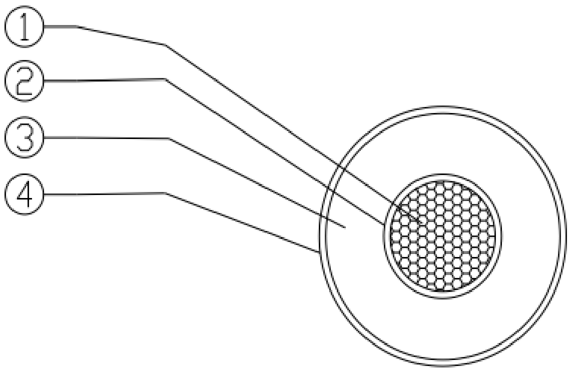
ANNEX 2. CABLE STRUCTURE



Note: Drawing is not to scale.

1 – Aluminium stranded compacted class 2 according to IEC 60228 of nominal cross-section equal to 240 sq.mm

2 - Conductor non-metallic extruded screen: Extruded semiconducting compound bonded to inner surface of insulation

3 - Insulation: XLPE of 8.0 mm minimum average thickness

4 - Core non-metallic extruded screen: Extruded semiconducting compound bonded to outer surface of insulation

- Semiconductive tape helically applied over the insulated core
- Copper wire screen helically applied for being the electrode for the test

Figure 1. Cable structure

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ANNEX 3. PHOTOS AND DIAGRAMS

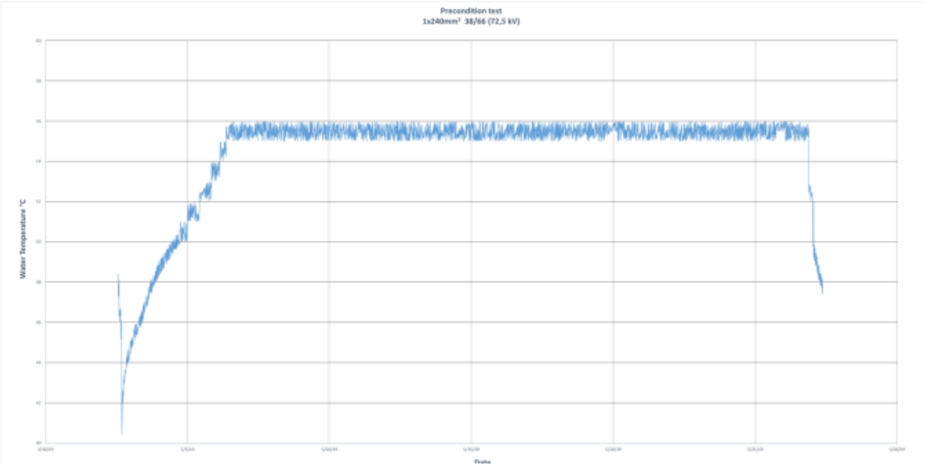

Figure 2. temperature recording of preconditioning

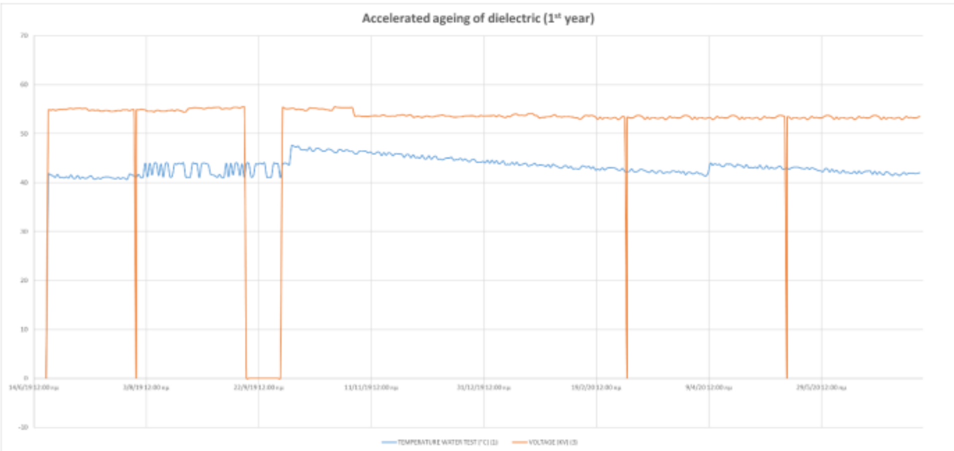

Figure 3. Voltage & temperature recording of 1st year of accelerated ageing

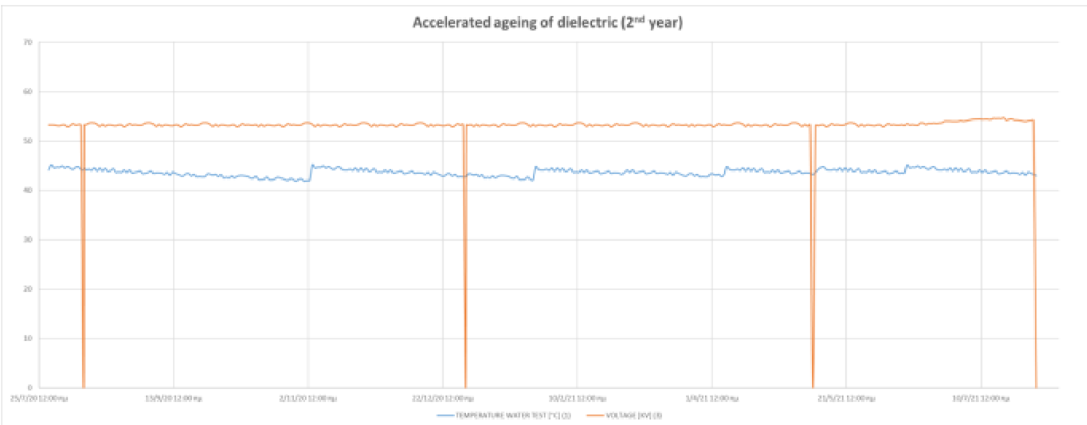

Figure 4. Voltage & temperature recording of 2nd year of accelerated ageing

Figure 5. Voltage & temperature displays

Figure 6. AC voltage step breakdown test