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Preliminary Result on Multiple Acoustic Sensor Placement for PD Location Based on TDOA Technique

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ABSTRACT

Partial Discharge (PD) are frequently begins inside cracks or gas-filled voids in solid insulation or within gaseous bubbles in liquid insulation. The quality of insulator will deteriorate due to presence of air bubbles. The objective of this paper is to analysis on multiple acoustic sensor for partial discharge location on power transformer based on Time Difference of Arrival (TDOA) technique. This technique is acquired to calculate the localization of PD source and time arrival by using simple iteration algorithms. However, the placement of sensors has been considered to obtain the time arrival between PD source and sensor using TDOA technique.

1. Introduction

PDs are electrical arks which form the flows between electrodes of any area of the insulating media of a transformer between the conductors [1-4]. The localization of partial discharge faults in transformers is often necessary when such incipient faults are identified. Thus, any sign of failure at power transformer should be detected at early stage. Power transformers and power cables are high voltage equipment that PDs usually occur [3,5-8]. The causes of phenomenon of partial discharge are ageing within the insulation and electrical overstressing on presence of voids or cracks presented during manufacturing [4,9-12]. The partial discharges are included in four main group which are internal discharge, surface discharge, corona discharge and electrical treeing [2-5,9,11-15].

Acoustic Emission (AE) method is used in this paper for localization partial discharge at power transformer. AE waves are produced and these signals travel from PD source to entire transformer tank during PD occurs. Acoustic sensors have two possible of sensors which are piezoelectric transducer and condenser microphone [16,17]. The acoustic sensors are placed on the surface of the transformer tank. These sensors are simple installation and anti-interference to external electrical

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noise [10]. AE method is generally used for detection and localization of PD. However, the AE sensors are sensitive to external mechanical noise. Hence, it may cause errors in PD detection and localization [17]. The PD localization algorithms have been explored by researchers based on AE data [18,19], to refine localization accuracy. Nowadays, the TDoA algorithm is commonly used in localization of partial discharge [8]. In this method, the differences in the arrival times of various acoustic emission (AE) sensors and localization the origin of PDs are calculated. The equation can be solved by some simple iteration algorithms such as the least squares method, steepest decent method, and Newton–Raphson method [8,10,11,16,18].

2. Methodology

In this section is to describe overall process of methodology, methods used in this paper and achievement of paper objective which is analysis on multiple acoustic sensor for partial discharge location on power transformer. All the information procedures and elucidation in paper realizing are contain in this part.

2.1 The Possible Sensor Placement

The possible sensor placement has utilised to obtain and calculate the time arrival between artificial PD and sensor in each case. The dimensions of tank have been observed based on power transformer at substation laboratory Universiti Malaysia Perlis, UniMAP, Malaysia with the ratings of 11 kV/0.433 kV, 315 MVA. The length, width and height of the tank are equal to 1.3 m, 0.8 m and 0.9 m, respectively as shown in Fig. 1.

Fig. 1. Transformer at substation laboratory Universiti Malaysia Perlis, UniMAP, Malaysia

The value of oil velocity (V_s) is 1431 m/s in temperature of 20°C based on the previous research in [6,20]. There are six different cases have been proposed to described the acoustic sensor placement and two different of artificial PD sources which are PD1 and PD2. The acoustic sensors placement on transformer are placed with the different sided. Fig. 2 illustrate the different cases with different acoustic sensors and PDs position.

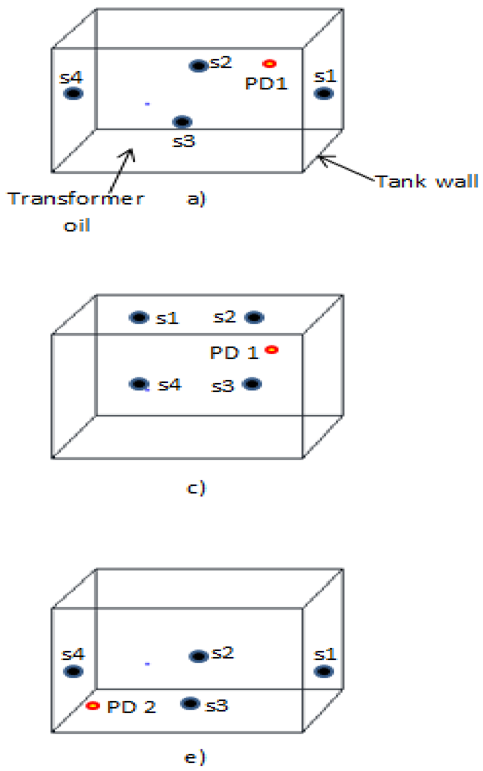

Fig. 2. Position of PD source and sensor installation for oil immersed transformer (a) Case 1, (b) Case 2, (c) Case 3, (d) Case 4, (e) Case 5, (f) Case 6

Case 1 in Fig. 2(a) shows the location of sensors and PD source. Each sensor is placed at the middle of each side of transformer. The coordinate of each sensor is s1(1.3,0.4,0.45), s2(0.65,0.8,0.45), s3(0.65,0,0.45), s4(0,0.4,0.45). The target of PD1(1.2,0.6,0.8) source is upper corner rear side of transformer.

In Case 2, the sensors are installed at the upper (increase 0.3m from the bottom in case 1) middle of each side of transformer. The coordinate of each sensor in case 2 are s1(1.3,0.4,0.75), s2(0.65,0.8,0.75), s3(0.65,0,0.75), s4(0,0.4,0.75). The target of PD1 source is same as in case 1.

In Case 3 in Figure 3,2 (c), all the sensors are at rear side of transformer. The coordinate of each sensor is s1(0.2,0.8,0.8), s2(0.9,0.8,0.8), s3(0.9,0.8,0.4), s4(0.2,0.8,0.4).

In Case 4, the PD2 source with the coordinate (0.2,0.3,0.2) is at bottom corner in front side of transformer. The arrangement and coordinate of sensors are same as case 1.

In Case 5, the PD2 source is at the bottom corner side of transformer and the placement of sensors are bottom each side of transformer. The coordinate of each sensor is s1(1.3,0.4,0.15), s2(0.65,0.8,0.15), s3(0.65,0,0.15), s4(0,0.4,0.15).

In Case 6, the sensors are installed in front side of transformer. The coordinate of each sensor is s1(1.0,0,0.8), s2(0.3,0,0.8), s3(1.0,0,0.4), s4(0.3,0,0.4). The location of PD2 source is same as case 4 and case 5.

Table 1
Sensor coordinate at PD1 for case 1,2 and 3

PD 1				
Cases	Sensor Type	Sensors Coordinate		
		x(m)	y(m)	z(m)
1	s1	1.3	0.4	0.45
	s2	0.65	0.8	0.45
	s3	0.65	0	0.45
	s4	0	0.4	0.45
2	s1	1.3	0.4	0.75
	s2	0.65	0.8	0.75
	s3	0.65	0	0.75
	s4	0	0.4	0.75
3	s1	0.2	0.8	0.8
	s2	0.9	0.8	0.8
	s3	0.9	0.8	0.4
	s4	0.2	0.8	0.4

Table 2
Sensor coordinate at PD2 for case 4,5 and 6

PD 2				
Cases	Sensor Types	Sensors Coordinate		
		x(m)	y(m)	z(m)
4	s1	1.3	0.4	0.45
	s2	0.65	0.8	0.45
	s3	0.65	0	0.45
	s4	0	0.4	0.45
5	s1	1.3	0.4	0.15
	s2	0.65	0.8	0.15
	s3	0.65	0	0.15
	s4	0	0.4	0.15
6	s1	1	0	0.8
	s2	0.3	0	0.8
	s3	1	0	0.4
	s4	0.3	0	0.4

2.2 Calculation of PD Location using TDOA Techniques

The coordinates of the PD source (x, y, z) and the arrival time (T) between sensor and PD source are the unknown variables. Since there are four unknowns, a minimum of four sensors are required in order to locate the PD source. The formula for distance can be calculate by following Equations 1 to 4 [21].

$L_1 = V_sT_1 = VsT$ (1)

$L_2 = V_sT_2 = Vs(T+t_{12})$ (2)

$L_3 = V_sT_3 = Vs(T+t_{13})$ (3)

$L_4 = V_sT_4 = Vs(T+t_{14})$ (4)

where L_n is distance from sensor to PD source, while T_n is time from PD site to the sensor, t_{1n} is time delay between S_1 and S_n and Vs is velocity in oil. Thus, from the relationship between position of sensors and PD site as follow as Equations 5, 6, 7 and 8:

$(x - x_{s1})^2 + (y - y_{s1})^2 + (z - z_{s1})^2 = (V_s \cdot T)$ (5)

$(x - x_{s2})^2 + (y - y_{s2})^2 + (z - z_{s2})^2 = (V_s \cdot (T + t_{12}))^2$ (6)

$(x - x_{s3})^2 + (y - y_{s3})^2 + (z - z_{s3})^2 = (V_s \cdot (T + t_{13}))^2$ (7)

$(x - x_{s4})^2 + (y - y_{s4})^2 + (z - z_{s4})^2 = (V_s \cdot (T + t_{14}))^2$ (8)

Assume time delay is known and solve equation above by least square algorithm. Then, T and coordinate PD(x,y,z) are determined by simple iteration method [21]

$$x = \frac{1}{N}\sum_{i=1}^{N} x_{si} + \frac{1}{N}\sum_{i=1}^{N} \frac{(T + t_{si})(x - x_{si})V_s}{[(x - x_{si})^2 + (y - y_{si})^2 + (z - z_{si})^2]^{\frac{1}{2}}} \quad (9)$$

$$y = \frac{1}{N}\sum_{i=1}^{N} y_{si} + \frac{1}{N}\sum_{i=1}^{N} \frac{(T + t_{si})(y - y_{si})V_s}{[(x - x_{si})^2 + (y - y_{si})^2 + (z - z_{si})^2]^{\frac{1}{2}}} \quad (10)$$

$$z = \frac{1}{N}\sum_{i=1}^{N} z_{si} + \frac{1}{N}\sum_{i=1}^{N} \frac{(T + t_{si})(z - z_{si})V_s}{[(x - x_{si})^2 + (y - y_{si})^2 + (z - z_{si})^2]^{\frac{1}{2}}} \quad (11)$$

$$T = \frac{\sum_{i=1}^{N}[(x - x_{si})^2 + (y - y_{si})^2 + (z - z_{si})^2]^{\frac{1}{2}}}{\sum_{i=1}^{N} V_s} \quad (12)$$

The flowchart in Fig. 3 is the process of calculation for PD origin and T in each case.

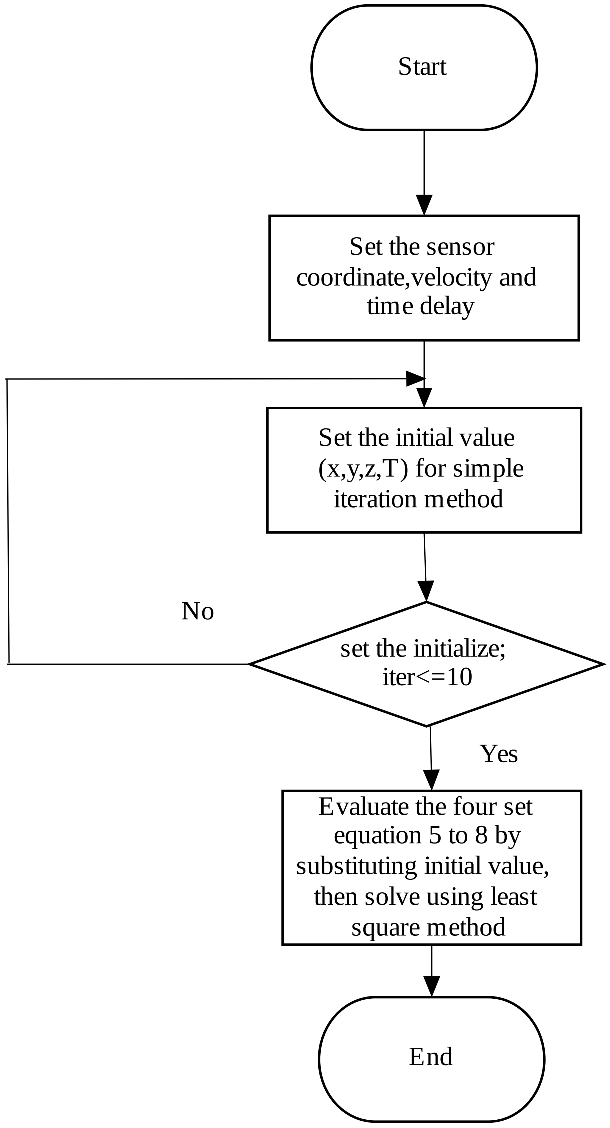

Fig. 2. Flowchart for calculation PD origin and T

3. Results

3.1Time arrival between PD source and sensor in each case

Table 3 shows the result of time arrival between PD source and sensor using Equations 5 until 8 by substitute the value of velocity oil, PD 1 and PD 2. In this result, the artificial PD1 and artificial PD2 were set (1.2,0.6,0.8)m and (0.2,0.3,0.2)m respectively. The value of velocity oil is 1431m/s while the value of coordinate of sensor is based on Fig. 2, Tables 1 and 2. The value of velocity in oil will affect the time arrival of acoustic signal to the sensors based on the calculated value. However, the different of oil can effect to the accuracy to identify the PD position in the power transformer.

Table 3
Result of Time Arrival

PD location	Cases	Time Arrival (ms)			
		T1	T2	T3	T4
PD 1	1	0.29	0.48	0.62	0.88
	2	0.16	0.41	0.57	0.85
	3	0.79	0.50	0.38	0.77
PD 2	4	0.79	0.50	0.42	0.23
	5	0.77	0.47	0.38	0.16
	6	0.73	0.47	0.61	0.26

4. Conclusions

In this works, the six different cases for acoustic sensor placement and PD location have been analysed. The mathematical equation can use to identify the time arrival from origin PD signal travel to the different sensors as a preliminary result before the simulation and experimental work assessment. The TDoA technique can be improve in order to reduce the percentage error for further analysis on PD location technique.

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