DIELECTRIC COMPATIBILITY OF DISTRIBUTION NETWORK SPACER SYSTEM

Credson De SALLES
Unifei – LAT-EFEI – Brazil
credson@lat-efei.org.br

Alan M. de NOBREGA
Unifei – LAT-EFEI – Brazil
alan@lat-efei.org.br

Manuel L. B. MARTINEZ
Unifei – LAT-EFEI – Brazil
martinez@lat-efei.org.br

Edson L. BATISTA
AES Sul – Brazil
Edson.batista@AES.com

Juliana I. L. UCHOA
AES Sul – Brazil
Juliana.Uchoa@AES.com

Hermes .R. P. M. de OLIVEIRA
AES Sul – Brazil
Hermes.Oliveira@AES.com

ABSTRACT

The objective of this paper is to verify the parameters that influence the performance of the spacer systems for medium voltage distribution networks and the dielectric compatibility stresses. It is one objective of this paper, and also generally expected, to provide scientific basis for the present Brazilian National Standard Committee. Some of the present data can be useful for countries – utilities that intend to apply these systems. This research takes into account the economic point of view, a Brazilian common practice, of purchasing parts from different manufacturers of spacers and of covered cables.

INTRODUCTION

The spacer systems have been widely used in distribution networks in Brazil in the last 10 years and part of the problems observed after field application is commonly addressed to the dielectric compatibility between the spacer and the covered cable. Due to the insulation collapse this results in power supply interruption and in potential risks to the system itself, to the integrity and life, due to the melting of the spacer and/or the cable coverage.
Similar to other equipments, the process of acquisition of any spacer system must follow specific steps of each utility, among them the execution of routine and type tests.
Considering the covered cables, Brazilian Association of Technical Standards – ABNT) provides the document NBR 11873 [1]. Nevertheless, for the system hardware – spacers, insulators, and others – there is not, by the moment, an available document issued by ABNT. The tests procedures are carried out according to a document issued in partnership association amongst the Brazilian Utilities known as ABRADEE [2]. At the present moment an ABNT standard for the system hardware is under study based mainly in the ABRADEE documentation and field and laboratory experience. An interesting point is that the dielectric compatibility test is not mentioned in the Standard NBR 11873 it is only a request of ABRADEE based in several years of operation of covered conductors for medium voltage networks.
A failure in a dielectric compatibility laboratory test does not mean that the cable or the spacer comes from a poor manufacturer, but just that they are not able to work together for material and dielectric reasons. This situation results in another problem regarding registered and non registered suppliers on the utility. In view of this situation this paper carries out dielectric compatibility tests considering the combinations between six cable manufacturers and five spacers 25 kV class manufacturers registered to supply to AES Sul utility. The objective is to verify if the test parameters can be considered reasonable, to find some key points that must be consider during the test running, and to guide manufacturers, if needed, with data to get the necessary improvements.

THE DIELECTRIC COMPATIBILITY TEST

According [2], the dielectric compatibility test is carried in three sets of samples. Each set consists of three phase cable with recommended fixing rings, grounded aluminium messenger cable and one spacer or three high density polyethylene pin insulators. It is recommended at least 3 meters of cable per phase, and a minimum distance of 1 meter between each set. The present recommend test parameters are:
- Cable insulation temperature: 60 ºC;
- Rain cycles of 5 minutes wet followed (standard rain time) by 15 minutes dry (usually time for drying a pre-heated cable);
- Aspersion: 1 mm/min;
- Aspersion water conductivity: 750 μS/cm.
- Applied voltage to ground: $2U_0$. (U_0 is the system operating voltage to ground);
- After thirty continuous days no material must presents any evidence of cracking, tracking or erosion.

Considering these parameters it is possible to make some comments, for example: the temperature 60 ºC reached by induced current must be obtained with the dry cable or wet cable, or in both situations? The aspersion must be 1 mm/min at total or for each component vertical and horizontal? What is the tolerance for the water conductivity? Is this conductivity so high, so low or suitable? As the water conductivity is obtained by salt addition, is this correct or can result in extra stresses that can damage the system? There is also any mention about the voltage application, if phase to ground or three-phase. By the moment, due to costs and equipment restrictions all tests around Brazilian laboratories are carried out on a phase to ground way. However, ABNT studies are pointing to a next step based on three-phase voltage applications.
For 25 kV systems, the frequent failures observed at laboratory are as shown in Figures 1 to 3.

Figure 1 – interface spacer-covered cable

Figure 2 – Erosion for cable, spacer and fixing ring

Figure 3 – Drilling cable coverage

Figure 1 shows erosion and burning signals in the spacer and in the cable with some material melting. This failure is generally assigned to dielectric compatibility. Figure 2 shows burning signals in the spacer, the cable and the fixing ring. Figure 3 shows erosion and puncture at the cable insulation in a point located at halfway between two consecutive spacers. Can this last case be attached to dielectric compatibility failure?

THE STANDARDS

The Brazilian Association of Technical Standards – ABNT provide standards including those related to electrical equipment such as power cables and fittings or hardware for overhead distribution networks. However, the use of polymeric devices is relatively recent and all the recommendations about their application come from an Association of Brazilian Utilities – ABRADEE. The development of an ABNT document concerning spacer systems is in progress based on the ABRADEE document. The present situation is that spacers and hardware standards development is based mainly in a document not so clearly written and the covered cables standard does not mention or even consider the dielectric compatibility with the component for what was designed to work with. Practically, in the present view the performance of the spacer system is a concern just for the spacer's and hardware's' manufacturers.

Therefore, considering the present trend it is expected that the spacer's and hardware's new standards will be the only to define the minimum requests for a suitable performance of system 'spacer/insulators/fittings–covered cable' at all. At this point a question arises: In a case of a system failure, mainly if followed by personal injuries, who is the responsible for the event?

THE ELECTRICAL EFFORTS

The spacer system is designed to be installed in a three-phase system. However, considering the present document there is not any mention about the way of applying voltage. Consequently, there are two possible ways to carry out the dielectric compatibility tests: phase to ground or three-phase voltage application.

According to Figure 4, for phase to ground voltage applications (same voltage to every phase) the tested system works as in as a bundle conductor system, and no leakage current flows through the three phases A-B-C. All the current flows to the grounded messenger cable M. There is also a straight forward conclusion to "the voltage stresses (due to normal and tangential electrical fields) on cables and hardware during the laboratory tests are lower than in filed operation" once that this is the purpose of bundle systems. Instead of this, for the three-phase voltage applications, considering a balanced symmetrical system, there are leakage currents through the phases, and a close to zero current to grounded messenger cable. This also results in higher voltage stress. The voltage to ground value $2U_0$ ($1.15* \sqrt{3}$) considers the possibility of applying full spacer systems in insulated or resonant grounding networks a condition that must be observed for all medium voltage apparatus and devices. This means that any reduction on the testing voltage must be effectively avoided.

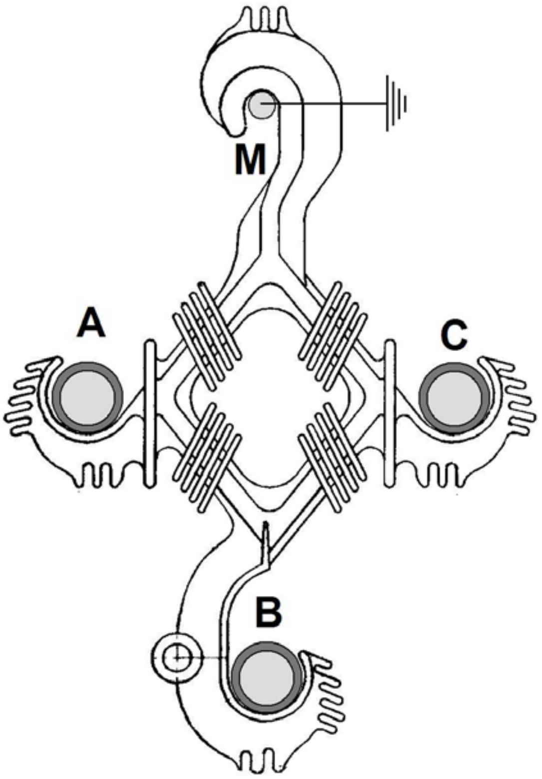

Figure 4 – Typical spacer, cables phases and messenger [2]

Take into account only the effect of the leakage current, the first result is tracking on both the cable and insulation. From this initial deterioration, results the punctures, the melting and the subsequent failure of the complete system.
If on one hand the leakage current can cause tracking on the other hand the concentration of electric field can cause punctures mainly due to distortions at interface region of cable insulation and spacers/hardware. The presence of the water during the wet cycle also is a source of electrical field distortion and stress enhancement along the cable, and it can be the cause of failures as the one shown in Figure 3 where it is possible to see the aluminium conductor.
Figure 5 shows the influence of the application of a semi-conductor layer above the conductor another key point. According to the Brazilian standards [1], the semi-conductor layer is required only for cables of rated voltages greater than or equal to 35 kV.

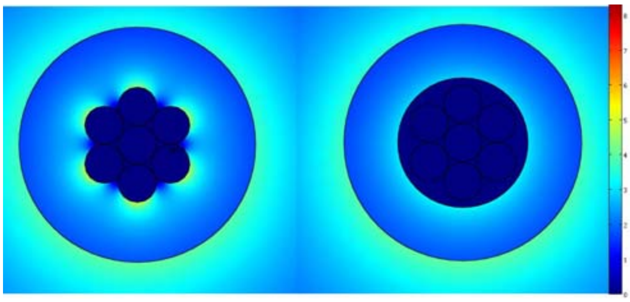

Figure 5 – Semi-conductor layer and the electric field
The absence of a semiconductor layer results in an increasing of at about of 60% in the value of the normal electric field close to the conductor in the interior of the cable insulation. This suggests that any puncture development can start from the conductor to the surface of the cable.
Figure 6 shows the electric field distortion on the surface of the cable insulation due to the presence of a water drop. When the cable insulation surface is dry, the normal electric field gradient at coverage surface is 0.4 kV/mm. The water drop at the bottom surface of the insulation increases the value of this gradient to 1.1 kV/mm. The gradient is amplified per almost 3 times the initial value at dry condition, at the interface point between the insulation and the water drop as shown by Figure 7, in a zoom to the interface point between the insulation and the water drop.

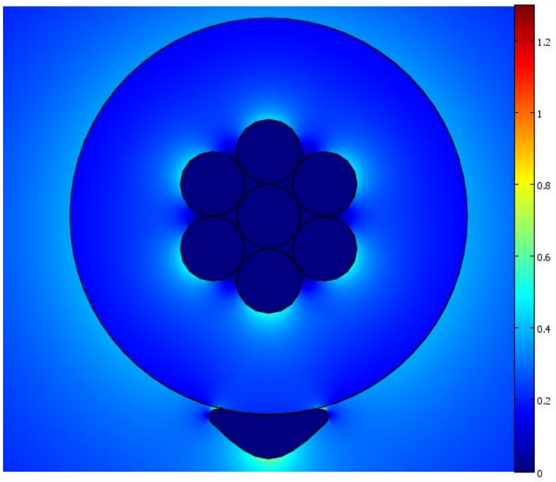

Figure 6 – Electric field between cable coverage and the water drop

This larger electrical field concentration suggests that any puncture development can also start from surface of the cable to the conductor.

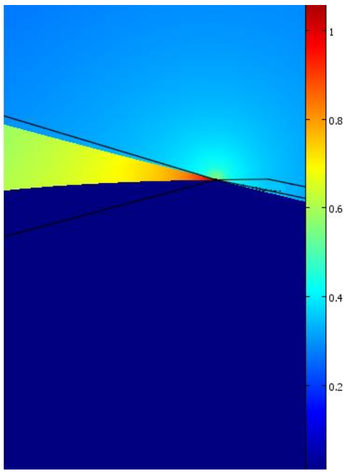

Figure 7 – Electric field between cable coverage and the water drop – closed view

TESTS RESULTS

Up to present, considering the voltage class of 25 kV there were carried out on 12 sets according to the parameters of ABRADEE and phase to ground voltage application. No one of these sets supported more than 15 from the requested 30 days of a full test. The damages observed on these tests are typically those shown in Figures 1 to 3. Following the failure progress, it was possible to observe that the damage signals first appear on the cables surface. There are some cases where the test was interrupted due to serious damages to the cable without any damage signal in the spacers. Consequently, there was no spacer failure without a simultaneous cable failure.

In theory, during the dry period all the insulation withstanding is attributed to the spacer/hardware. However, during the wet cycle, it is possible to assume that the spacer/hardware is shorted circuited by the presence of highly conductive water film on the spacer/hardware surface. Therefore, all the insulation is attributed to the cable insulation. From this point of view, both components must reduce as more as possible the phase to ground leakage current

In Brazil, for distribution networks, there is not spacers/hardware specifically designed for 25 kV networks. In these cases it is usual to apply the present 36.2 kV spacers/hardware. However, considering the standard arcing distance for these 36.2 kV systems does not fit the requested basically insulation level these designs are under review. All this adds new considerations because in fact the present designed 25 kV spacers/hardware are not oversized.

The failures in this system due to dielectric compatibility problems can be addressed to various reasons. In laboratory, however, there is a trend among the manufacturers to affirm that the problem is not with their parts, either spacers/hardware or cables. For practical reasons it does not matter if the poor component is the cable or the spacer/hardware or if both are the best of ever manufactured. The result is: “By the moment there is not dielectric compatibility between these two specific parts/components”.

However, in case of puncture in a position of the cable distant from the spacer, considering the electric field gradient, is there dielectric compatibility between the cable insulation and the water drop?

COMMENTS

The compatibility test was designed based on real field experiences, obtained by several Brazilian utilities during several years of trial with standard covered cables and systems. The main reason behind the test is to enhance the system corona aging, one of the most important factors during dielectric collapse. To get a proper performance either parts or sets must work jointly and this must be recognized by all involved during the standard drafts studies. The present situation is that just one of these parts recognizes the necessity of dielectric compatibility tests, this results is a real problem for the utilities purchase department. The present procedure results in different procedure when dealing with both sector of the industry. The cables manufacturers must fulfil the cable standards and the spacer/hardware manufacturers must fulfil the requirements of spacer/hardware standards and specifically a joint operation of the parts, only referred in these particular documents. This suggests that “The responsibility for a suitable performance of a spacer system at all must to be just of the spacer manufacturer”. The question is: Is this correct? Indeed this is not observed on the relations between the manufactures of insulated cables and their accessories like terminations and splices.

Once each manufacturer of each part/component is approved and registered, the decision of buying is taken mainly based on the price. Of course this happens only if it is not taken into account the joint performance of these suppliers of spacer/hardware and cables as required by the dielectric compatibility test.

The current interpretation is that if the system failure, it is because the spacer/hardware does not attend the minimum requirement for a suitable performance. After all, the dielectric compatibility test is mentioned just in the spacer/hardware standards and there is any mention about this test on the covered cables standards. Of course, every interpretation is in agreement to what is most interesting for each part manufacturer.

This paper shows that there are several possible start points to the system failure. One of them the high electrical field gradient on the interface point between the cable insulation and the spacer/hardware. This can be addressed to material compatibility or to the necessity of reducing the gradient or even to request for a greater resistance against tracking.

The presence of the semi-conductor layers at 25 kV covered cables can or cannot provide a better performance to the system. However, considering prices figures this can result in several further purchasing problems face to some local procedures.

Out of the tolerance values to the water conductivity, until the moment there is no reason to change the proposed value, or even aspersion rates since it takes into account the effects of the gravity and the wind on the water during the rains. Concerning the applied voltage, it seems to make more sense the application of three-phase voltages during the tests.

Finally, the dielectric compatibility test must be a procedure recognized by all parts of the industry.

REFERENCES

[1] ABNT NBR 11873:2003 – Polymeric covered cables for application compact over head systems from 13.8 up to 34.5 kV – In Portuguese.

[2] ABRADEE – Polymeric hardware for application compact over head systems from 13.8 up to 34.5 kV – In Portuguese.