# Special qualification and characterization tests on 525kV HVDC submarine cable system

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## *ABSTRACT*

*A submarine 525kV HVDC pre-qualification test was successfully completed fully in accordance with CIGRE Technical Brochure 852. This recently released brochure adds some new tests compared to TB 496 that are considered part of the qualification process and calls for sharing of development test results, when requested. The paper will present the new qualification tests introduced by TB 852 performed as part of the 525kV submarine cable system qualification process, such as thermal stability test, space charge measurement and temperature monitoring performed during the test and along the test loop, by using a DTS system and an integrated fiber optic cable. These results will be critically reviewed and interpreted.*

## *KEYWORDS*

HVDC, 525kV, submarine, cable, development test, prequalification test.

## INTRODUCTION

The global offshore wind power potential is expected to reach 450GW in 2050. Offshore wind power and HVDC submarine cable have become a global development trend for the connection between wind farms and onshore grids. In the past ten years, the voltage level of extruded HVDC cable in operation had continuously upgraded to 400kV moving now to 525 kV. As an example, the Dutch IJmuiden Ver Wind Parks offshore project will use 525kV extruded DC submarine cable system to link the 2GW offshore grid connections, with an offshore distance of about 190km. Up to 2022, 525kV extruded DC submarine cable system with a 2GW capacity were not implemented in any project and qualified. Prysmian Group has been the first cable manufacturer to complete the prequalification of such technology in August 2022. The qualification has been performed following the requirements of the recently released Technical Brochure 852. This TB adds some new tests compared to TB 496 that are considered part of the qualification process and calls for sharing of development test results. The paper presents the new qualification tests introduced by TB 852 performed as part of the 525kV submarine cable system qualification process: thermal stability test, space charge measurement and temperature monitoring along the test loop, by using a DTS system and an integrated fiber optic cable.

## THERMAL STABILITY TEST

### Technical background

Thermal runaway is characterized by two situations [1] [2]:

- *intrinsic* thermal runaway, where after a certain electric stress and at any given temperature, the increase in insulation current is faster than insulation resistance reduction, due to nonlinear electric stress dependency of DC conductivity; this phenomenon does not depend on surrounding heat dissipating medium and can be investigated in a state where the outer sheath temperature is kept constant (or, conversely, there is a perfect heat sink outside the insulation);
- *interactive* thermal runaway, where the heat losses due to joule losses in the conductor and insulation are causing more heat generation than the cable and surroundings can dissipate. This phenomenon does depend on the surrounding heat dissipating medium and it can be associated with an outer insulation temperature increase.

Such unstable scenarios may result in uncontrollable and catastrophic temperature escalation.

In [3] the temperature control during prequalification testing (PQT) and type testing (TT) was allowed to be performed by means of thermal insulation or active cooling. In this way interactive thermal instability phenomena could have been hidden, as active cooling corresponds to a situation where the outer sheath temperature is kept constant. Also, achieving both qualification parameters (maximum conductor temperature $T_{MAX}$ and maximum temperature drop across insulation $\Delta T_{MAX}$) poses two issues:

- it's difficult to attain both qualification parameters in a laboratory environment due to seasonal and daily changing of ambient temperature, especially for long term tests such as the PQT [4];
- the thermal insulating medium cannot be selected to represent the worst heat dissipating installation conditions where interactive thermal instability might occur, as it would prevent to achieve reasonably high ΔT, relevant instead for electric field inversion.

Therefore [5] introduced a new thermal stability test (TST) as part of the DC qualification process. The objective of the test is to verify the absence of any interactive thermal runaway; this is achieved by keeping the ΔT to a minimum (i.e., representing very demanding heat dissipation conditions), which then becomes a new qualification parameter $\Delta T_{min}$. It also introduced the possibility to use active cooling/heating during PQT and TT: this methodology should in the end be preferred, because it allows to better control $T_{MAX}$ and $\Delta T_{MAX}$, but it can also ascertain that in case of a breakdown during TT or PQT due to thermal runaway, this is surely due to intrinsic thermal instability.

### Test setup description

TST was performed on a length of 50 m of submarine XLPE cable. The test object and the reference loop were heated up, with no voltage applied, until the reference cable conductor had steadily reached the desired maximum conductor temperature. The heating current was maintained at a constant level on both test loops for the further duration of the test, with a margin of ±2%. Once the temperature was steadily reached, the test voltage of $1.45U_0$ was applied to the test object. After the voltage reached the test value, the test current is applied for a