

Theoretical and Experimental Investigation of Transformer Winding Fault Detection Using Comparison of Transfer Function Coefficients

Mehdi Bigdeli¹, Mehdi Vakilian²,
Ebrahim Rahimpour³, and Davood Azizian⁴, Non-members

ABSTRACT

In this work, a new model of transformer winding is developed. The components in the model are determined by the geometric and electric data of the winding (detailed model) and using experimental data based on genetic algorithm. Under different degrees of axial displacement and radial deformation in the winding, the circuit parameters of the model will change and thus the equivalent circuit characteristics will be influenced. After acquiring the model parameters in the intact and faulted cases, transfer function coefficients are derived in model using nodal analysis. Subsequently, introducing a new index based on these coefficients, the type and extent of penetration of the fault in the winding can be specified. Results presented in this work demonstrate the potential of the proposed method.

Keywords: Transformer Winding, Axial Displacement, Radial Deformation, Transfer Function Coefficients

1. INTRODUCTION

Power transformers are among the most important equipments in electrical power transmission and distribution systems and occurrence of any fault in these transformers will reduce the power system reliability. In other words increases the possibility of power supply interruption. In addition, it will impose extra costs required for their maintenance and for their transportation to a repair factory. Due to the existence of a strong competition in the electrical power supply industry, the importance of application

of the transformer monitoring systems has increased over the time.

Different fault modes in transformers are classified into two main groups; the mechanical types, and the electrical types. Different methods have been offered for detection of each of these faults. According to the statistics of transformer disasters, nearly 50 percent of accidents were caused by mechanical faults, and number is still increasing [1]. The past researches indicate transfer function (TF) method is a well-known method for detection of the mechanical faults [2-4].

Mechanical faults such as axial displacement (AD) and radial deformation (RD) of the winding affect the TFs and modify them. The ability of a detailed RLC model of a winding to calculate the TF and to demonstrate the effects of various winding damages on TF has been proven on windings by previous studies [5-6].

Different methods have been proposed in order to obtain TF in different frequency ranges. In most cases [2-5] experimental results in time or frequency domain have been used and in some cases [6] that it is difficult to access experimental data instead of it detailed model has been used.

Nonetheless, in previous studies [1-12] largely discussed about specifying the extent of fault and paid less attention to specifying the type of fault. While at the first step (in winding fault detection studies) we should be able to specify the type of fault without opening the unit. So, in this article it is tried to specify the type of fault by introducing a simple model of transformer. For this purpose at first TF of transformer is calculated in Laplas domain using nodal analysis. Next, for two sample transformers using detailed model and experimental data based on genetic algorithm (GA) the parameters of model calculated in both intact and faulted conditions (under different conditions of AD and RD of winding). The obtained results demonstrate a good agreement between the calculated and the measured TFs. Finally, comparing the TF coefficients of the intact condition against TF coefficients of the faulted condition, the type of fault can be specified. Additionally, the extent of its penetration can be calculated accurately.

Manuscript received on July 25, 2011 ; revised on October 10, 2011.

¹ The author is with the Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran, E-mail: bigdeli_aznu@yahoo.com

² The author is with the Department of Electrical Engineering, Sharif University of Technology, Tehran, Iran, E-mail: vakilian@sharif.edu

³ The author is with the ABB AG, Power Products Division, Transformers, Bad Honnef, Germany, E-mail: ebrahim.rahimpour@de.abb.com

⁴ The author is with the Department of Electrical Engineering, Abhar Branch, Islamic Azad University, Zanjan, Iran, E-mail: d.azizian@srbiau.ac.ir

2. THE PROPOSED MODEL

The model of transformer is shown in Fig. 1, Can be used for specifying the type and extent of fault.

The parameters of the model are defined as follows:

- 1- Ideal transformer with turns ratio n to consider the voltages ratio,
- 2- C_{hl} : Parallel capacitance between two windings,
- 3- C_{gh} and C_{gl} : Capacitances between each winding and earth,
- 4- L_h and L_l : Self inductances of windings, and
- 5- M : Mutual inductance between two windings.

3. DETERMINATION OF MODEL PARAMETERS

The components in the model can be determined by the geometric and electric data (Detailed Model) of the winding or using experimental data. These methods are discussed in detail as follow:

3.1 Estimation using Detailed Model

3.1.1 Calculation of L_h , L_l and M

Since the disk or layer windings consist of turns, the first step to calculate the winding self inductance is determination of one turns self inductance. The self inductance of one turn (Fig. 2) can be achieved by the following equation [7]:

$$L = \mu_0 R \left(\ln \frac{8R}{GMD} - 2 \right) \quad (1)$$

Where, GMD (Geometric Mean Distance) of turn is calculated as following [7]:

$$GMD = \sqrt{a^2 + b^2} \exp \left[\begin{aligned} & \frac{2b}{3a} \tan^{-1} \frac{a}{b} + \frac{2a}{3b} \tan^{-1} \frac{b}{a} \\ & - \frac{b^2}{12a^2} \ln \left(1 + \frac{a^2}{b^2} \right) - \frac{a^2}{12b^2} \ln \left(1 + \frac{b^2}{a^2} \right) - \frac{25}{12} \end{aligned} \right] \quad (2)$$

As a satisfactory approximation, equation (1) can be used directly to calculate one disk self inductance. In this case, Fig. 2 will show a disk and the parameters a , b and R will represent disk's geometries.

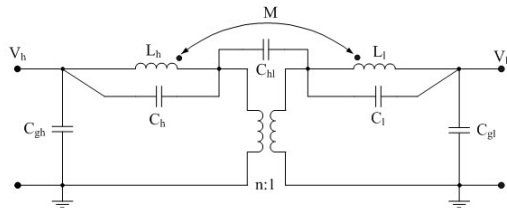


Fig.1: The Proposed model for specifying the type and extent of winding fault



Fig.2: Definition of one turn parameters: a is conductor radial length, b denotes conductor axial length, and R indicates turn radius

Mutual inductance between two circular turns is given by the following equations [5]:

$$M_{12} = \frac{2\mu_0 \sqrt{r_1 r_2}}{\sqrt{k'}} \cdot [K(k') - E(k')] \quad (3)$$

Where, r_1 and r_2 show the radius of considered turns and d represents the axial distance between them. While, $K(k')$ and $E(k')$ are the complete elliptic integrals of the first and second kinds, respectively, that can be defined as follow [5]:

$$k' = \frac{1 - \sqrt{1 - k^2}}{1 + \sqrt{1 - k^2}}, \quad k = \sqrt{\frac{4r_1 r_2}{(r_1 + r_2)^2 + d^2}}$$

The winding self inductance and mutual inductance between two windings can be calculated using equations (1) and (3) and proper summation of turn's inductances. The method of summation, i.e. the converting of a matrix inductance of order $(n+m) \times (n+m)$ to a matrix of order 2×2 , is shown schematically in Fig 3 [8].

$$L_{(n+m) \times (n+m)} = \begin{bmatrix} 1 & \dots & n & 1 & \dots & m \\ \vdots & & \Sigma & & \Sigma \\ n & & & & \\ \vdots & & \Sigma & & \Sigma \\ m & & & & \end{bmatrix} \Rightarrow L_{2 \times 2} = \begin{bmatrix} L_h & M \\ M & L_l \end{bmatrix}$$

Fig.3: Using turn inductances to calculate the model inductances

The number of disk winding units and layer winding units is shown in Fig 3 by n and m , respectively. A turn, a disk or a double disk can be chosen in a disk winding as a unit. In a layer winding, a turn, a number of turns or a layer may be chosen to represent a unit.

3.1.2 Calculation of Capacitances

3.1.2.1 Estimation of C_h and C_l

In order to calculate the series capacitance of a disk winding, the series capacitance of a double disk must be calculated at first. With assumption of the linear voltage distribution along a double disk in [5], the total electrical energy stored in a double disk is used to calculate the capacitance of a double disk. By connecting the double disks capacitances in series, series capacitance of winding will be obtained.

For calculation of series capacitance of a layer winding, not only the series capacitance of each layer but also the parallel capacitances between layers must be calculated. Parallel capacitance between two layers can be determined similar to that of two windings as will be explained in section 3.1.2.2. Series capacitance of a layer is equal to series connection of capacitances between two adjacent turns, which can be calculated like two parallel plate capacitance. Finally, the equivalent series capacitances of a layer winding (between its L1 and L2 terminals) can be determined using Fig. 4 [8]. In this figure, K_{si} denotes the series capacitance of i -th layer and C_{pij} the parallel capacitances between i and j layers.

3.1.2.2 Estimation of C_{hl} , C_{gh} and C_{gl}

The capacitance between two windings and/or between winding and earth potential (tank or core) is calculated by the following equation like a capacitance between two parallel plates:

$$C = K_f \varepsilon_0 \varepsilon_{eq} \frac{A}{d} \quad (4)$$

Where, K_f , given in [5], is used to consider fringe effect. Since different types of insulation materials are present together in a transformer (Fig. 5), the calculation of an equivalent dielectric coefficient is necessary. This coefficient is calculated by the following relation [5]:

$$\frac{1}{\varepsilon_{eq}} = \frac{1}{\varepsilon_{pap}} \cdot \frac{d_4}{d_{tot}} + \frac{1}{\varepsilon_{press}} \cdot \frac{d_3}{d_{tot}} + \frac{1}{\varepsilon_{oil}} \cdot \frac{d_2}{d_{tot}} + \frac{1}{\varepsilon_{press} \cdot \frac{l_1}{l_{tot}} + \varepsilon_{oil} \cdot \frac{l_2}{l_{tot}}} \cdot \frac{d_1}{d_{tot}} \quad (5)$$

Where, ε_{pop} , ε_{press} and ε_{oil} are oil impregnated paper, press board and oil dielectric coefficients, respectively.

The value of C_{hl} is half of the value of capacitance between two windings, which is calculated with the help of equations (4) and (5). Furthermore, C_{gh} (or C_{gl}) is half of the capacitance between disk (or layer) winding and earth potential [8].

3.2 Estimation using Experimental Data

For checking the validity of proposed method, the model parameters are estimated using experimental data. For this purpose, GA is used. At first, all necessary tests are carried out on two sample transformers. Thereafter, the model parameters are estimated using GA toolbox in MATLAB [13].

In present investigation all measurements were executed in the time domain to determine different TFs defined by the terminal conditions of the transformer which is illustrate in [8].

In Fig. 6, the necessary circuits for measuring frequency features in different conditions of terminal connections are shown.

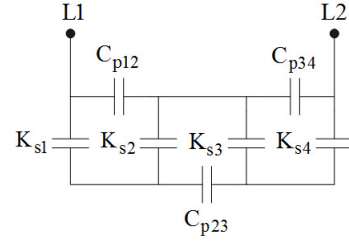


Fig.4: The capacitive circuit of a four layer winding

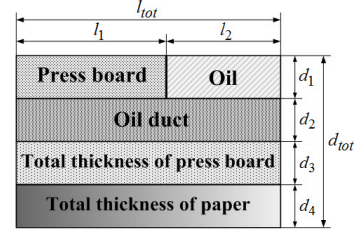


Fig.5: A composite dielectric material

If Z_{si} is the simulated models response to the input X_{ei} and Z_{xi} the output vector got from experimental results, the goal of parameters identification is in this way: $Z_{si} = Z_{xi}$

According to the noise, numeral errors in simulation and the errors of measurement devices, there is never equality. So the best estimation for parameters is the estimation which decreases the sum of squares of errors for n couple of Y_{si} and Y_{ei} or in other words, increases the standard function to maximum:

$$f_{fit} = \sum_{i=1}^n \left([real(Z_{xi} - Z_{si})]^2 + [imag(Z_{xi} - Z_{si})]^2 \right) \quad (6)$$

Parameter identification is converted to an optimizing problem and can be solved using GA toolbox in MATLAB software

For estimating parameters, the GA is done by two groups of different parameters. In the first stage, we use T_1 and T_2 (two functions are measured) for estimating C_{gh} , C_{gl} and C_{hl} . So the parameters vector is like this: $P_1 = [C_{gh} \ C_{gl} \ C_{hl}]$

In the second stage, for estimating of C_h and L_h , we use the T_3 ; in this case, the parameters vector is like this: $P_2 = [C_{eq1} \ L_h]$

In the above relation, C_{eq1} is the sum of C_{gh} , C_{hl} and C_h . The amount of C_h can be obtained by C_{gh} and C_{hl} .

In the third stage, we act like stage two and use T_4 for estimating following parameters: $P_3 = [C_{eq2} \ L_l]$

Where, C_{eq2} is the sum of C_{gl} , C_{hl} and C_l . According to the facilities of MATLAB7.0.4 [13] and the toolbox of GA, for running the original program and estimating model parameters, this facility is used. For using this toolbox at first we should enter "mfile".

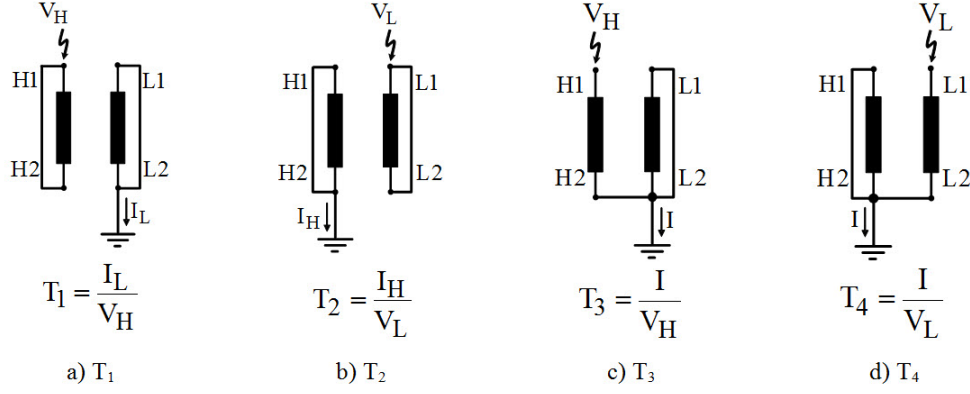


Fig.6: Measuring circuits in various conditions of terminal connections

As the output, we can require various waveforms. Other quantities are given as default, but there are some changes in this quality; as follow:

1. It is better for increasing the speed of convergence in GA, to determine the initial amount of variables, manually (inductances in mH and capacitances in microfarad range).
2. At first, the probability of mutation is high and at last, its down (because we close to the response). For this at first we use the uniform probability function with rate 0.5 and then, use the Gaussian probability function rates of 0.1 to 0.0001 by closing to the response at the problem.
3. The limiting amounts of running toolbox are assumed high amounts so that the end of running the program becomes an option for the user. The remaining settings of toolbox can be defined according to the type of the problem.

4. TRANSFER FUNCTION ANALYSIS

We use nodal analysis method to obtain TF in model. For example if we want to find TF_v , will have:

$$TF_v(s) = \frac{V_l(s)}{V_h(s)} = \frac{a_6 S^6 + a_4 S^4 + a_2 S^2}{b_6 S^6 + b_4 S^4 + b_2 S^2} \quad (7)$$

$$a_6 = C_l [C_{gh} + C_h] [2L_h L_l M^2 - L_h^2 L_l^2 - M^4]$$

$$a_4 = [L_h L_l - M^2] [nMC_{gh} - C_{gh} L_h - C_h L_h - C_l L_l]$$

$$a_2 = [M^2 - L_h L_l]$$

$$b_6 = nC_h [C_{gl} + C_l] [2L_h L_l M^2 - L_h^2 L_l^2 - M^4]$$

$$b_4 = [L_h L_l - M^2] [MC_{gl} - nC_{gl} L_l - nC_l L_l - nC_h L_h]$$

$$b_2 = n [M^2 - L_h L_l]$$

It means that coefficients of TF related to inductances and capacitances, and using calculating the parameters of equivalent circuit in both intact and faulted cases the amount of changes in coefficients of TF can be observed.

5. TEST OBJECTS

Two test objects were considered in this study and TFv were performed on them to evaluate the accuracy and ability of the proposed method for finding the type and extent of the faults. As a test object for the study of AD a high voltage winding with 31 double inverted disks, where 6 turns are present in each disk, and a four layer concentric low voltage winding, where 99 turns are present in each layer, were used. They correspond to windings of a transformer with a rated voltage of about 10 kV and a rated output of 1.3 MVA. The test object has 82.7 cm height and therefore a 1cm axial displacement is equivalent of 1.2% displacement.

As a test object for the study of RD a high voltage winding with 30 double inverted disks, where 11 turns exists in each disk, and a one layer low voltage winding, having 23 turns are used. The double disk winding has a rated voltage of 10 kV and a rated output of 1.2 MVA. The deformation has occurred on the double disk winding in four degrees, as follow:

- Degree 1: The 6th up to the 54th coil were radially deformed on one side. The size of deformation was about 7% of the coil's radius
- Degree 2: The 6th up to the 54th coil were all radially deformed on two opposite sides. The size of deformation was about 7% of coil's radius.
- Degree 3: The 6th up to the 54th coil were all radially deformed on three sides with 90° with respect to each other. The size of deformation was about 7% of coil's radius.
- Degree 4: The 6th up to the 54th coil were all radially deformed on four sides with 90° with respect to each other. The size of deformation was about 7% of coil's radius.

The geometric dimensions of both transformers have been shown in Figures 7 and 8.

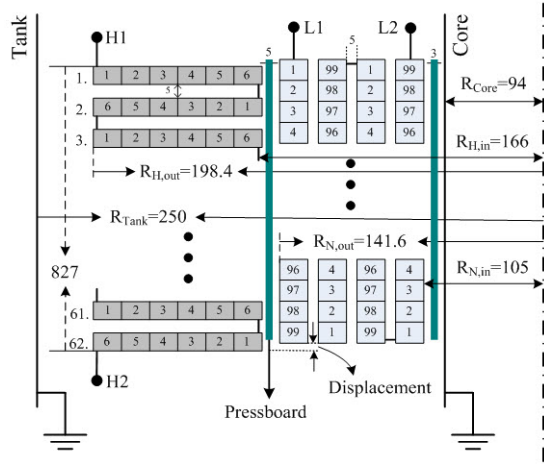


Fig. 7: The geometric dimensions of test object for the study of axial displacement

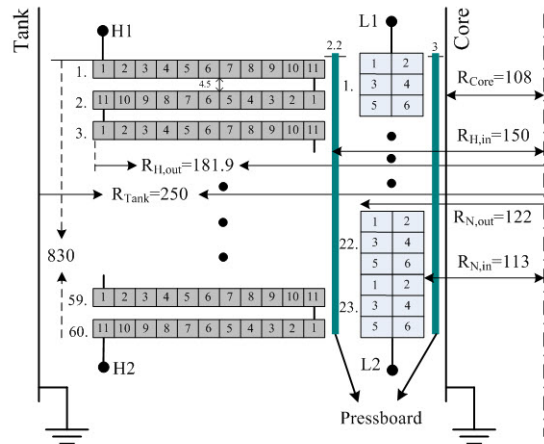


Fig. 8: The geometric dimensions of test object for the study of axial displacement

6. THE INTERPRETATION OF RESULTS

In first stage, using mentioned relations in previous sections the amount of TF coefficients have been calculated from 1 to 8 cm for AD of winding and in four degrees for RD. The obtained results for test objects using detailed model (theoretical method) are shown in tables 1, 2. As shown in tables 3, 4, same results are obtained by experimental data. As a result, we can say there is good agreement between analytical and experimental data.

In second stage, results of these tables are used for fault detection studies. In this regard, we use the coefficients of a_2 and b_2 to specify the type of fault. The reason is that these coefficients only related to model inductances and there is no capacitance parameter in them. Since, in the situation of RD the inductance

change in winding is very little [5], these coefficients are very suitable to specify the type of fault.

As it has been shown in tables 1 to 4, the most change obtained as for RD in the coefficient of a_2 is equal to degree 4 of it which is less than the least obtained change as for AD which related to 1 cm of displacement.

Studying the tables shows that the most obtained change for RD is 0.22% which is less than the least obtained change for axial displacement of winding which is 5.6%. It means if the amount of obtained change in the coefficient of a_2 at the happening of fault is more than 2%, the type of fault would be AD, and otherwise fault is RD. Moreover the changes in RD are decrement, while in AD is increment (in all of states). Hence, discrimination between these faults and fault type detection can be done, easily.

Therefore, to specify the type of a fault, the coefficients of TF_v is determined using detailed model or experimental data, if modifications of these coefficients due to a fault are increment, that fault is AD and otherwise the fault is RD. In addition, we can use the mentioned coefficients to specify the extent of fault. As in different degrees of AD these coefficients increase and in RD decrease, regularly.

Table 1: the results of calculated coefficients of TFs for axial displacement (using detailed method)

Displacement (cm)	$a_6 \times 10^{-29}$	$a_4 \times 10^{-17}$	$a_2 \times 10^{-5}$	$b_6 \times 10^{-27}$	$b_4 \times 10^{-15}$	$b_2 \times 10^{-3}$
0	8.72	4.75	8.55	2.74	6.66	2.15
1	8.78	4.81	8.60	2.78	6.70	2.17
2	8.84	4.88	8.64	2.83	6.74	2.19
3	8.91	4.94	8.68	2.88	6.79	2.21
4	8.99	5.03	8.73	2.93	6.84	2.24
5	9.12	5.14	8.78	2.99	6.89	2.27
6	9.27	5.25	8.85	3.05	6.95	2.31
7	9.44	5.41	8.93	3.11	7.01	2.35
8	9.63	5.58	9.03	3.18	7.07	2.39

Table 2: the results of calculated coefficients of TFs for radial deformation (using detailed method)

Displacement	$a_6 \times 10^{-34}$	$a_4 \times 10^{-19}$	$a_2 \times 10^{-8}$	$b_6 \times 10^{-33}$	$b_4 \times 10^{-17}$	$b_2 \times 10^{-6}$
Without	1.74	5.81	9.12	6.55	1.39	2.28
Degree1	1.58	5.49	9.11	5.96	1.32	2.28
Degree2	1.41	5.16	9.11	5.34	1.24	2.28
Degree3	1.29	4.90	9.10	4.89	1.18	2.27
Degree4	1.15	4.71	9.10	4.45	1.11	2.27

Table 3: the results of calculated coefficients of TFs for axial displacement (using experimental data)

Displacement (cm)	$a_6 \times 10^{-29}$	$a_4 \times 10^{-17}$	$a_2 \times 10^{-5}$	$b_6 \times 10^{-27}$	$b_4 \times 10^{-15}$	$b_2 \times 10^{-3}$
0	8.51	4.61	8.44	2.81	6.62	2.13
1	8.59	4.69	8.50	2.86	6.67	2.19
2	8.65	4.75	8.53	2.92	6.71	2.22
3	8.70	4.89	8.59	2.99	6.78	2.25
4	8.77	4.96	8.65	3.03	6.85	2.29
5	8.87	5.05	8.71	3.06	6.89	2.34
6	9.01	5.16	8.74	3.10	6.97	2.37
7	9.25	5.29	8.80	3.17	7.04	2.40
8	9.49	5.41	8.97	3.22	7.09	2.43

Table 4: the results of calculated coefficients of TFs for radial deformation (using experimental data)

Displacement	$a_6 \cdot 34$ $\times 10^{-34}$	a_4 $\times 10^{-19}$	a_2 $\times 10^{-8}$	$b_6 \cdot 33$ $\times 10^{-33}$	$b_4 \cdot 17$ $\times 10^{-17}$	b_2 $\times 10^{-6}$
Without	1.71	5.80	9.09	6.58	1.42	2.31
Degree1	1.62	5.52	9.08	6.12	1.35	2.30
Degree2	1.45	5.21	9.07	5.47	1.27	2.30
Degree3	1.31	4.97	9.07	4.98	1.21	2.28
Degree4	1.19	4.75	9.07	4.51	1.14	2.28

7. CONCLUSIONS

In the most cases, AD and RD of winding are the most important faults which result in transformer to break down. Comparing of measured TFs from the transformer is used to detect the faults, while a reliable method hasn't been introduced to specify the type of fault in the past works. In this paper a new transformer model is developed, not only to specify the type of fault, but also to identify the extent of its penetration accurately. The model parameters are determined by the detailed model and using experimental data based on GA under both intact and faulted conditions. Then the TF of transformer calculated using nodal analysis method. Finally, the type and extent of fault is identified via the comparison of the TFs coefficients. The obtained results show that:

- When RD occurs, the coefficients of numerator and denominator of TF decrease and if AD happens, related coefficients increase.
- When RD takes place, the amount of changes in the coefficients of a_2 is less than 2% and if AD occurs, those changes would be more than 2%.
- The coefficients vary regularly under different degrees of AD and RD, in the fault conditions. Therefore, the extent of fault penetration can be easily specified.

It should be noted that although in present research the mechanical fault detection has been investigated deeply using the TFs analysis, the algorithm should be tested on several power transformers with different sizes to develop a set of general and solid conclusions for detection of the type of mechanical faults. Applying the given algorithm on different type of transformers (including several windings of different types) will reveal more knowledge for the fault detection.

References

- [1] A. Singh, F. Castellanos, J. R. Marti, and K. D. Srivastava, "A comparison of trans-admittance and characteristic impedance as metrics for detection of winding displacements in power transformers," *Electric Power Systems Research, Elsevier*, Vol. 79, No. 1, pp. 871-877, 2009.
- [2] T. Leibfried, and K. Feser, "Monitoring of power transformers using the transfer function method," *IEEE Transactions on Power Delivery*, Vol. 14, pp. 1333-1341, 1999.
- [3] J. Christian, and K. Feser, "Procedures for detecting winding displacements in power transformers by the transfer function methods," *IEEE Transactions on Power Delivery*, Vol. 19, pp. 214-220, 2004.
- [4] P. M. Nirgude, D. Ashokraju, A. D. Rajkumar, and B. P. Singh, "Application of numerical evaluation techniques for interpreting frequency response measurements in power transformers," *IET Science, Measurements and Technologies*, Vol. 2, pp. 275-285, 2008.
- [5] E. Rahimpour, J. Christian, K. Feser, and H. Mohseni, "Transfer function method to diagnose axial displacement and radial deformation of transformer winding," *IEEE Transactions on Power Delivery*, Vol. 18, pp. 493-505, 2003.
- [6] P. Karimifard, and G. B. Gharehpetian, "A new algorithm for localization of radial deformation and determination of deformation extent in transformer windings," *Electric Power Systems Research, Elsevier*, Vol. 78, pp. 1701-1711, 2009.
- [7] A. Miki, T. Hosoya, and K. A. Okuyama, "Calculation method for impulse voltage distribution and transferred voltage in transformer windings," *IEEE Transactions on Power Apparatus and Systems*, Vol. PAS-97, No.3, pp. 930-939, 1978.
- [8] E. Rahimpour, and M. Bigdeli, "Simplified transient model of transformers based on geometrical dimensions used in power network analysis and fault detection studies," *proceeding of IEEE Second International Conference on Power Engineering, Energy and Electrical Drives (Powereng)*, Lisbon, Portugal, pp. 375-380, 2009.
- [9] J. R. Secue, and E. Mombello, "Sweep frequency response analysis (SFRA) for the assessment of winding displacements and deformation in power transformers," *Electric Power Systems Research, Elsevier*, Vol. 78, No. 6, pp. 1119-1128, 2008.
- [10] E. Rahimpour, and D. Gorzin, "A new method for comparing the transfer function of transformers in order to detect the location and amount of winding faults," *Electrical Engineering, Springer*, Vol. 88, No. 5, pp. 411-416, 2005.
- [11] S. A. Ryder, "Transformer diagnosis using frequency response analysis: results from fault simulations," *Proceeding of IEEE Conference on Power Engineering Society, Summer Meeting*, pp. 399-404, 2002.
- [12] A. Shintemirov, W. H. Tang, and Q. H. Wu, "Transformer winding condition assessment using frequency response analysis and evidential reasoning," *IET Electric Power Applications*, Vol. 4, No. 3, pp. 198-212, 2010.
- [13] "MATLAB Genetic Algorithm Toolbox," Version 5, MathWorks Inc, 2006.



Mehdi Bigdeli was born in 1981 in Zanjan, Iran. He received the B.Sc. degree in electrical engineering from Iran University of Science and Technology (IUST) in 2004 and M.Sc. and Ph.D. degree from Faculty of Engineering of Zanjan University and Islamic Azad University, Sciences and Research Branch, in 2006 and 2012 respectively. His research interests are in fault detection, transient modeling and application of transformers.

Dr. Bigdeli is a faculty member and director of electrical engineering department of Islamic Azad University, Zanjan Branch.



Davood Azizian received his B.Sc. and M.Sc. degrees in electrical engineering from the Zanjan University. He is now a Ph.D. student in Islamic Azad University, Science and Research Branch, Tehran, Iran. He has work in Iran Transformer Research Institute, R&D Department and Dry-Type Technical Office of Iran Transfo Company, and Abhar branch of Islamic Azad University. His fields of interests include

electromagnetics, thermal modeling and dry-type transformers. Mr. Azizian is now a lecturer and faculty staff of Islamic Azad University, Abhar Branch.



Mehdi Vakilian received his B.Sc. in electrical engineering (1978) and M.Sc. (1986) in electric power engineering from Sharif University of Technology in Tehran, Ph.D. in electric power engineering from Rensselaer Polytechnic Institute, Troy, NY, USA in 1993. He worked with Iran Generation and Transmission Company (Tavanir) (1981-1983), and then with Iranian Ministry of Energy (1984-1985). From 1986 he

joined the Faculty of Department of Electrical Engineering of Sharif University of Technology. From 2001 to 2003 he was Associate Professor and also Chairman of the Department. From 2003 to 2004 and next from July 2008 to December 2008 he was on leave of study at School of Electrical Engineering & Tel. of University of New South Wales, Sydney. He has been the director of the committee in charge of restructuring the Electrical Engineering Undergraduate Education in Sharif University of Technology. From 2007 he is working as Professor in this department, and from March 2010 he is also the Director of a research center for Management and control of Power System. His research interests are; the transient modeling of power system equipments, design and modeling of power transformers, optimum design of high voltage equipments insulation, insulation monitoring, steady state analysis of power system, optimum design of distribution systems and distribution transformers.



Ebrahim Rahimpour was born in 1971 in Bijar, Iran. He got his B.Sc. in electrical engineering from Tabriz University in 1993 and M.Sc. and Ph.D. in electrical power engineering from faculty of engineering of Tehran University in 1995 and 2002 respectively. He received a German Academic Exchange Service (DAAD) scholarship in 1998 and worked at the Institute of power transmission and high voltage technology of Stuttgart

University of Germany from 1999 to 2001.

He was an associate professor at Zanjan University, working on modeling and monitoring of electrical machines, especially transformers from 2002 to 2007. He acquired a Georg Forster Research Fellowship of the Alexander von Humboldt Foundation (AvH) scholarship in 2007 and performed some researches about Transfer Function Method at the Institute of power transmission and high voltage technology of Stuttgart University until 2008. Up to now he has had several outstanding positions such as "Director of Electrical Engineering Department of Zanjan University", "Program Chairman of 13-th Iranian Conference on Electrical Engineering" and "Workshops Chair of 9-th Conference on Electrical Power Distribution Networks". Currently, he is working on transformer transients and electric field simulations at ABB AG, Power Products Division, Transformers, Bad Honnef, Germany and is a Senior member of the IEEE.