PARTIAL DISCHARGES MEASUREMENTS AT FIELD, IN AGED SURGE ARRESTERS

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ABSTRACT

Surge arresters are essential equipments for protecting electrical power systems from overvoltages caused by lightning strikes and switching transients. However, arresters themselves don't have, in general, any kind of monitoring device to indicate their operation condition, for example, aging condition or malfunction. Large utilities may have installed a large quantity of aged arresters, with growing failure rate. Replacement of old units means costly downtime periods, so it is important to choose a criteria for choosing which arrester needs priority replacement. Our research has successfully shown that detection of internal discharges, or partial discharges (an important failure mode for this kind of equipment), is an effective tool for arresters' condition assessment, to pinpoint defective equipment before its failure. Measurement of high frequency components of equipments' leakage current, performed in the grounding conductor during normal operation, keeping arrester energized, can identify suspect units. Measurements were performed using high frequency current transformer. Considering measurements performed at field, problems with electromagnetic interferences arise. This problem was treated in this research by recognizing discharges using its signatures, which were previously established in laboratory tests. Using this approach, defective surge arresters were identified, prior to its failure. Suspect arresters were removed from service and field tests result were confirmed in laboratory analysis, in many successful cases.

INTRODUCTION

The aim of this research focused the evaluation of zinc oxide (ZnO) arresters, considering the historic data of failures observed in a particular family of surge arresters. In this surge arrester family, with 18 years of service, several failures were observed in the 345k surge arrester class. The analysis of the failed arresters showed the incidence of internal electrical discharges. This fact lead to the choice of using the technique of measuring the conducted electromagnetic field produced by the electrical discharges. Electrical discharges consists in the acceleration of electrical charges, mainly electrons, by the applied electrical field, generating electromagnetic fields from the discharge location, in every direction, and presents spectral energy from low frequencies up to high frequencies in the GHz range [2]. Measurement of high frequency components of equipments' leakage current, performed in the grounding conductor during normal operation, keeping arrester energized, can identify suspect units. Signatures of high frequency components of the leakage current can be obtained in laboratory test, as shown in Fig. 1

Fig. 1 shows test setup for generation of partial discharges in artificial voids introduced in polyester insulating slabs with 6 mm thickness, under 20kV potential.

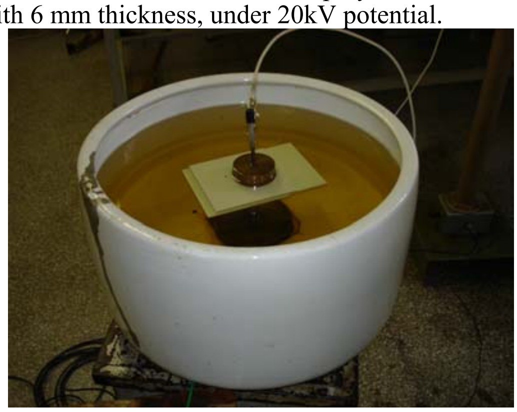

Fig. 1 - Test vessel with polyester slab containing artificial void, placed between two ASTM type brass electrodes and immersed in insulating oil.

Measurements were performed using high frequency current transformer.

Examples of measurements are shown in Figs. 2 and 3.

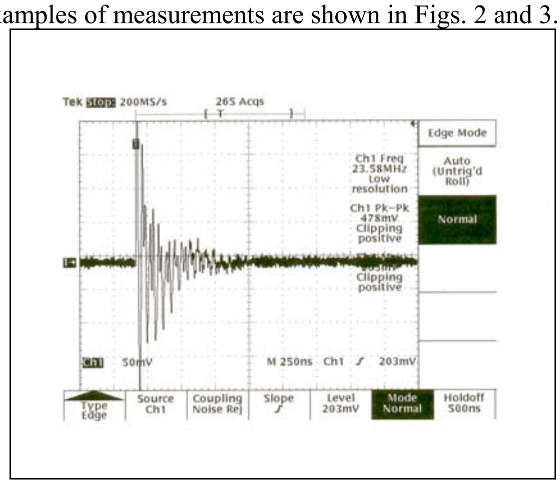

Fig. 2 – Current pulse generated by partial discharge – polyester slab sample – test voltage 29 kV - (scales 250ns/div, 50mV/div)

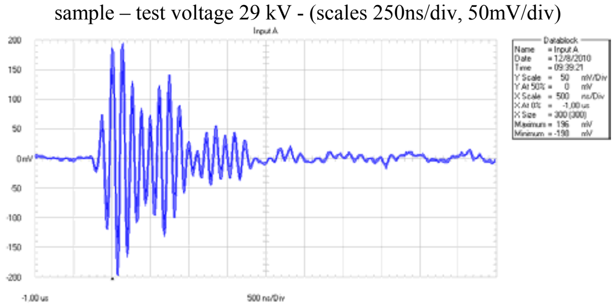

Fig. 3 – Example of partial discharge measurement at field in surge arrester.

Waveforms similar to Fig. 2 and 3 can be used as reference for characterizing and for identification of partial discharges in equipments.

MEASUREMENTS PERFORMED AT FIELD

This technique of measurement of the conducted electromagnetic field generated by partial discharges was used at the substation environment, for evaluation of 345kV class ZnO arresters. In these measurements, high frequency current pulses produced by discharges were measured in the time domain by an oscilloscope, using the high frequency current transformer installed in the grounding conductor. The obtained waveforms were analyzed by comparison with partial discharges signatures previously obtained in others laboratory and field tests [1]. This technique allowed the evaluation of 345kV ZnO arresters under normal operation, by identifying equipment suspect of degradation processes, and afterwards subjected to priority substitution, avoiding in service failures, material damages and personal hazards.
Figs. 4 and 5 show 345kV ZnO arresters tested with this technique, and the installation of the high frequency CT at the arresters' grounding conductor, respectively.

Fig. 4 - Partial discharge measurement in 345 kV substation in ZnO surge arresters.

Fig. 5 - Partial discharge measurement in 345 kV substation – Detail of the high frequency CT applied to the grounding conductor.

Figs. 6, 7 and 8 show measurement results obtained using the high frequency CT applied to the grounding conductor of the ZnO arresters, presenting a similar pattern with the ones produced by partial discharges, considering previously obtained laboratory and field test results. [1].

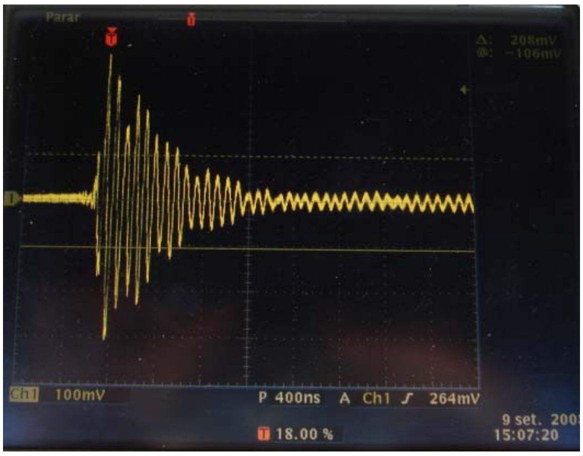

Fig. 6 - Current measured with the high frequency CT, installed in the grounding conductor of the ZnO arrester (scales: 100mV/div and 400ns/div). Pattern similar to partial discharge.

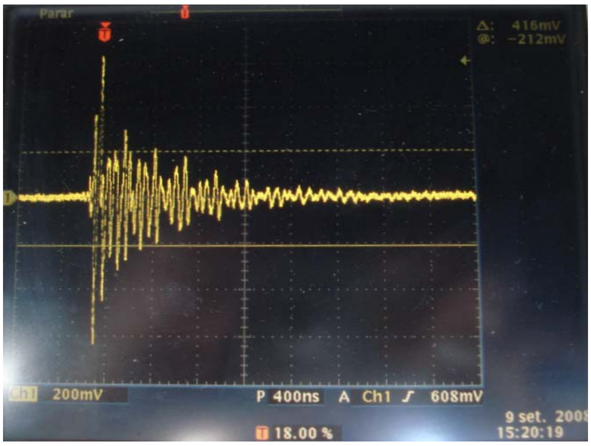

Fig. 7 - Current measured with the high frequency CT, installed in the grounding conductor of the ZnO arrester (scales: 200mV/div and 400ns/div). Pattern similar to partial discharge.

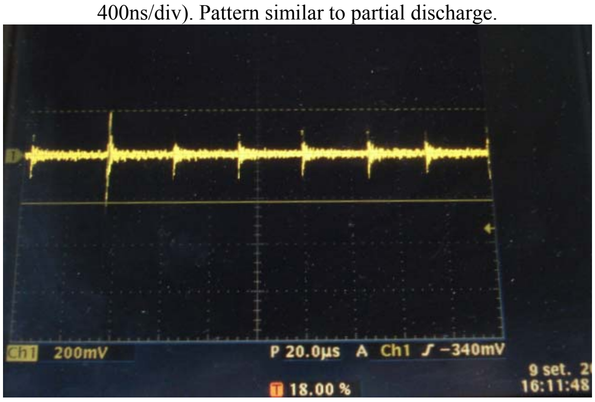

Fig. 8 - Current measured with the high frequency CT, installed in the grounding conductor of the ZnO arrester (scales: 200mV/div e 20µs/div). Pattern similar to partial discharge.

For comparison purposes, Figs. 9 and 10 show examples of waveforms in which similarity with partial discharges signatures are not observed, considering visual aspects and repetition rates. In these measurements, a low repetition rate was observed, with period of approximately 10 seconds. Possibly, those waveforms were produced by another kind of unidentified phenomena.

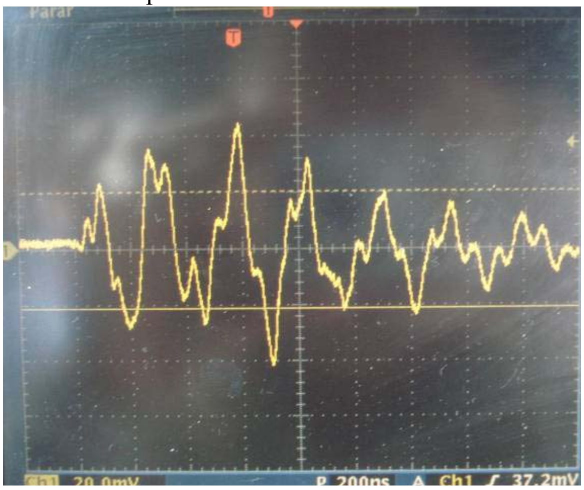

Fig. 9- Current measured with the high frequency CT, installed in the grounding conductor of ZnO arrester (scales: 20mV/div and 200ns/div). Pattern without similarity with partial discharge.

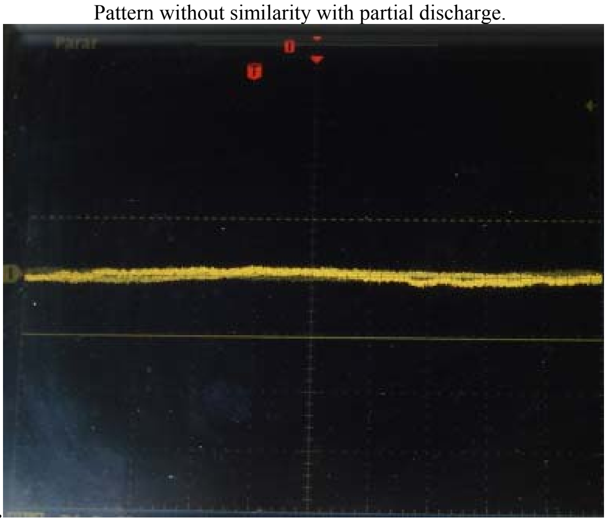

Fig. 10 - Current measured with the high frequency CT, installed in the grounding conductor of ZnO arrester (scales: 50mV/div e 200ns/div). Pattern without similarity with partial discharge.

Using this technique, 13 surge arresters where tested, and 5 were considered suspect of partial discharge activity considering the obtained waveforms. Those arresters were prioritized for replacement.

ANALYSIS PERFORMED AT THE LABORATORY

After replacement of the suspect arresters, laboratory tests were performed, using the conventional apparent charge measurement of IEC 60270 Standard [3]. According to IEC 60099-4 Standard [4], the partial discharge level limit is 10pC.

Table 1 shows the partial discharge measurement results obtained at field and at laboratory, for all 13 ZnO arresters.

TABLE 1
COMPARISON BETWEEN PARTIAL DISCHARGE MEASUREMENT RESULTS AT FIELD AND AT LABORATORY

Sample	Peak to peak value (mV) measured at field with high frequency CT	pC values obtained at Lab – IEC60270 Std.	
		At operating voltage	At 1.05 x MCOV
1	360	890	970
2	200	220	360
3	1160	1002	1510
4	260	350	900
5	1800	1650	2450
6	40 (*)	< 5	1500
7	90 (*)	< 5	2120
8	100 (*)	< 5	3600
9	360	620	980
10	20 (*)	< 5	700
11	620	100	Not measured
12	1280	< 5	Not measured
13	82 (*)	New	New

In second column of Table 1, *Peak to peak value* means the sum of the highest positive peak with the highest negative peak for each measured waveform (for example, see Fig. 4). By analyzing the results obtained at field (column 2) and at lab. (column 3), one can find that both columns show some close relationship, in the sense that obtained mV values (column 2) are an approximate estimate of the pC values (column 3) obtained at lab, with apparent charge measurement according to IEC 60270 Standard. This relationship needs a more accurate analysis, but what can be taken as conclusion is that high values (in mV) obtained at field means high levels of partial discharge activity (in pC) measured at lab. Column 4 of Table 1 shows partial discharge measurements at 1.05 x MCOV (Maximum continuous operating voltage)

INTERNAL INSPECTION OF THE ZNO ARRESTERS

At the beginning of this research, the arresters failures were supposed to be caused by discharges in the surface coating of the ZnO internal blocks inside the arrester, creating conductive paths and leading to equipment failure. After opening the arresters, shown in Figs. 11 and 12, it was concluded that the actual arresters failure was caused by failure in the arrester sealing and subsequent moisture migration inside the equipment. This kind of problem had been already seen in old silicon carbide (SiC) arresters in the past, and seems to be happening in this family of ZnO arrester.

Fig. 11 – ZnO arrester after opening. Some white corrosion can be seen in metallic parts.

Fig. 12 – Damaged grading condensers inside arrester, possible cause of partial discharges.

CONCLUSIONS

The technique shown in this research resulted in conclusive diagnostics for this kind of problem in ZnO arresters presenting internal discharges, even in the presence of electromagnetic noise. An important advantage of this technique is that the measurements are performed applying the sensor, a high frequency CT, in the grounding conductor, allowing the measurements be performed safely, and without the need of shutting off the equipment under test. The measurements performed at field provided important information for the decision making process of the arresters replacement. The laboratory tests confirmed the partial discharge activity measured at substation. After disassembling some arresters, internal damages were observed caused by moisture ingress. In the sequence, more field tests were scheduled for other arresters of this same family.

REFERENCES

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