Pre-breakdown current discrimination diagnose technique for transformer mineral oil

F. BENYAHIA[a], H. MOULAI[a*], A. NACER[a], F. ABERKANE[a], A. BEROUAL[b]
[a]*Laboratory of Electrical and Industrial Systems, FEI, USTHB, BP 32, Bab Ezzouar, Algiers, Algeria*
[b]*Ecole Centrale de Lyon, Ampere CNRS UMR 5005, 36 avenue Guy de Collongue, 69134 Ecully, France*

This paper presents a survey of positive pre-breakdown and breakdown currents in transformer mineral oil submitted to 50 Hz alternating voltage. The streamer positive currents are classified according to their possibility to lead towards breakdown. The data constituting the current vectors are collected in real time and smoothed by the use of arithmetic and geometric averages in order to serve as a fast and reliable diagnosis element.

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1. Introduction

Engineers always tried to find techniques and methods enabling to diagnose the inner state of power transformers, especially their insulation system [1-8]. This challenge has been the subject of different standards dedicated to measurement techniques and diagnosis methods. A great part of these recommended methods are executed with a better time limit of one day or plainly at the stopping of the transformer [9, 10]. They sometimes come very late, notably when the deterioration process is accelerated. Several techniques and equipments of supervision or pre-diagnosis in real time have been developed to serve as a complementary contribution to the classical methods [1-4]. They are based on the detection of a lowest electric, acoustic, optic or electromagnetic signature radiated by the transformer [5-7].

The streamers generation and propagation phenomena in liquid dielectrics are relatively complex and depend on several parameters such as the shape and magnitude of the voltage, the molecular structure of liquids and the electrode geometry [11,12]. The knowledge and the understanding of the influence of these parameters are essential for the development of diagnosis techniques to make decisions in real time.

This paper deals with the development of a methodology of diagnosis on transformers insulation through the analysis of the shape and amplitude of pre-discharge currents. The technique is based on the filtering of current signals followed by the calculation of their averages. The used database is obtained by a systematic study on the currents (charges) of positive streamers propagating in transformer mineral oils under ac voltage.

2. Methodology

The processing program of supervision of transformers we developed consists in selecting data to discriminate between currents of electrical discharges and classifying them in several categories: high or low current level discharges and streamer currents followed by electric arcs. Each type of current signal is presented in Fig. 1.

The followed steps are described in the flowchart of Fig. 2.

The obtained data are adjusted in order to make the same size to the matrixes of acquired signals by generating other points by linear interpolations. The signals thus obtained are then sampled. From this database, the different graphs are sorted according to their shapes. This allowed us to clear three shapes of currents classification susceptible to appear at practically the same voltage ranges:

(i) Currents of type A of weak energy whose period is not sufficient to enable their corresponding streamers to reach the opposite electrode. It corresponds to the propagation of a streamer extinguishing before crossing the entire electrode gap.

(ii) Currents of type B correspond to streamers extinguishing after their arrival on the opposite electrode. They are characterized by the existence of an inflection point observed especially when applied voltages are sufficiently high. This inflection point is localized between the middle and the 2/3 of the rise period corresponding to the arrival of streamer on the plane.

(iii) Currents of type C are similar to those of type B with regard to the rising phase corresponding to the streamer propagation, except that they can transit at any time into an arc, the current of which is inverted and its magnitude is very high. These are the current types that must be necessarily identified.

3. Sampling of the digitized curves

The aim of this section involves with the creation of coordinates with regular step. This is fixed by the user in the calculation program, because the original files don't present any equidistance between successive points.

In addition, the data sources don't maintain the same number of points, which is a mandatory condition for the progress of the analysis program, and then in the comparison between the input current vector and the typical samples of the database.

The used principle in the present case is based on the linear interpolation. From this principle, a Matlab software program has been built. It aims with solving a regular or no regular sampling problem. The problem starts from an ill-sampled source "with no regular step", or a perfectly regular sampling but whose the sampling step is not adapted to what one searches for.

After standardization of the sampling, and in order to ensure the same size for all data vectors, one introduces a by-program that prevents vectors to overtake the size fixed by the user. In the opposite case, the program interpolates the last value automatically in order to complete the missing value. For the present case, the step has been fixed to 0.015 µs with a number of 1150 points for each signal.

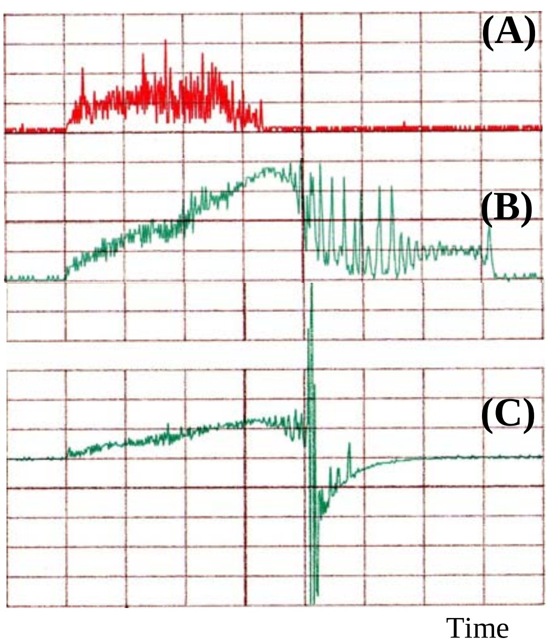

Fig. 1. Different typical shapes of positive currents. Scale: Current: (A) and (B): 1.5 mA/div; (C): 4.5mA/div; time: 2µs/div.

4. Transition from real values to reduced ones

In this section, all current magnitudes have been converted into relative (or reduced) values, in percents (%) of the most elevated recorded value of the current continuous component. The current peaks that are superimposed to them and which can have very high magnitude are not taken into account. They will be partially smoothed at the end of the present work. It is well known that electric discharge currents keep more or less the same shape, but their amplitudes differ with the application of more elevated voltages.

This is also justified by the fact that the sources of discharges can be multiple and can generate currents of the same shape but of different magnitudes which can however represent the same danger with regard to the whole insulation.

5. Database creation for each group of graphs

It consists on reassembling all data of the different graphs that have the same general shape in a matrix of dimension x*750, where x represents the number of graphs of the same type, as "x.mat" file type. This phase comes after sampling and translating to relative values for each current type in order to be ready to programming and compilation of the software.

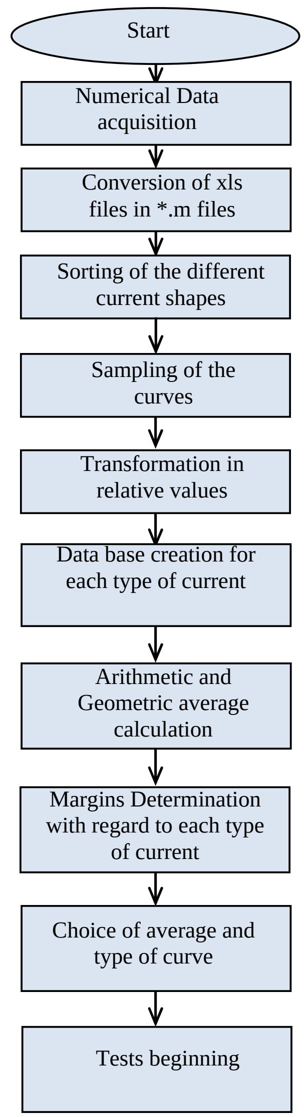

Fig. 2. General flow chart of the used technique.

6. Arithmetic and geometric average calculation

For each category of current, one calculates the wanted total average (arithmetic or geometric) in order to bring the curves of the same type further closer together by the minimization of background noises and to gain in time of calculation that is a fundamental parameter for what concerns us. Figs. 3 and 4 show the variations of the arithmetic and geometric averages of currents of types B and C. However, this process enabled to maintain some persistent variations of current peaks as well as the point of inflection of the continuous component that can have some physical interpretations as for the distribution of energies and the dynamics of discharge. Note that the geometric average is always greater than the arithmetic one.

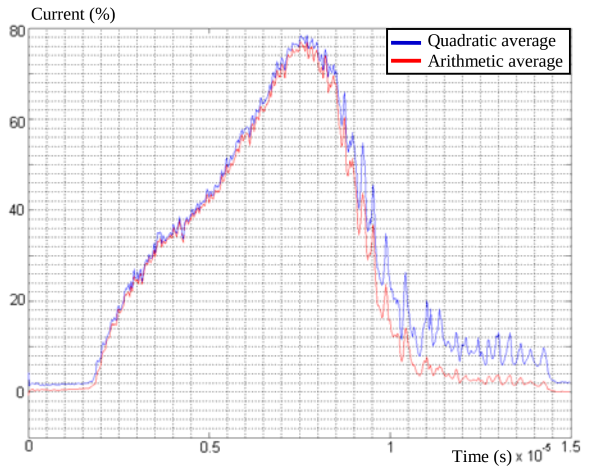

Fig. 3. The two average curves (Quadratic and Arithmetic) of the current of type B.

7. Testing part of the software

At the beginning of test, one enters the vector to be tested, and at the same time one receives the different averages that are stored in the database. The number of average for each type is called at the beginning of subroutine. A comparison will be performed point by point with the database curves. At the end, a vector containing the gaps between the vector in test and the database stored averages will be obtained. The minimum gap for each point will be calculated and stored inside a variable vector noted "mini" and its corresponding index noted k. and so forth until the end where one can get back the resulting vector that can indicate to which signal it fits better.

8. Results and interpretations

In the present case, one uses as a testing source 81 signals that share in 3 wide types: (i) Current signals of type A corresponding to weak positive streamers not having sufficiently energy to reach the opposite electrode; (ii) Currents of type B, more energetic and disposing sufficiently energy to reach the opposite electrode and to die out afterwards; (iii) Currents of type C, much more energetic and corresponding to streamers reaching the plane and followed by an electric arc occurrence.

The obtained results are given in Table 1 for the quadratic average and Table 2 for the arithmetic mean. Currents of type A are better identified by the quadratic mean whereas the test performed by the arithmetic mean classifies them in majority as being of type B. It is true that the fact to transform all signals in relative values eliminates the difference of amplitude that exists between these types of current. On the other hand, currents of type B are better identified by the arithmetic average which gives 84.72% of success. Both methods yield the same rate of reconnaissance for currents of type C which is 83.33%. The assimilation errors are however exclusive to neighboring current types. It is null with regard to the assimilation of type A currents by C type currents and vice versa.

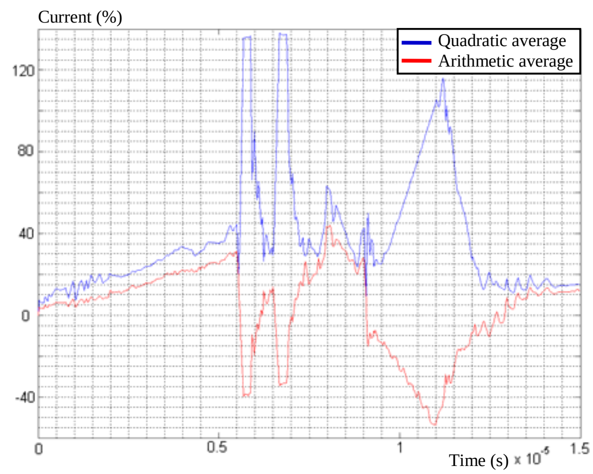

Fig. 4. The two average curves (Quadratic and Arithmetic) of the current of type C.

Table 1. Rate of reconnaissance in % for each type of current obtained from the quadratic mean.

Quadratic average	Type A	Type B	Type C
3 Samples type A	67	33	0
72 Samples type B	12.5	83.33	4.16
6 Samples type C	0	16.67	83.33

Table 2. Rate of reconnaissance in % for each type of current obtained from the arithmetic mean.

Arithmetic average	Type A	Type B	Type C
3 Samples type A	33.33	66.67	0
72 Samples type B	13.89	84.72	1.39
6 Samples type C	0	16.67	83.33

In this section, we proceeded to the total elimination of peaks in order to lighten the matrixes of current and so to save calculation time. The received signal is transformed to an average signal by proceeding with arithmetic averages between two successive components of the vector on test.

The current magnitudes are then decreased while performing the average between its components two by two. One can see the obtained results on the basis averages that represent each type of current. They are presented on Figs. 5 and 6. Results of tests based on smoothed currents are presented on Table 3 for the quadratic average and Table 4 for the arithmetic average.

The tests concerning currents of type A are less conclusive as they much more diagnose currents of type B. This is not constraining because the currents of type A and B don't represent any imminent danger for the insulation. The only major difference that exists between these two current types concerns the amplitude of each of them. As the currents have been reduced to relative values, one can understand the reasons of such assimilation. Currents of type B are however identified with a rate of success of 94.4% for both quadratic and arithmetic averages.

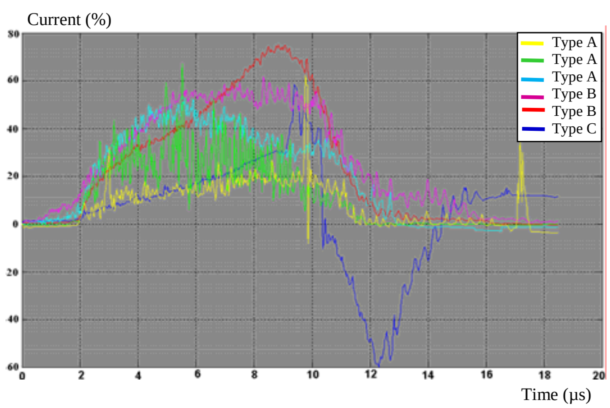

Fig. 5. Different types of positive current before smoothing.

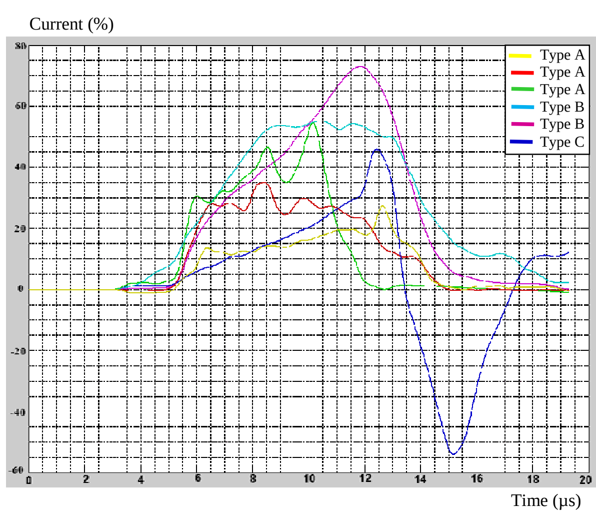

Fig. 6. Different types of positive current after smoothing.

Table 3. Rate of reconnaissance in % for each type of smoothed current obtained from the quadratic mean.

Quadratic average	Type A	Type B	Type C
3 Samples type A	33.33	66.67	0
72 Samples type B	2.78	94.44	2.78
6 Samples type C	0	33.33	66.67

Table 4. Rate of reconnaissance in % for each type of smoothed current obtained from the arithmetic mean.

Arithmetic average	Type A	Type B	Type C
3 Samples type A	33.33	66.67	0
72 Samples type B	2.78	94.44	2.78
6 Samples type C	0	16.67	83.33

The error on the assimilation to currents of type C is 2.78%. Currents of type C are better identified by the arithmetic average method. The rate of identification is 83.33%, identical to that one obtained previously without signal smoothing.

For the 4 considered approaches, no signal of type A has been identified as being of type C, and no signal of type C was identified in its turn as being of type A.

9. Conclusion

This work shows that it is possible to supervise in real time the state of transformers by means of the analysis of discharge currents. To render the proposed technique acceptable, it is necessary to undergo the recorded digital signals a specific processing as they will be easily comparable. An operation of peaks elimination is also necessary to take into account only the intrinsic characteristics of each signal, and thence to facilitate its ranking and to gain in computation time.

The database we acquired evidences three apparent types of current, apart from those characterizing negative discharges, which are of lower amplitude with regard to the positive currents and are initiated at higher voltage levels. The developed program is well adapted to the acquisition and processing of signals directly received via RS 232 port or others.

This methodology represents a useful tool of observation, analysis and corrective decision taking or stopping of the transformer in real time. It can constitute a complementary tool to the classical techniques of periodical diagnosis.

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*Corresponding author: moulaih@yahoo.fr