Software System for Finding the Incipient Faults in Power Transformers

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***Abstract* – In this paper a new software system for finding of incipient faultsis presented.An experiment is made with real measurement of partial discharge(PD) that appeared in power transformer. The software system usesacquisition data to define the real state of this transformer. One of the most important criteria for the power transformer's state is the presence of partial discharges. The wave propagation caused by partial discharge depends on scheme of the winding and construction of the power equipment. In all cases, the PD source had a specific position so the wave measured from the PD –coupling device had a specific waveform. The waveform is different when PD-coupling device is put on a specific place. The waveform and the time of propagation are criteria for the localization of the source of incipient faults in the volume of power transformer.**

***Keywords* – power transformer, partial discharge, localization.**

1. Introduction

Power transformers are used to transform voltage from one to anothervoltage level and are an integral component of a power system. A typical transformer incorporates coils of conducting wire wrapped around a core and covered with a paper-based insulator. Essential to the operation of these units are transformer oils that have two functions: electrical insulation and heat dissipation. Regrettably, there are instances of transformers failing whilst in service, creating significant cost implications for the power supplier and, in extreme cases, explosion with a consequent threat for workers for severe injury or death and significant environmental impacts.

According to International Standard of the IEC (International Electrotechnical Commission) related to partial discharge measurements, partial discharge is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor. Partial discharges (PDs) are in general a consequence of local electrical stress concentrations in the insulation or on the surface of the insulation [1].

The electrical partial discharge measurement is the most suitable method for assessing the condition of insulation systems in high voltage equipment. Conventional partial discharge measurement systems areproven to have some difficulties in the measurements, particularly in online conditions and noisy environments.

2. Partial discharge measurement and software system implement

In order to study the phenomenon of partial discharge, a simple model with insulation between copper conductor and steal tank is made. Partial discharge can be described as an electrical pulse or discharge in a gas-filled void or on a dielectric surface of a solid or liquid insulation system. This pulse or discharge only partially bridges the gap between phase insulation to ground, or phase to phase insulation. These discharges might occur in any void between the copper conductor and the steel of the grounded tank. The voids may be located between the copper conductor and insulation wall, or internal to the insulation itself, between the outer insulation wall and the grounded shield, or along the surface of the insulation. The pulses occur at high frequencies; therefore they attenuate quickly as they pass to ground. The discharges are effectively small arcs occurring within the insulation system, therefore deteriorating the insulation, and can result in eventual complete insulation failure.

The possible locations of voids within the insulation system are shown in Fig. 1.

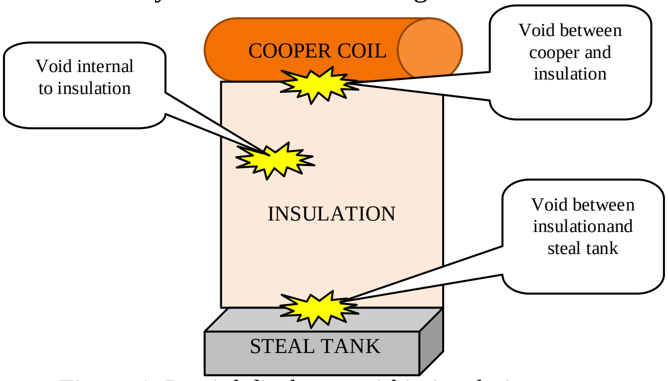


Figure 1. Partial discharge within insulation system

The other area of partial discharge, which can eventually result, is insulation tracking. This usually occurs on the insulation surface. These discharges can bridge the potential gradient between the applied voltage and ground by cracks or contaminated paths on the insulation surface. This is illustrated in Fig. 2. The above can be illustrated by development of a simplified model of the partial discharges occurring within the insulation system[4].

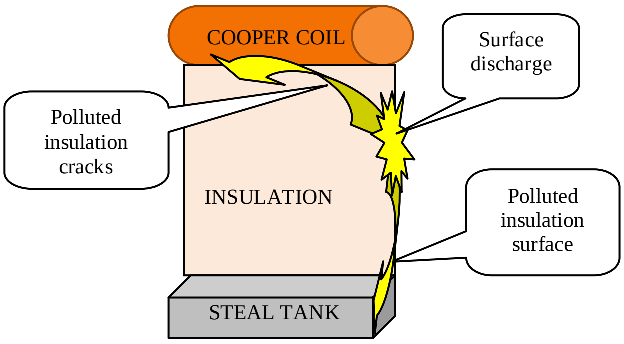


Figure 2 Surface partial discharge

Themeasurement of the partial discharge begins with placement the sensors around the transformer. The transformer is shown in Fig. 3.The outputs are linked to the digital oscilloscope. Measurement circuit consists of measuring transducers (sensors) with bandwidth from 1 to 400MHz, connecting cables with same length and digital oscilloscope with bandwidth 400MHz, 2,5GSa/s.

Figure 3. Power transformer

In order to improve the existing analysis of measurement result a software systembased on an algorithm for localization of partial discharges in the volume of the transformeris made.Time delays of the electromagnetic waves travelling in the volume of the power transformer, from the assumed location of the partial discharges to the location of each of the measuring sensors, turned out to be of a paramount importance.

When the measurement system is connected, the signals are registered. Next, the partial discharge (PD) impulses are separated and the data is transferred to the Module of Comparison. The time delay between registered PDs is obtained from each measuring channel as well as the time of their occurrence. This information is then transferred into the Module of Calculation, where the approximate position of PD is calculated with *x*, *y* and *z* coordinates. This position of the PD is visualized through the Module of Visualization and an expert determines this part of the transformer where the partial discharge occurs. Using the partial discharge signal structure, the Module of Classification determines the type of the partial discharge. Together with the chemical condition of the oil in the power transformer, the final decision is taken from the Module of Decision.

The block diagram of software system consists of described modulesthat explain the process step by step, as shown in Fig.4.

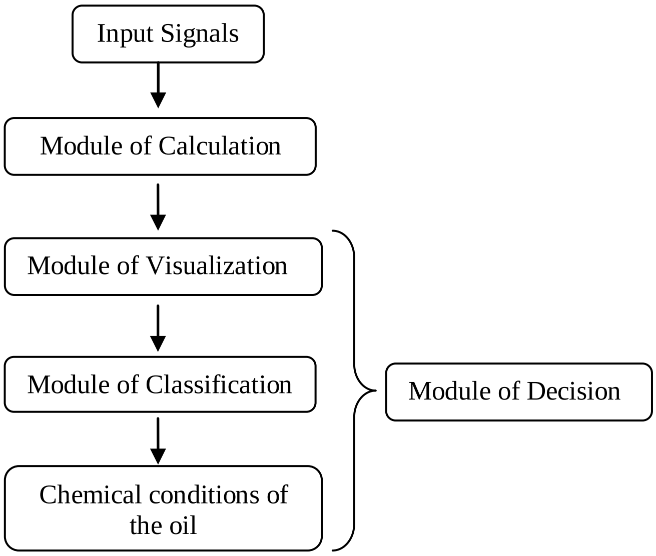


Figure 4. Block diagram of a software system

3. Input signals

The signals are acquired from the sensors and they are transferred to the local control centre where they are processed.

The method that is applied for determining the position of the partial discharge uses the relative delay of the signals from different sensors. Based on the first appearance of the filtered signals, their delays are easily calculated. The procedure can be carried out in various ways.

Signals from the measurement with their delays are shown in Fig. 5.

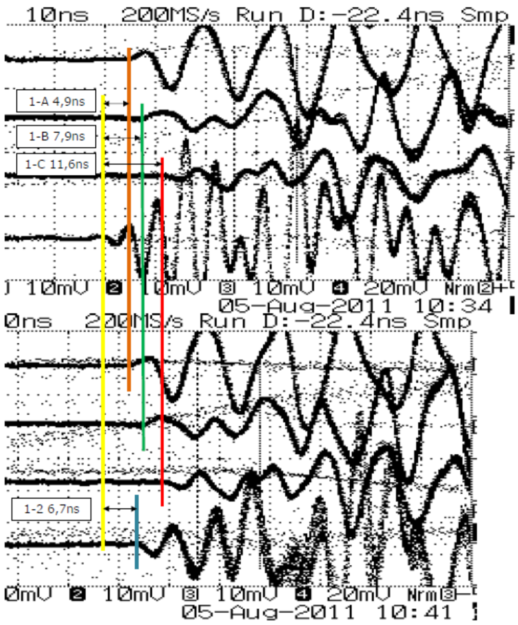


Figure 5. Obtained signals

4. Module of Calculation

In order to localize the flaw in the power transformer every source of partial discharge has to be connected to a flaw, which does not change its place in the volume of the transformer. The aroused electromagnetic wave is distributed both in the winding of the transformer and in the volume of the insulation construction and reaches the place, where the measurement is taken with a delay, corresponding to the speed of propagation. During propagation, the electromagnetic wave is being refracted, cut and deformed depending on the path taken. Consequently, the shape of the voltage or current wave, measured by the instruments is unique for every source of partial discharge and every place of conducting the measurement.

The input data is: the number of measurement sensors, the speed of electromagnetic wave from PD, the coordinates of the sensors and the time delay.

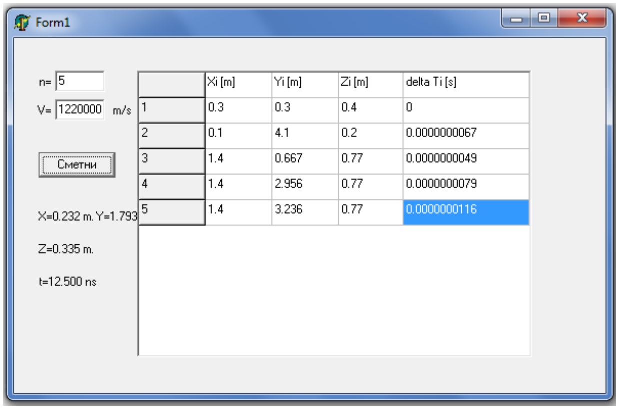
n – number of measurement sensors (in this example the sensors are six);

V– speed of the electromagnetic wave calculate from calibration data;

Xi, Yi, Zi – coordinates of the sensors;

Delta Ti – time delay for each sensor.

In the Module of Calculation all parameters have to be given in International System (SI). The results are the coordinates of partial discharges in the power transformer volume, i.e. there is information for the estimated position of the fault with the exact coordinates *x*, *y* and *z*.



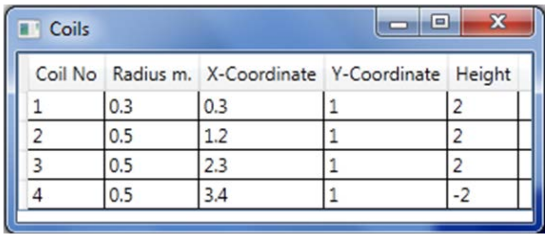
	Xi [m]	Yi [m]	Zi [m]	delta Ti [s]
1	0.3	0.3	0.4	0
2	0.1	4.1	0.2	0.0000000067
3	1.4	0.667	0.77	0.0000000049
4	1.4	2.956	0.77	0.0000000079
5	1.4	3.236	0.77	0.0000000116

Figure 6. Module of Calculation screenshot

5. Module of Visualization

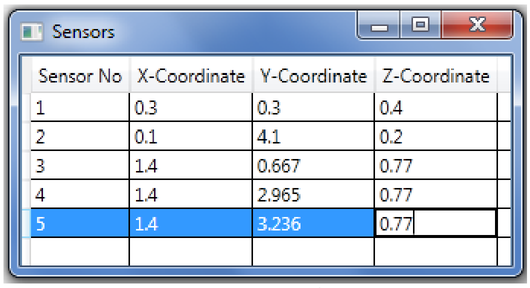
When the position of the partial discharge is calculated in the corresponding coordinate system, the exact location has to be verified.

The Module of Visualization is started and “Model parameters” is chosen, then two functions are allowed - “Coils” and “Sensors”. The geometric parameters of coils and sensors should be entered. The data is shown inFig.7 and Fig. 8



Coil No	Radius m.	X-Coordinate	Y-Coordinate	Height
1	0.3	0.3	1	2
2	0.5	1.2	1	2
3	0.5	2.3	1	2
4	0.5	3.4	1	-2

Figure 7. Geometric parameters of coils



Sensor No	X-Coordinate	Y-Coordinate	Z-Coordinate
1	0.3	0.3	0.4
2	0.1	4.1	0.2
3	1.4	0.667	0.77
4	1.4	2.965	0.77
5	1.4	3.236	0.77

Figure 8. Position of sensors

The aim of this module is to visualize the main framework of the transformer under investigation, the positions of the measuring sensors and the position of the partial discharge – big red sphere shown in Fig.9. Based on the image, the operator has to decide where the exact place of the partial discharge is.

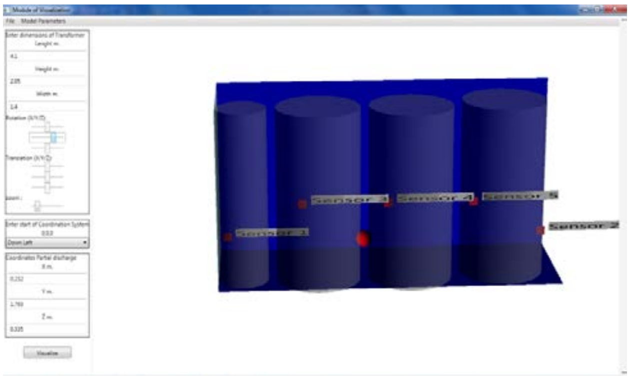


Figure 9. Module of Visualization screenshot

6. Module of Classification

After acquiring the data from the Module of Visualization, the analysis continuesin the Module of Classification. The most popular cases for partial discharges appearance are given in IEC 60076-3:2000-03. These cases depend on parameters such as location of discharges on test voltage, variability of response, relative magnitude of discharges on positive/negative half cycle and variation of discharge magnitude depending on test voltage and time of application.In the specific case the data is different.

In this measurement the input data is:

✓ Location of discharge: most pulses in advance of the voltage peaks

✓ Variability of Response: Steady or repeated motion.

✓ Relative Magnitude of discharge: Similar magnitude on both half cycle.

✓ Test voltage: Constant with test voltage

✓ Time of application: Constant with time

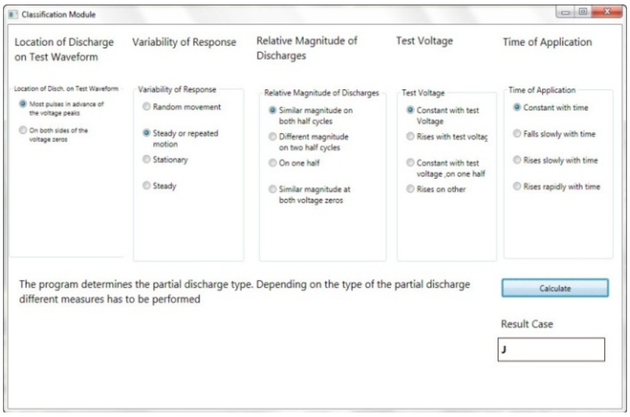


Figure 10. Module of Visualization screenshot

The output data is the result case J.Indication: Internal discharges. Usually it is a gap between two quite independent metallic objects (or a single metallic object and earth) across which a voltage is produced by electrostatic induction from the test circuit. The disturbance may, for example, be caused by metallic objects lying on the ground. It should be noted that similar but very large discharges may be produced by gas discharge tubes built into the input circuit of the discharge detector for overvoltage [2].

7. Module of Decision

This module determines the state of the power transformer. The most important parameters regarding the final decision about the actual transformer state are the location of the partial discharge, the partial discharge case and the transformer oil conditions.

According to IEC 60076-3:2000-03 [2]the most possible cases of partial discharge occurrence are A, B, C, D, E, F, G, H, J, K, L, M and N. The possible locations of partial discharges are in the tank, windings, leads, tap changer and the other.

In this paper, the results from the chemical conditions of the oil could be summarized as GOOD OIL (if the concentrations of the gases are **incompliance** to standard IEC 60599 [3]) or BAD OIL (if the concentrations of the gases are **notin compliance** to standard IEC 60599 [3]). These results are used in the decision module where the operator takes the final decision regarding the emergency of detected the partial discharge. In substations, information for the condition of the oil is provided by technical labs in six month intervals.

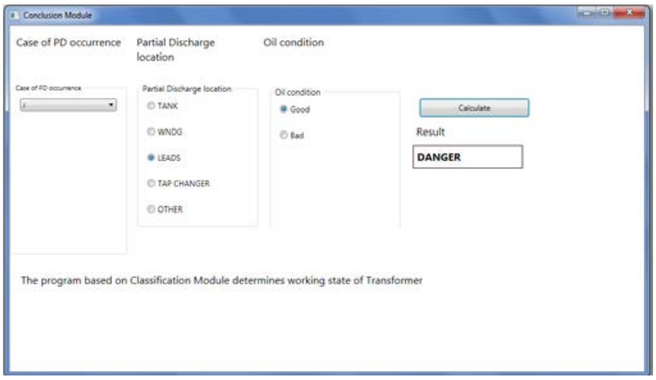


Figure 11. Module of Decision screenshot

The software determines the level of the power transformer criticalstate. It can be: Work, Attention or Danger.

The software result was: Danger. It means that the transformer should be open for repairing as soon as possible.

The software which determines the level of critical state ofthe power transformeris describedin this paper. There are many methods to diagnose the state of the power transformers. The electrical method of measurement of the electromagnetic waves caused by the partial discharges in the volume of the power transformer provides the maximum information which can be analysed.

This kind of software analysis is considerably new and it is still in progress. The possibility to make calculations of the pulse shape features offers a powerful tool for a pulse classification.

A partial discharge in power transformers is one of the main indicators of insulation degradation. Power transformers are oil filled transformers with a highly refined mineral oil that is used to insulate internal live parts of the transformer.

The most popular internal and external damages that appear in transformers could be seen in Table 1.

Table 1. Popular transformer damages

Internal	External
Insulation deterioration	System switching operations
Solid contamination in the insulating oil	Lighting strikes
Loss of winding clamping	System overload
Overheating	System faults
Partial discharges	
Moisture	
Oxigen	
Design and manufacture defects	

The oil prevents partial discharges, corona and manages temperature control inside the transformer for the prevention of equipment and machinery overheating during the operation of large job applications. Because of the oil inside the transformer being of non-combustible properties, these transformers are very safe and can operate for long periods of time.

The chosen approach provides accurate method for determining the incipient faults accompanied with partial discharges and also the final assessment of condition of the power transformer.

8. Conclusion

The experiment presented in this paper shows the mutual connection between the software system for finding the incipient faults and the real measurement of a partial discharge.

After dismantling the transformer it is established that the actual location of the defect and the location received by the software system differs less than 20 centimeters.

Acknowledgements

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