TRANSFORMER DIAGNOSIS CORRELATING DGA WITH PD MEASUREMENT RESULTS

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Abstract **– This contribution describes an off-line partial discharge (PD) detection technique for large power transformers in the substation environment.**
It is demonstrated that off-line PD-analysis is one of the most meaningful method to asses the insulation condition of large transformers. The interpretation of PD test results needs complementary diagnostic methods such as dissolved gas-in-oil analysis.

Keywords: *large transformers, partial discharges, DGA.*

1. INTRODUCTION

The power transformer is the most expensive component of the electric power generation and transmission system having at the same time a special strategic importance. That is why its safety is of a crucial importance for the operation of the power grid.
A major failure of the transformer caused by the breakdown of its insulation can generate great repair costs and financial losses due to the interruption of the power transmission process. Therefore, the utilities are very interested to evaluate the condition of transformer insulation.
In Romania, as well as in most West European countries, the average operation time of the transformers in service is over 30 years [1] being necessary special monitoring and control measures.
Obviously, energy market liberalization generates investment strategies having as a result the extension of the lifetime and the decrease of the maintenance costs. These strategies have created the necessary conditions for the implementation of advanced on-site diagnosis methods.

2. ON-SITE PARTIAL DISCHARGE (PD) MEASUREMENT

PD measurement represents an efficient evaluation method for the failures in transformer insulation. It is validated in the diagnosis process of the new or repaired transformers before sending them to the user [2, 3, 4].
The transition from PD measurement in areas with weak electromagnetic disturbances to areas with strong ones was possible due to the use of the digital technique in signal acquisition process and to signal processing with programs specially developed to discriminate partial discharges from external disturbances [5, 6, 7].
The measuring technique developed within the frame of ICMET Craiova has as main element of the PD measuring circuit a digital system (with three channels) for the synchronous recording of the electric signals picked up from the outputs of the analyzed transformer bushings (Fig.1).

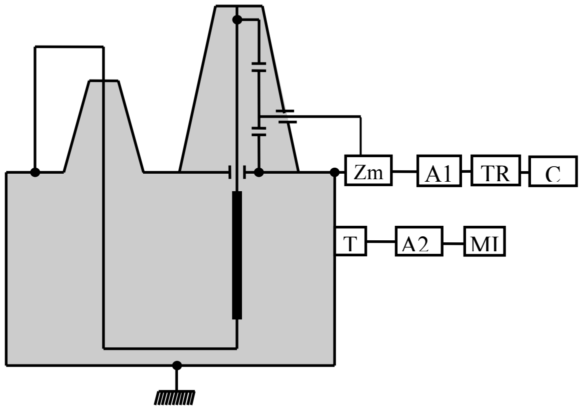

Fig.1 Block diagram of PD electric and acoustic measuring circuit

Zm - measuring impedance
A1 - broad band amplifier
TR - transient recorder
C - computer
T - acoustic transducer
A2 - narrow - band amplifier
MI - measuring instrument

The measuring chain for each channel is composed of a coupling quadripole and an amplifier with a band within 50-300 kHz.
The recorded signals are processed off-line. The filtering algorithm is based on the difference existing between the spectral function of the PD impulse and that of a periodic type disturbance. While the energy of the PD impulse is relatively uniformly distributed on the analyzed frequency range, the energy of a periodic disturbance has specific frequencies. The acquisition time was calculated so that to minimize its influence on the spectral functions of the periodic signals. The sampling rate was determined correlating the frequency where the signal attenuation becomes significant with the requirements of Shannon's theory.

The signals organized in data blocks are transferred from time to frequency range multiplying them with a window function and applying then the Fast Fourier Transform. The best results are obtained with Hamming window function that do not introduce parasitic components in excess.
In the frequency range, the periodic disturbance is identified and the spectral function of the PD impulses is restored in the areas where suppressions were made.
PD impulse discrimination from the Corona ones is achieved in the time domain by a comparative analysis of the impulse location place and of the DC high voltage phase.

3. Correlation between PD measurement and DGA

All the tests described hereinafter were performed using a mineral transformer oil type TR -30.1 that was artificially aged keeping it for 100 hours in a special enclosure at 80 □C in the presence of some samples of iron, copper and aluminum. Samples of the said oil were placed in a peak-plate electrode configuration and energized for a pre-set period of time.

The experiments showed that the apparent charge q does not depend on the test duration (Fig.2). However, the number of partial discharges n decreases with test duration.

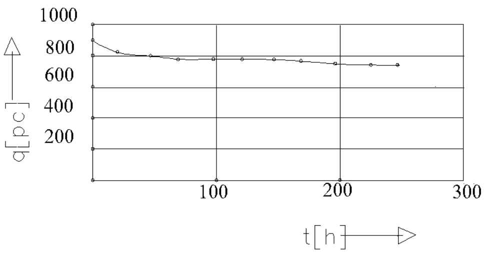

Fig.2 Apparent charge q versus test duration t

The experiment was resumed and after about 100 hours the voltage was interrupted, the experiment being resumed again after 24 hours.
It was ascertained that the number of partial discharges increased but within the next hours it decreased continuously (Fig.3).

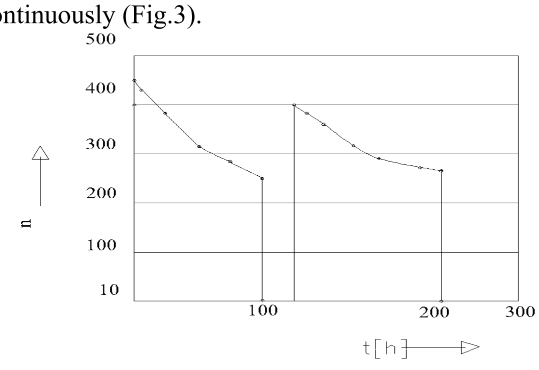

Fig.3 Number n of PD versus the test duration t

In order to clarify this influence the oil was energized for different periods of time (8 hours and 8 days).
Afterwards, the number of impulses was recorded for 80 hours. It was ascertained that the PD activity after an 8 days energizing is lower than the PD activity after 8 hours (Fig. 4).

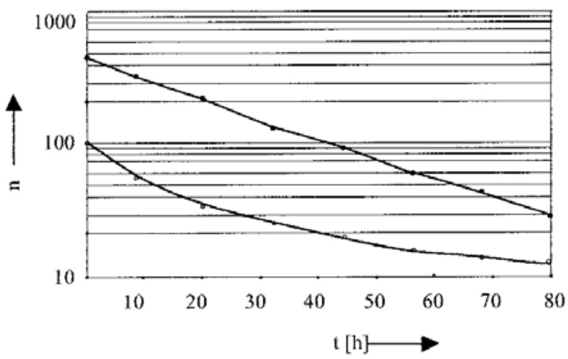

Fig. 4. Number n of PD versus the test duration t

Δ t - standing time
- Δ t : 8 days
- Δ t : 8 hours

The experiment shows that under the action of the electric field, the partial discharges are a reversible phenomenon and their activity in oil is time decreasing.
The experiments continued with Oil Dissolved Gas Analysis (DGA) after the measurement of some PD pre-set levels.
The following ones were found out:

- O_2 content is decreasing significantly when PD energy is increasing (Fig.5)
- H_2, CH_4, C_2H_2 and C_2H_6 content is increasing when PD energy is increasing (Fig.6)

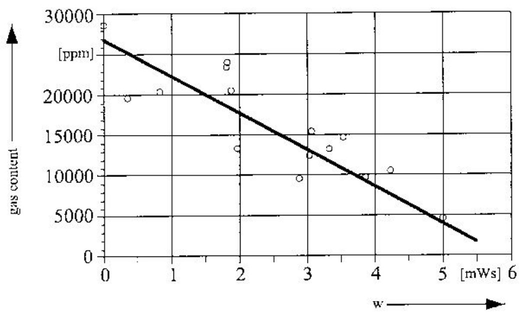

Fig.5 Oxigen content versus the PD – energy w

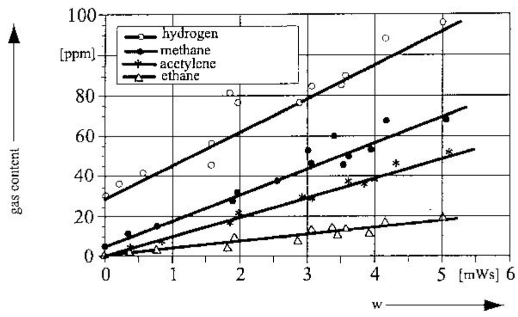

Fig.6 Gas contents of hydrogen, acetylene, methane and ethane versus the PD – energy w

- H2/ CH2 ratio is decreasing with PD energy (Fig.7)

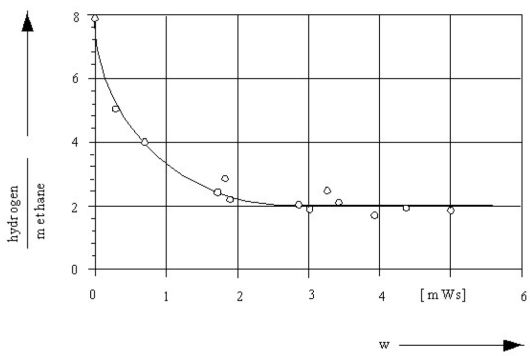

Fig. 7

The results obtained are in compliance with the interpretation of DGA proposed by CIGRE WG 15.01 [9] that uses H2/CH4 ratio to identify the PD of low energy and C2H2/ C2H6 ratio for discharges of high energy.

4. Experimental results

So far, there were performed on-site PD measurements at over 6o transformers. Each transformer had its own history. In order to prove that the method is objective, it is presented the case of a 250/250/80 MVA; 400/110/24 kV transformer from Constanta substation. After diagnosis, the said transformer was brought for untanking and inspection to the transformer factory of Electroputere Craiova .

The PD measurements showed that at no-load operation the PD level of the transformer was relatively low. Transformer monitoring by measuring the PD level continuously and the gas content daily showed a PD level increase proportional with the loading degree (Fig.8) at one of the windings with a rated voltage of 400 kV.

Analyzing the PD level (Fig.10) and the evolution of different gas dissolved components (Fig.9) it is noticed that:

- PD level increases proportional with transformer load;
- H2/ C2H4 ratio is practically constant varying within the range 1,5-2,75
- C2H2/C2H6 ratio is constant and has an acceptable value in the first three days at no-load operation of the transformer but afterwards a spectacular increase takes place at on-load operation
- CO2/CO ratio also increases proportional with the increase of the transformer load.

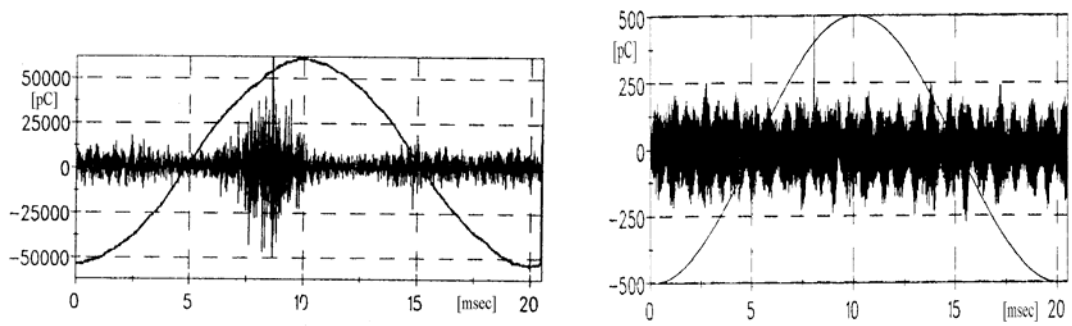

Fig. 8 PD signal after processing measured at a 250/250/80 MVA 400/110/20 kV transformer

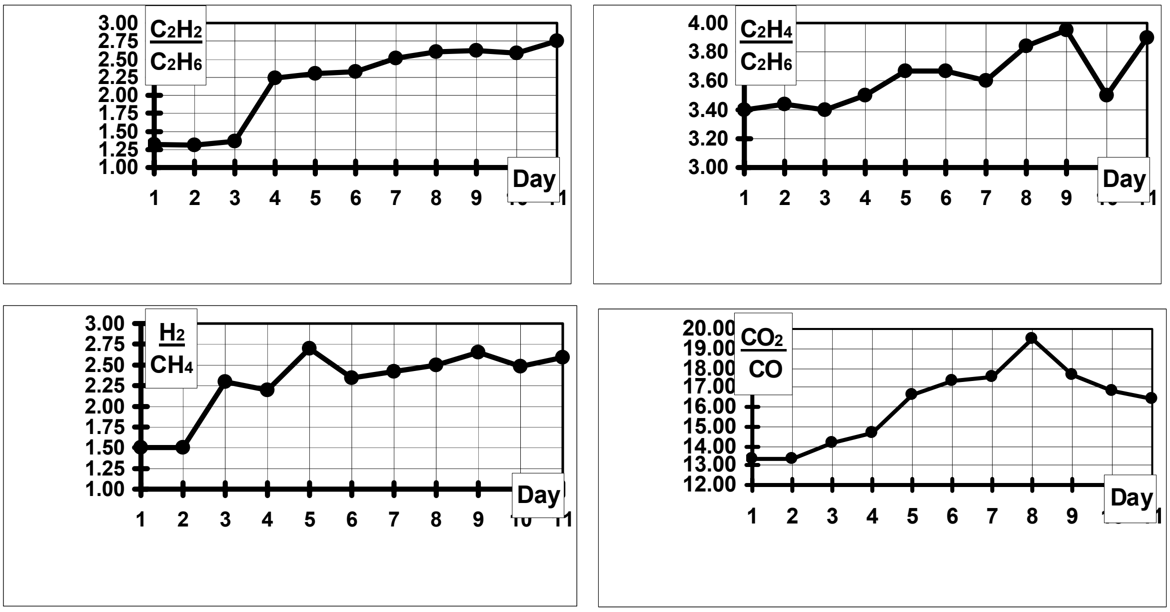

Fig. 9 Time evolution of the significant key ratios at 250/250/80 MVA, 400/110/24 kV transformer from Constantza Station

Days 1 ÷ 3 U = 400 kV I = 0 A Days 4 and 5 U = 400 kV I = 25 A
Days 6 and 7 U = 400 kV I = 100 A Days 8 and U = 400 kV I = 200 A
Days 10 and 11 U = 400 kV I = 150 A

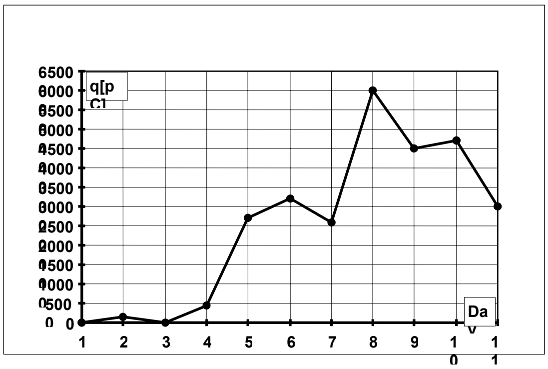

Fig.10 PD level variation at transformer 250/250/80 MVA, 400/110/20 kV CONSTANTZA

In the 8-th and 9-th day the transformer load was maximum, 80 MW and had as a result a maximum value of the PD level and also of the ratios: C2H2/C2H6 and CO2/CO.

When the transformer was untanked, the failure was found at the indicated phase. It was located at the circular screen (Fig.11) mounted on the top side of the winding with the rated voltage of 400 kV. Following the above investigation, the following conclusions arise:

- If only DGA performed, the failure magnitude cannot be assessed and the allowed limits for the key ratios are not enough [10].

- PD measurement is complementary to DGA enabling the determination of the failure place, nature and hazard degree for the transformer lifetime.

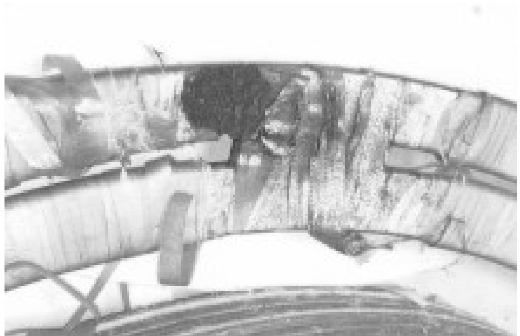

Fig.11 Photograf of the fault screen

5. CONCLUSIONS

Taking into account that oil dissolved gas measurement is relatively easy to perform and at low costs, it is advisable to perform it frequently and even an on-line monitoring to be performed.

When an increase of the key ratios is noticed, a PD measurement shall be proposed to asses the insulation condition of large power transformers and if high PD levels are measured a long time monitoring of electric discharges evolution is advisable.

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