Fundamental Differences of the PD Measurement according to IEC 60270 and in UHF range

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***Abstract*—PD measurements in the UHF frequency range are an important tool for diagnostic at GIS. A general correlation between the measurement according to IEC standard 60270 and measurements in the UHF range is not possible. By the use of a "sensitivity check" the quality of the UHF measuring system is verified at GIS. In this contribution the usual procedure is pointed out and the boundary conditions and simplifications are shown. The knowledge of this is important for the interpretation of the result of the sensitivity check.**

***Index Terms*—partial discharge, gas insulated switchgear (GIS), UHF measurement, IEC standard, IEC60270, verification of the sensitivity**

I. Introduction

TO optimise processes in utilities a condition based maintenance strategy is essential. The liberalization of the energy market forces all utilities to reduce costs. Considering the maintenance strategy of GIS, a sensitive PD detection is important. To identify the type of the PD, various proven methods are possible, like the analyses of the phased resolved partial discharge (PRPD) pattern or other techniques. For an on-line and on-site, suitable PD measurement is it possible to use the method within the UHF range, because this method is more resistive to disturbances than the measurement according to the IEC 60270 standard. The sensitivity of this measurement method is proved with a procedure called “verification of the sensitivity” or “sensitivity check”, recommended by CIGRE. By the interpretation of this sensitivity, it is necessary to keep the boundary conditions in mind.

II. Sensitivity Check for GIS

Because the measurement in the UHF range cannot be calibrated, a two-step procedure is used to guarantee a certain sensitivity of the UHF measurement system on-site. For the practical use of the UHF method, it is sufficient to guarantee a certain sensitivity of the UHF measurement system. The procedure is based on the injection of a very fast broadband impulse, so that the measurable spectrum in the UHF range is comparable to the spectrum of a mobile particle with a discharge level of 5 pC, according to the IEC standard [1]. The moving particle is used as the reverence level because it is the most common failure type [2]. The value of 5 pC according to the IEC standard is chosen because this sensitivity is needed for on-site measurements [2]. A sufficient sensitivity is verified if the injected impulse is measurable at the adjacent sensors.

A. Two step procedure for the verification of the sensitivity of a UHF-PD- measurement system

1) Step 1: Measurement in the laboratory

In the first step the needed value of the impulse magnitude is determined to create comparable PD spectrums in the lab. It is necessary to put a moving particle nearby an installed UHF-sensor inside the GIS. The voltage of the inner conductor is increased until the PD–measurement system according to IEC 60270, measures a value of 5 pC. If the PD value is reached, the UHF spectrum of the moving particle should be measured at the adjacent UHF sensor. Now the high voltage, which is responsible for the PD of the moving particle, must be switched off. The value of the impulse, which is injected at the sensor near by the particle, is changed until the measurable spectrum at the adjacent UHF sensor is in best conformity with the spectrum of the moving particle, which was measured before.

Besides a visual correlation of the spectrums, it is possible to use different mathematical analysis methods to find the impulse with the best correlation of the spectrum in the frequency range between 300 MHz and 1,4 GHz [3].

2) Step 2: On-site measurement

To verify the sensitivity of an on-site installed UHF-PD-measurement system it is necessary to inject the impulse as defined in step 1 at a sensor. It is important to use the same sensor, cable connections and measurement system as in the lab. Also the impulse shape and magnitude must be the same. If the spectrum, stimulated by the injected impulse, is measurable at an adjacent UHF sensor, the system will ensure a sufficient sensitivity for the area between these sensors. Furthermore, the maximum distance between a real moving particle and a sensor approximates half of the distance of these two sensors. This means that the PD signal has a smaller damping as the injected impulse of the sensitivity check.

B. Boundary conditions of the sensitivity check

By using this verification, it is important to consider the boundary conditions of the method. The sensitivity check simplifies the transfer functions and uses boundary conditions, which must be carefully observed for the interpretation of the results [3].

1) Disregard of the reflexion and resonance

The measurable UHF-PD signal depends on the position of the PD and the sensor, caused by the complexity of resonance inside GIS [Feger]. If the position and orientation of the PD source is known, it will be possible to calculate the transfer function with a complex high frequency model [4] for a coaxial arrangement. It is difficult to calculate the transfer function form the sensors to all locations of potential PD sources in respect of all details of the geometry of the GIS. The sufficient transfer function from sensor to sensor, which is secured by the sensitivity check, must not be the worst-case transfer function between the PD source in the GIS and the sensor. But it is a good approximation for large distances, because the damping effects dominate in this case the transfer function. Influence is thinkable in case of strong reflexion or resonance for example at T-junction or outgoing line.

2) Definition of a sufficient sensitivity

The sensitivity check is based on the use of very fast impulses, which are injected at a UHF- sensor. The UHF-spectrum, which is stimulated by the impulse, is comparable to the apparent discharge of 5 pC of a moving particle. It must be pointed out, that the value of 5 pC apparent discharge for a moving particle or an other failure type can be considered already as critically. [5]

3) The reference failure type

The procedure is based on the comparison of the measurement according to the IEC and the UHF method for a moving particle. For other failure types, for example point-plain, floating electrode or other arrangements, the ratio between the level of IEC measurement and the measurement spectrum (or impulse energy) of the UHF method is different.

Reid [6] shows in his work that the ratio between these measuring principles depends on the failure type. The ratio between the measurement values according to the IEC and the UHF method of a moving particle is for example advantageous in comparison to a point-plain arrangement [6]. The moving particle, as a reference failure type, represents not the hardly detectable failure, but is the most common failure type in a GIS. This effect is also recognizable in measurement of PRPD pattern. The characteristic pattern for different types of failures is comparable for the IEC method and also in UHF method, however the ratio of the signal intensity differs depending on the failure type.

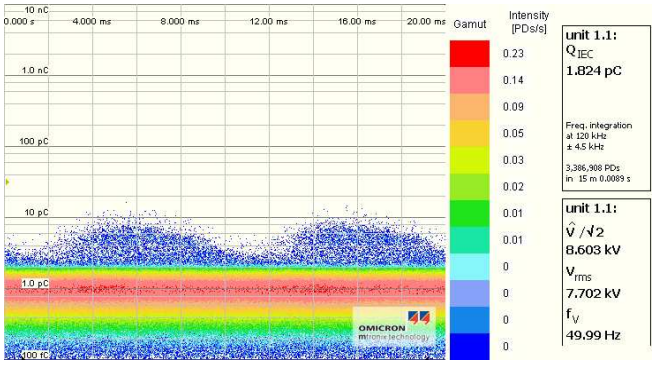

Fig. 1. Measurement of moving particle accordance with IEC

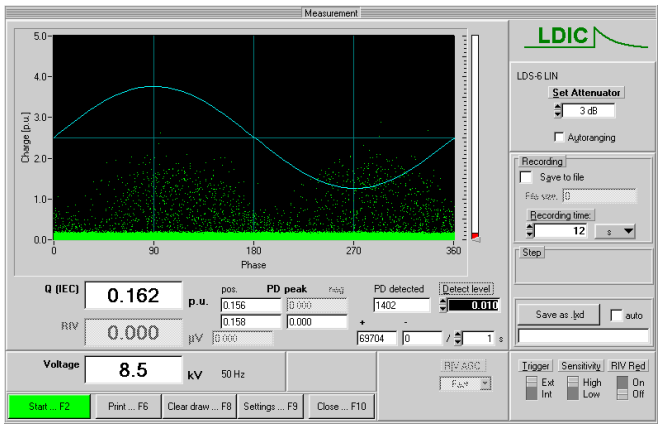

Fig. 2. Measurement of the same failure (simultaneous measurement / moving particle) with the UHF method

Figure 1 shows a PRPD pattern of a moving particle with a discharge of approximately 2 pC according to the IEC standard. In Figure 2 is a simultaneous measurement of the same failures measured in the UHF range. The typical pattern is measurable and recognizable in both figures.

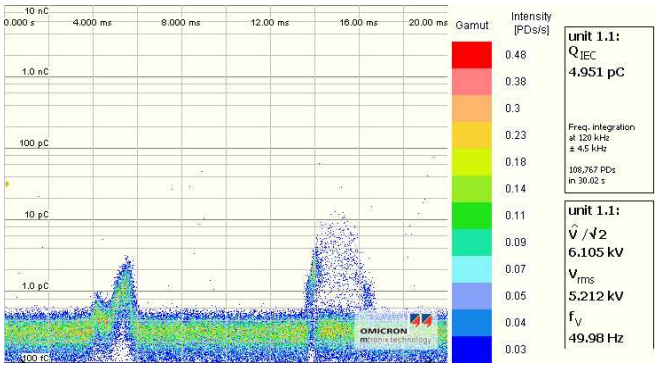

Fig. 3. Measurement of a protrusion at the inner conductor at low level according IEC

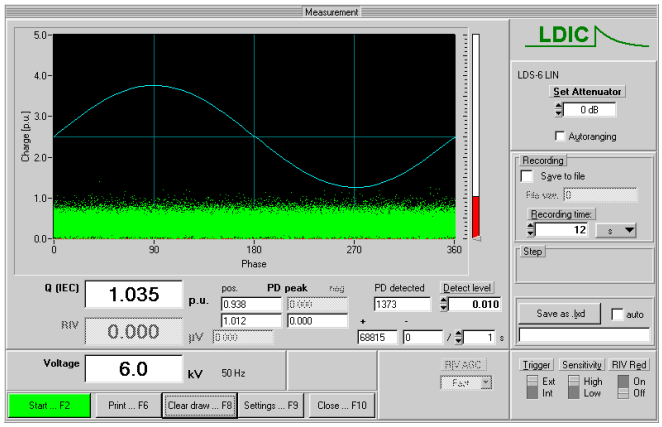

Fig. 4. Measurement of the same failure (protrusion on an inner conductor at low level / simultaneous measurements to Fig. 3.) with the UHF method

At the point-plain arrangement in Figure 3, an apparent discharge of 5 pC according to the IEC standard is measurable. But the signal of the PD source is not measurable in the UHF range (Fig 4.). The source is measurable in the UHF range not until the apparent discharge becomes about ten times higher. (Fig 5. + 6.).

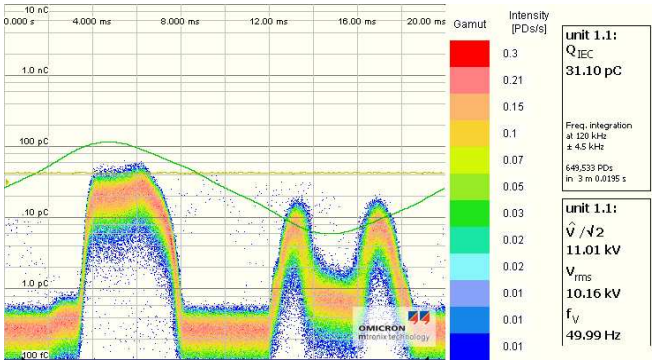

Fig. 5. Measurement of a protrusion on an inner conductor at higher level according to IEC

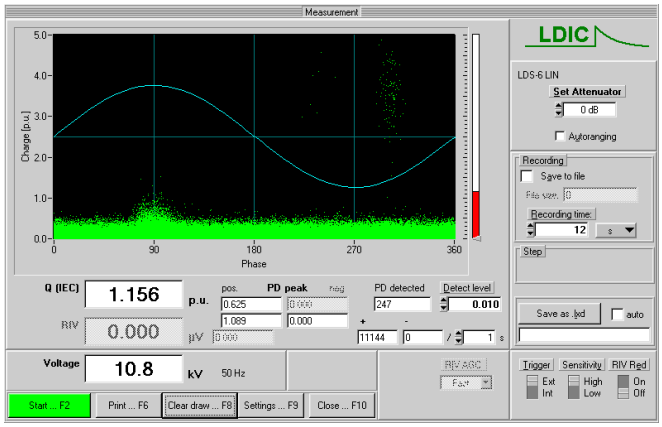

Fig. 6. Measurement of the same failure (portion on an inner conductor at higher level / simultaneous measurements to IEC Fig.5) with the UHF method

Additionally the PRPD pattern is not directly comparable for this PD source. Fig. 6. shows higher detectable UHF signals in the second half-wave than in the first one, while according to IEC the results in both half-waves seems to be of comparable amplitude. This is caused by the impulse less persistent corona of the point-plain arrangement at high field strength. The bandwidth of such a corona is small and not detectable in the UHF range. I.e. that the point-plain arrangement, especially during the first half-wave, seems to be better for performing a worst-case estimation of the sensitivity of UHF measurements.

III. Conclusion

This article shows the „sensitivity check“ at GIS as recommended by CIGRE. For the interpretation of this procedure attention is necessary for different simplification and special definitions.

The meaning of the reference failure type is important. The moving particle is not the minimum detectable case in the UHF range. Other failure types can have a much smaller intensity than the moving particle at similar value, according to the IEC standard. The moving particle is the most common failure and so it is possible to measure in majority of cases very sensitive. Founded by the on-line the applicability and because of the robustness against disturbances, the measurement with the UHF method is a useful alternative, compared to other measurement principles. Additionally in all cases, such a sensitivity check is a possibility to verify the function of the sensor, the connection cable, the amplifier and the measurement system.

In connection with proceedings [7] to establish new verification of the sensitivity procedure at other equipment like power transformers, it is necessary to discuss the test conditions for each device under test, especially regarding the failure type.

IV. References

[1] CIGRE, Joint Task Force 15/33.03.05 (1999) "Partial Discharge Detection System for GIS: Sensitivity Verification for the UHF Method and the Acoustic Method", ELECTRA Nr. 183, April 1999, S. 75-87

[2] CIGRE, Joint Working Group 33/23.12 (1998) "Insulation Coordination of GIS: Return of Experience on site tests and diagnostic techniques", ELECTRA Nr. 176, Feb. 1998, S. 67-97

[3] R. Feger, "Sensoren und Verfahren der UHF-Messtechnik an GIS" Ph.D. Thesis, IEH, Universität Stuttgart, 2001.

[4] Judd, M. D.; Farish, O.; Hampton, B. F. (1996) The Excitation of UHF Signals by Partial Discharges in GIS, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 3 No. 2, April 1996,

[5] Colombo, E., Kultonowicz, W., Pigini, A.: "Sensitivity of Electrical and Acoustical Methods for GIS Diagnostics with Particular Reference to On-Site Testing", CIGRE-Symp., Berlin, 1993, paper 130-13.

[6] A. J. Reid, M. D. Judd, B. G. Stewart, R. A. Fouracre and S. Venkatesan, "Correlation between RF energy and IEC60270 apparent charge for selected partial discharge source geometries", ISH Ljubljana, Slovenia, August 27-31, 2007, Proceedings of the 15th ISH, T7-531

[7] S. Coenen, S. Tenbohlen, S. Markalous, T. Strehl "Performance Check and Sensitivity Verification for UHF PD measurements on power transformers", ISH Ljubljana, Slovenia, August 27-31, 2007, Proceedings of the 15th ISH, T7-100