Splinters in Copper Wire Screen of ABB Moskabel 220kV Cable – Moscow Ring, delivered by Nexans

Contents

Summary

Splinters were discovered on the copper screen wires of 220kV cables produced by Nexans and delivered to ABB Moskabel in Moscow. By the information obtained from the provided documents, KEMA concludes, because of the size of these splinters and there amount, that these cables have a considerable chance to have decreased reliability. Tests on the cables on which these splinters are observed cannot ensure a reliable lifetime of these cables. Therefore KEMA recommends to not use these cables.

The corrective action taken in Nexan's production plant appears to not have resolved the problem. Therefore, KEMA recommends only installing new cables after the real problem has been found and is proven to be solved.

1 Introduction

In March 2008 splinters were discovered on the copper screen wires of 220kV cables produced by Nexans and delivered to ABB Moskabel in Moscow. As a result of that, various investigations have been conducted in order to examine the severity and extent of this defect.

KEMA was provided with the documents describing these investigations and was asked to see whether it is possible for KEMA to make any conclusion on whether the defective cables might be safely used on the bases of the provided reports.

The reports provided describe investigations of ABB – High Voltage Cables (Sweden), All-Russia Research, Design and Technology Institute of Cable Industry (2 reports) and Nexans (3 reports). In section 4 the provided documents are listed as [1-6]. Document [6] was provided to KEMA after the draft version of the report at hand was already written. In this document additional visual inspections are described, which was one of the most important recommendations of the draft version of the report at hand. Therefore, this report was modified in order to include also the results from the inspections described in [6].

The report at hand does not repeat all the detailed information that is already described in the mentioned documents. KEMA studied the documents in detail and in section 2 of this report KEMA's main findings from the information in the various documents are given. Based on these conclusions, chapter 3 gives the recommendations for further approach of this situation.

2 Conclusions from studied documents

2.1 Consequence of the observed splinters

From the various investigations being done, it is clear that a large number of splinters are present on the screen wires of the cables under investigation. The sizes of these splinters obviously differ a lot, but it is clear that heights up to 0.71 mm are seen [3] and lengths up to 3 mm [6]. Furthermore, the direction of these splinters are inwards, so in the direction of the insulation (screen). The thickness of the swelling tapes, between the copper wires and the insulation screen is not given in the documents, however the thickness of the insulation screen itself is 1.2 mm [3].

It is true that an important purpose of this (semi-conducting) insulation screen is to eliminate the influence of all kind of disturbances on the outside of this screen on the radial electrical field in the insulation material. This can also include small irregularities on the wires of the copper wire screen (After all, a wire screen itself can also be seen as an irregularity compared to the fully closed metal sheath). So as long as these irregularities do not penetrate the insulation screen fully (or almost fully), the electrical field inside the insulation material remains undisturbed and there the cable will operate normally and will be able to withstand all the normal electrical fields applied. So in principle, in a pure steady state situation, cables with these kinds of splinters would be perfectly able to withstand electrical fields, just as cables without the splinters, as long as the splinters do not penetrate the insulation screen fully. Judging from the fact that these cables all passed the routine tests ($2.5U_0$), we can conclude that indeed at this moment the splinters do not penetrate the insulation screen fully, and the current state is not harmful as it is.

<u>However</u>, cables never remain in a steady state situation. All kind of mechanical forces are applied on the cable, during installation (bending, etc.) but also during operation (warming up, cooling down, vibrations in ground, subsidence of ground, etc.). These mechanical forces can be such, that the splinters will penetrate a (maybe tiny) little bit more in the direction of the insulation. At this moment there is no way to tell how far some of the splinters have already penetrated the insulation screen. The only thing known is that at this moment they have not reached the insulation, but we cannot tell what the distances are. Furthermore, it is impossible to predict precisely how large the forces will be in the future lifespan of the cable.

Fact is that the maximum size of the splinters observed is such that their height is already over half the insulation screen thickness and their lengths are much more than the insulation screen thickness. As these sizes are observed, it is most likely that even larger sizes do exist in the cables (as not all are inspected). But even having the observed sizes it is not unlikely, that due to mechanical forces, these splinters will be pushed in a more vertical position and therefore get a chance to penetrate deeper. Due to the large quantity of the splinters, all the above is statistically more likely to become true, i.e. it is more likely that there will be a combination of a large enough splinter with the correct forces on that location. Furthermore, this should be regarded during the complete lifespan of the cable, also increasing the chances of something like this could happen over time.

Another, less likely, problem that may arise is that the insulation screen might be torn open slightly and locally at the location of one or a few larger splinters which may puncture in the insulation screen and get moved a bit due to mechanical forces. If the insulation screen is opened somehow until the insulation, a breakdown will occur. Obviously, this all depends on also the material properties (strength) of the semi-conducting material, etc.

Applying higher test voltages at this moment to the cable, will only tell whether splinters have already penetrated the full insulation screen at this moment, but will not give any information about the penetration depth or the penetration of these splinters in the future. Heat cycle tests will do slightly better in this respect, but will also never be able to approach all the possible mechanical forces that will be experienced by the cable during its lifetime. Normally this is also not necessary and therefore accepted, but in this case the risks would be too high. Therefore the tests described in [5] should, according to KEMA, not lead to the conclusion that all the cables are fit for use.

Summarizing the above, KEMA states that given especially:

1. the size of the splinters, and
2. the large amount of splinters,

there is no way to ensure that none of these splinters will penetrate the insulation material or damage during the lifespan of the cable. Therefore, these anomalies in the copper wires of these cables make KEMA having the conclusion that it can not be ensured that these cables will have the same reliability during operation.

2.2 Nexans corrective actions on the production line

In [3], Nexans reports about the problem in the production line and the corresponding corrective action taken. As far as can be judged from [3] and without the information from [6], the found cause of the damage to the screen wires (the sharp edge of the damaged die) could indeed very well have been the cause of the observed splinters. Such a die would normally be used if the wire would come from more or less the direction of this die. In the pictures in [3], the wire is clearly pulled from a location not in line with the die, but at and app. 90^0 angle to it.

Also, if the above would indeed have been the (only) cause of damage to the observed splinters, the corrective action taken by Nexans (applying a wheel in front of a die to guide the wire and eliminate any edge) would seem the correct action to take in this situation as the 90^0 angle is than handled correctly. It would probably even be better if before the new wheel, a new die would be mounted in the direction of the wire, eliminating possible future problems with the edges of the wheel itself too. But this is obviously difficult to judge from the pictures.

However, in [6] various (19) samples of cable were again examined, including cable parts produced after the corrective actions, mentioned above, were taken. During this examination, again many splinters and anomalies were found on the screen wires on cables from both before and after the corrective action. Both the maximum length and the average length of the observed splinters do not seem to have been reduced significantly with the corrective action taken. On the contrary, the largest splinter was even observed on a cable part produced after the corrective action. From this we must conclude that the found problem in the production line was not the actual or only cause for the splinters on the screen wires, or that the corrective action was after all not effective. Anyhow, the problem is shown to be not solved yet.

2.3 Comments on PD results during routine tests

Although this is not directly the first question asked to KEMA about the provided documents, KEMA wants to draw the attention to one other issue. In the documents [3], [4] and [5], the results of the PD measurements during the routine tests and additional test are given. It is stated that PDs with levels up to 3.4 pC are measured and that this is ok. Maybe KEMA's interpretation of the text is not what the author (Nexans) means, but if PDs of any level are detected, IEC 62067 states this is not expectable. IEC 62067 clearly states that "There shall be no detectable discharge from the test object at 1,5U_0". Furthermore, it states that the sensitivity as defined in IEC 60885-3 shall be 10 pC or better. This is something different than allowing PDs smaller than 10 pC. So if the detection sensitivity was indeed low and PDs of up to 3.4 pC were detected, this should not have been approved.

However, the author might mean (but it is not literally stated like this) that the sensitivity was a few pC (up to 3.4 pC) and no PDs were detected, in which case this would be in line with the IEC 62067.

3 Recommendations for further approach

- According to KEMA cables with splinters on the wire screen like observed in this situation have a significant chance to not have the same reliability of operation during their lifetime as cables without the splinters. High voltage and load cycle test will not be able to simulate all the possible forces that may in this case be fatal to the operation of the cable. Therefore, KEMA recommends to not use any of these cables.

- The cables that were produced after the corrective action of Nexans to the production plant show the same anomalies, resulting in the conclusion that the main cause of this problem has not been solved yet. Before examining document [6] it seemed not unlikely that the corrective action taken could have been effective. However, in the previous version of this report (before document [6] became available to KEMA), KEMA already pointed out that there may still be another problem. This appears to have become reality. Therefore, Nexans will have to find to real cause of the observed splinters. This could very well be done with help of an independent party (like KEMA). After a new plausible explanation has been found, we recommend to at least let its plausibility be judged by an independent and knowledgeable party, to minimize to chances of further delay / costs.

- After a new corrective action has been taken, KEMA recommends to inspect the new set of cables from the plant visually for the presence of these splinters. KEMA recommends to inspect again a large amount of the cables (e.g. 20) in order to minimize the chance of missing something. KEMA could send an inspector to witness this inspection as an independent party, if required.

- As the text in the Nexans documents indicate that PDs of a few pC are measured, which is in contrast with the IEC 62067, KEMA recommends to verify this issue with Nexans.

- In the documents provided, nothing is mentioned about a Test After Installation. KEMA would like to address the fact that KEMA, in line with IEC 62067, always recommends doing such a Test After Installation, preferably and if possible with $1.7U_0$. The separate components of a cable connection (cable, joints, terminations) can be made under very well controlled, indoor and dust free conditions. And even there things go wrong (as the problem of the report at hand is an example for). The jointing and termination has to be done in outdoor, field conditions, making this step often much more vulnerable to mistakes or dust entrapments. It would be very unlogical to not check these last, most vulnerable, step in the process before going in operation. Maybe, such tests are already foreseen, in which case this recommendation can be regarded as obsolete.

4 References

[1] ABB AB High Voltage Cables, Test Report No. 2GM08603-036 - Analysis of splinters on screen wires of NEXANS cable, dd 2008-05-22

[2] All-Russia Research, Design and Technology Institute of Cable Industry (VNIIKP) - Report No. 01-08 – Cable Sample Research to Assess Quality of Screen Copper Wire and Its Impact Upon Insulating System, dd 2008

[3] NEXANS - Non-conformity report - Claim on defective 220kV cable from Marfino project, Moscow Ring, dd 2008-07-25

[4] NEXANS - Letter ref. 220kV Defect cables - Your letter ref. GD-33-8-169, dd. 2008-10-10

[5] NEXANS - Letter ref. 220kV Defect cables - Trails performed on Moscow ring returned cable, dd. 2008-10-10

[6] All-Russia Research, Design and Technology Institute of Cable Industry (VNIIKP) - Minutes No. 1/3-05-08 - Cable Sample Research to Assess Quality of Screen Copper Wire, dd 2008-11-24