UPGRADING OF 10KV CABLE CONNECTIONS TO 2O KV IN THE NETHERLANDS

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ABSTRACT

Alliander has concluded, after an evaluation of the present distribution grid, that instead of 10 and 50 kV, 20kV will become the main system voltage. The system voltage of 20kV is more in line with European practice and offers for the same installation space the double transport capacity.
In the framework of this strategic decision, Alliander has decided to investigate if existing 10kV XLPE cable lines can be upgraded to 20kV. The purpose of this upgrading process is to get higher transport capacity at lower cost without the usual public inconvenience, as new cables need not to be installed yet and the existing cables need not to be removed.

Alliander has performed a study together with KEMA (now part of DNV GL), Technical University Delft and Prysmian consisting of the following parts:

- *Literature study*
- *Theoretical study*
- *Performing of a type test of 10 kV 630mm2Al and accessories according to 20kV requirements*
- *Performing of a long term test on 10kV cables and 20kV accessories*
- *Evaluation and conclusions*

The study has been successfully completed with the conclusion that upgrading of 10kV XLPE cable (630mm2 conductor cross-section) to 20kV is feasible, however with the exception of 10kV accessories.
Alliander has decided to apply upgrading in practice and to investigate in a later stage upgrading of 3 phase 240mm2 XLPE cable, another common cable in the Alliander distribution network.

INTRODUCTION

Alliander has decided that the distribution grid will be standardized on 20kV system voltage. When the system voltage will become 20kV the question may be raised if existing 10kV cables have to be replaced by 20kV or can still be operated at 20kV. It does not need to be explained that upgrading has advantages: higher transport capacity, and less public inconvenience as no new cable has to be installed. However there are also disadvantages: higher risk of failure as the cables and accessories are going to be subjected to 2 times higher voltage, than for which the cable and accessory have been designed [1], [2], [3], [4].

Alliander has performed a study to confirm the feasibility of this upgrading process, together with KEMA (now part of DNV GL), Technical University Delft and Prysmian, consisting of the following parts:

- Literature study
- Theoretical study
- Performing of type test of 10 kV 630mm2 Al and accessories according to 20kV conditions
- Performing of long term on 10kV cables and 20kV accessories

In [5] the first three steps were already dealt with, so in this paper they will be summarized, whereas the last step will be discussed in more detail.

PLAN OF APPROACH

Literature study

Based on information from the literature contact has been made with two utilities in Germany: Enso and envia M who are doing similar work since about 10 years. [2],[3],[4] About the procedure for upgrading the following can be said:

- Although the 10kV “cable upgrading” seems far more feasible than the “upgrading of the accessories”, still both cable and accessory are eligible for upgrading
- Both cable and accessory are being subjected to a diagnostic procedure (voltage, tan delta and PD testing) to safeguard the upgrading. Only components that pass the diagnostic tests successfully are being upgraded
- Both utilities do not necessarily want the upgrading to be “everlasting”. It is already accepted when the upgrading works for 5-10 year, in order to be able to

delay the investments for new cable and accessories with that period of time.

Theoretical study

Ageing is a complicated process, caused by thermal, mechanical and electrical stresses [6],[7].The interactions are shown in figure 1.

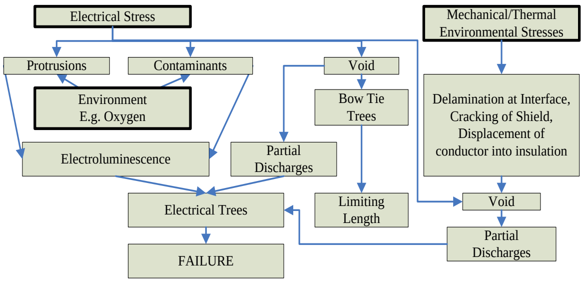

Figure 1 Ageing mechanisms under dry conditions

To understand the effect of doubling the voltage, the theoretical study aims to identify the critical ageing mechanisms and the resulting V-t characteristics, to decide about voltage level and duration of long term test.

The inverse power law L=K Vexp(-n) was selected as the life prediction method, taking into consideration the threshold effect by limiting the ageing stress to 8kV/mm. The slope of the V-t curve (the value n) should be properly selected. The higher value of n, the higher the quality of the insulation is [8]. Although some manufacturers report n values to be over 20, it was decided to be on the safe side by selecting n=9.

Type testing

The type test was performed on a 6/10kV cable with aluminium conductor in a 50 m test loop (figure 2). In a different set up (figure 3) both 10kV and 20kV accessories (in total 11 different types were tested. The test requirements are based on HD620 S1 1996.

The cable testing at 10kV level is based on:
- Voltage testing
- PD testing

The cable testing at 20kV level is based on:
- Voltage testing
- PD testing
- Long term test
- PD testing

The accessory testing at 10kV level is based on:
- Voltage testing
- PD testing
- Heat cycles
- PD testing
- Impulse testing

The accessory testing at 20kV level is based on:
- Voltage testing
- PD testing
- Heat cycles
- PD testing
- Impulse testing
- Voltage testing
- Long term testing
- PD testing

Figure 2 Type testing of 10kV cable

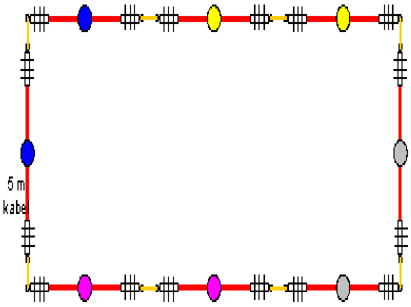

Figure 3 Type testing of 11 different accessories

The 10kV cable passed the requirements for 10kV and 20kV testing. For the accessories the situation is less favourable. Only 2 accessories passed the 20kV test requirements successfully.

Long term tests

The purpose of the long term testing is to prove that 10kV XLPE cable and related accessories being operated at 10kV during a certain time, can be reliably operated at 20 kV [9]. Therefore during several months the cable and accessories will be tested by overvoltage and heat cycles to demonstrate that the remaining life will be about 50 years.
The test was performed on 95 m XLPE cable, with a service life of already 10 years, with 10 accessories, as shown in figure 4. Based on the disappointing results of the type tests on 10kV accessories it was decided to exclude the 10kV accessories form long term testing and only include in the long term tests only 20kV accessories of 2 manufacturers that passed the 20kV tests successfully.

The conditions for the long term testing were taken from the table 1.

Table 1: Cable life under different n-value

Electrical stress	n=7	n=9	n=12	n=15
3Uo	200 hours	24 hours	50 minutes	2 minutes
2.5Uo	30 days	4.5 days	7.3 hours	28 minutes
2Uo	4-5 months	**1 month**	4.5 days	13.3 hours
1.8Uo	10 months	**3 months**	15 days	2.7 days
1.7Uo	14-15 months	**5 months**	1 month	6.4 days
Uo	50 years	50 years	50 years	50 years

The testing conditions are, assuming n=9:

- 1,8Uo
- Daily heating cycles 20-95 degree C
- PD testing before and after the test
- Destructive investigation of cables and accessories after the test has been completed.

The requirements for successful passing the long term tests are:

- Both cable and accessories have to pass the long term tests successfully
- The PD level may not increase during the test
- The destructive test at the end is only for information.

After completion of the long term tests the following results can be mentioned:

- Cable and termination have passed the test successfully
- One of the joints showed a very high discharge level, however this could be related to a wrong installation procedure
- The XLPE insulation showed discoloration, however further laboratory investigation could not confirm a relation with ageing due to upgrading
- Destructive inspection after completion of the long term test did not show any degradation due to the voltage upgrade.

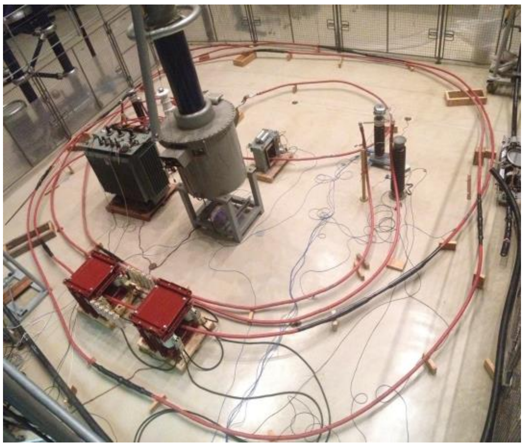

Figure 4 Long term testing set- up in the laboratory

EVALUATION AND CONCLUSION

The results of the type tests and of the long term test are decisive to determine if the upgrading from 10 to 20kV is technically feasible. The following type tests results for

10 kV cable and accessories can be summarized:

Type testing

- Cable
  - 10kV requirements were passed successfully
  - 20kV requirements, after a few problems not related to the upgrading were passed successfully as well.

- Accessories
  - 10kV requirements were passed successfully
  - 20kV requirements except one type were not passed

According to these results it was decided to perform the long term tests on cable and with exclusively 20kV accessories, as it did not seem feasible to use 10kV accessories for upgrading.

Consequently the long term test has been performed on cable and two types of 20kV accessories. The results are promising. The cable withstood the test without breakdown. The joints behaved similarly, except one joint that showed PD activities with increasing pC level. The other joints satisfied the conditions completely.

After completion of the long term test destructive visual inspection took place. The outer sheath showed significant shrinkage at all joints of a few mm to a few cm. An oxidation induction time test was performed to measure the level of antioxidants after the long term test, which was not changed compared with the level before the long term test, indicating that no measurable aging could be established.
The joint that was rejected showed next to PD activities, significant discolorations, presumably related to thermal stress.

It was therefore concluded that upgrading of 630mm2 6/10 XLPE cable is feasible, provided that only the joint type is used that passed successfully the long term test.

Alliander has decided to apply upgrading in practice and to investigate in a later stage upgrading of 3 phase 240 mm2 XLPE cable, another common cable in the Alliander distribution network.

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