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A Novel Approach of Transformer Oil Quality Analysis Using Image Processing

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ABSTRACT:*Electrical energy is the paramount need in a nation's development. To cater for large demand for electricity there is a need for reliable and proficient power system. For a power system to work reliably, the role of Transformers is critical. Health of the transformer mainly depends on its insulation. Among the different insulating material used in transformers, mineral oil is the most widely used as insulating medium in oil filled transformers. The performance of the transformer depends on the quality of the insulating oil. Hence, the oil quality analysis becomes essential. Traditionally chemical diagnostic criteria are used for oil quality evaluation. However, this conventional method is expensive and time consuming. Extensive experimental evaluation has been fruitful to establish the acidity and tanδ of the transformer oil. Here, we are proposing Image processing technique to estimate the oil properties, which is inexpensive and effective technique. Namely Texture Entropy is extended to compute the Neutralization Number (NN) or Acidity and tanδ (Dissipation factor). Further they compared.*

Keywords: *Transformer oil, Oil analysis, Acidity, tanδ (Dissipation factor), Image Processing (IP), Entropy (E).*

I. INTRODUCTION

Since, oil cooling is one of effective strategy in the transformer cooling strategy. Oil serves as both cooling and insulating agent in transformer, so health of the oil is very important [1]. Oil degrades because of gases dissolved in it due to the occurrence of various faults and deterioration with respect to age. Increase in dissolved fault gases concentration in oil, results in oil losing its effectiveness; this will influence the transformer performance. Variation in transformer performance will ultimately affect on power supplying company's revenue and consumers. Hence, to prevent the transformer failure, oil analysis is very essential and there are several methods to diagnose the health of the oil. Currently, in the practice of chemical diagnostic criteria has been end of with following significant observation such as, dangerous to operate during oil transaction, time consuming and expensive. As per the literature and practice of electrical system, oil changes have been modifying the colour as time varies. In other words, the changing of oil colour attempts to indicate its life cycle. This paper describes economical, optical method to highlight changes in transformer oil. Hence, we are able to notice the drastic change in oil colour and subjected to the testing. As oil gets aged, color of the oil changes which indicates the transformer oil condition. Here, the prominent oil characteristics are Acidity, Interfacial Tension (IFT), power factor and tanδ. They are quite interrelated to each other [10]. Due to the ageing of the oil, these two properties values also remarks through the change. Increasing of acidity will raise the tanδ of the oil [14]. In view of the overcoming the pitfalls of conventional practice, the most convenient strategy through appearance based automation with the help of Image Processing concept. An explorative experiment has been conducted with image processing technique namely Texture Entropy, subsequently compared the performance with conventional methods. The proposed work stuffing is set as follows. The related work has been dealt in Section 2. The project process is emphasized in Section 3. The experiment and results are discussed in section 4. Conclusion is presented in section 5.

II. COMPREHENSION OF RELATED WORK

There are several methods to analyze the dissolved gases in the oil, very famous and classical method is Dissolved Gas Analysis (DGA).This method gives more information about dissolved gas concentration in oil [3]. The various faults can generate different fault gases, those gases are separated from oil and gas concentration is measured. The major gases generated from faults are Hydrogen (H_2), methane (CH_4), Acetylene (C_2H_2), Ethylene (C_2H_4), Ethane (C_2H_6), carbon monoxide (CO), carbon dioxide (CO_2); these gases are called key gases [4].

Sherif S.M. Ghoneim et al. [4] studied about transformer faults and suggested that, sudden increase of gas concentration indicates an impending trouble within the transformer. The DGA test suggests that analyzing another sample and compares the new sample evaluation with previous one will determine the key gas concentration. DGA technique calculates the key gases ratios and compares these ratios with suggested limits.

Some other methods considered for diagnosing the transformer faults are; Roger Ratio Method, IEC Ratio Method, Dornenburg Ratio Method, Duval Triangle Method and Key Gas Method.

According to G. J. Pukel et al. [4], the thermal and Optical Diagnostic method collects the source of information from an electromagnetic spectrum frequency ranging between 104Hz to 1016Hz. Thermal imaging cameras capture the image and produces an infra red format for temperature measurement. Thermal imaging can easily identify the hot spots in bushings and tank.

The mechanical diagnostic method is illustrated by G. J. Pukel et al. [4] during short circuit condition, deformation is takes place due to decrease in the tension force of the transformer winding. After applying current surges, transient oil pressure is measured to determine the tension force. The tension force is inversely proportional to transient oil pressure.

Pollster Naveen Kumar Sharma et al. [5] describes how an Artificial Neural Network method is used as an application in DGA to increase the computational efficiency. There is a hidden relationship between dissolved gases and fault types; this can be very effectively recognized from the ANN method through training process. Back propagation algorithm is adopted in the ANN method to diagnose faults in the transformer.

A. Singh & P. Verma [6] has made an attempt to further improve the DGA using Fuzzy Logic to indicate fault condition in the transformers. There are three successive processes involved in the Fuzzy Logic analysis; they are Fuzzyfication, Fuzzy Interference, Defuzzyfication. Since there are several uncertainties in designing of the transformer fault diagnostic system, fuzzy logic method is divided into two types of data processing to obtain correct results.

W. Xu et al. [7] attempted to improve the DGA from Neuro – fuzzy system. It is the combination of neural network and fuzzy logic. This method utilizes the expert system and neural network for fault diagnosis.

Author M.H. Wang [8] proposed the Extension Neural Network to detect the major fault in the transformer by the help of gases dissolved in oil.

Author Hong-Tzer et al [9] attempted to employ the Self Organizing Map (SOM) method to diagnose the transformer fault; it is the combination of data mining technique and self organizing map. SOM algorithm and Self Organizing Polynomial network techniques are used to detect real time fault condition. In SOM technique modeling is done from recorded DGA data. This method eliminates uncertainty and haziness, so it is better than all other fault diagnosis methods.

Acidity and tanδ are the most important properties of the oil. It indicates whether the quality of the oil has deteriorated or not. I.A.R. GRAY Transformer Chemistry Services [10] describes acidity and other property connected to acidity. The amount of Potassium Hydroxide (KOH) in milligram (mg) that takes to neutralize acid in 1gm of transformer oil is called Acidity. The amount of Acidic or alkaline material present in oil is measured from Neutralization Number (NN). As oil gets aged, acidity increases therefore NN also increases. If oil NN is high, that indicates oil is more contaminated with materials, such as varnish foreign matter or oxidization. Usually there is no acid content in new oil, oxidation of insulation forms the sludge's and impulse out of transformer metal in side tank forms the soaps from acid assault and also increase the insulation degradation. NN is definite relation with Interfacial Tension (IFT). IFT measures the tension at interface between two liquid (oil and water) which do not mix and is expressed in dynes/cm. Solid insulation material produce the dissoluble polar contaminants and oil decompose product. Lower IFT indicates that oxidation products present on oil. TABLE II shows the relationship between NN to IFT.

Author [10] I.A.R. GRAY Transformer Chemistry Services define tanδ. It is the measurement of leakage current through an oil. In other words it determines the contamination or deterioration level of oil. Dissipation factor is defined as tanδ and power factor is defined as sinδ. tanδ has direct relation with power factor of insulating oil..

Electric stress changes the tan δ, relative permittivity and breakdown voltage of the oil. This is investigated by Suwarno et al. [11] from Fourier Transform Infra Red (FTIR) technique. Chemical changes in the oil leads to failure of insulation system in transformer.

In the work of Umashankar Babuparamashiva et al. [12] the ageing of insulating oil is a cumulative process and it affects on transformer consistency and useful life. Electrical stress and chemical stress are changing the chemical, physical and electrical properties of the oil.

According to G. Daemisch [13] the foremost reason for transformer failure is insulation degradation. Ageing of the insulation has been predicted as one of the main cause of transformer failure. Increasing of humidity, decreasing of breakdown strength of oil- paper insulation and partial discharge in insulation system is the effect of oil degradation. The oxygen comes from solved air and oil decays from thermal stress and form mud. All these factors have affect on insulation failure, ultimately leads to transformer failure.

The literature survey has prompted us to analyze the transformer oil condition to maintain good health of transformer.

The proposed method analyzes the quality of transformer oil by determining the acidity and tanδ value. This work attempts to give information about oil superiority and measuring the oil condition from its image texture.

III. PROJECTED PROCESS

3.1: Conventional diagnostic method of transformer oil

There are numerous investigating methods to determine the transformer oil quality. Chemical method is most enlightening technique to examine the oil properties. To evaluate the oil properties, chemical method is sub divided in to two types namely DGA and Oil analysis [5]. DGA furnishes information about fault in transformer and oil analysis assesses the oil properties like NN, viscosity, tanδ, IFT and power factor. Fig 1 shows the block diagram of traditional and proposed method of oil evaluation. To determine the acidity of oil, potentiometric titration with potassium hydroxide is used and for tanδ measurement Schering Bridge is utilized. These conventional diagnostic methods are devouring much time to estimate the oil properties. To overcome the disadvantages of traditional method, an image processing technique of Entropy method is proposed in this work. Strategy important

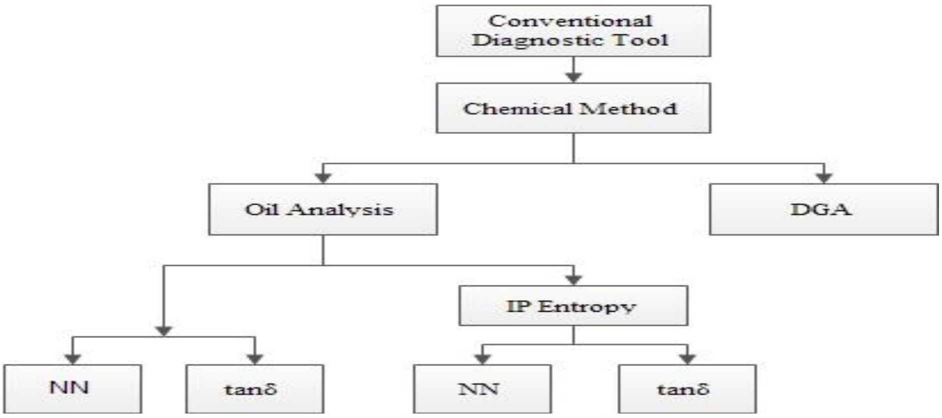


Fig 1: Block diagram of conventional and proposed diagnostic method

3.2 Oil properties assessment by Entropy technique

As oil gets aged color and texture of the oil changes, at the same time some of the properties related to oil also change. In this work Acidity and tanδ of oil is calculated from image processing approach called Entropy. Entropy can be described from equation (1) -

E=-sum(a.*log2(a)) (1)

Where 'a' contains the histogram counts

Entropy is a statistical measure of randomness that can be used to characterize the texture of the input image.

The acidity calculation is done on the basis of straight line formula, because when the samples Ageing v/s Acidity graph is drawn in Fig 2, a slope exists.

The NN values can be estimated from equation (2) -

NN= (Ac*y) + c (2)

Where,

NN = Neutralization Number c = constant = 0.013 y = years Ac = Acid constant

Acid constant value can be obtained from equation (3) -

Ac=(Fnn-Inn) / (Ty) (3)

Where,

Fnn = Final neutralization number from standard test Inn = Initial neutralization number from standard test

Ty = Total number of years Ac = {0.013 $0 \leq Ty \geq 14$ 0.0159 $15 \leq Ty \geq 25$}

Two Ac values are taken to acquire the NN, the reason behind this is that the acidity is not constantly enhancing.

tanδ or Dissipation factor can be calculated from equation (4) -

tanδ = y* k (4)

y ≠ 0 (fresh oil ageing is taken as 1)
k = constant
k = (Final tanδ value from standard test) / Ty
k = {0.0021 $\quad 0 \leq Ty \geq 14$
{0.00719 $\quad 15 \leq Ty \geq 25$
Power factor of the oil can be calculated from equation (5) -

$$\text{Power factor} = \sqrt{\frac{\tan\delta^2}{1+\tan\delta^2}} \qquad (5)$$

to acquire both NN and tanδ of transformer oil, ageing year of oil is essential. Equation (6) is used to calculate y value from Entropy of the image -

$$y = (E_1-E_0) / (k_1) \qquad (6)$$

E_0 = Entropy of the fresh oil $\quad E_1$ = Entropy of the oil sample (old) $\quad k_1 = 0.046$

3.2.1 Algorithm: Evaluation of NN and tanδ of Transformer oil by Entropy method
Load the image, convert into gray scale and resize.
To obtain the noise free image, Median filter is used.
Find the Entropy (E).
Declare k_1 and determine the *y* value
Ensure the *y* value ($y \geq 14$)
If *y* is less than 14 years, *Ac* is declared as 0.013 for NN and k_2 is stated as 0.0021 for tanδ calculation.
If *y* value is in between 15 to 25 years, *Ac* and k_2 are affirmed as 0.0159 and 0.00716 for acidity and tanδ computation.
If *y* value is more than 25, result will be displayed as ERROR.

IV. RESULT AND DISCUSSION

Experiments are conducted on images of tested transformer oil samples. During the experiment topping of oil to the transformer is neglected and working temperature is considered as 60 deg Celsius. All samples are not taken from single transformer and ratings of transformers are also not same. All formulas and calculations are based on standard test results. Proposed method works up to 25 years age of oil, if *y* is more than 25 or E is in excess of 4.97 results are displayed as ERROR. NN and tanδ mainly depends on *y* value, this means changing of *y* value resulting in NN and tanδ change. If the Entropy is more than 4.34, NN is considered as 0.3 according to TABLE II. NN and IFT are interrelated properties, IFT value is obtained from TABLE I. NN, tanδ, IFT and power factor of transformer oil is displayed in TABLE II.

TABLE I: The relationship between NN to IFT [10]

HISTORICAL DATA BASE ESTABLISHING CORRELATION BETWEEN NEUTRALIZATION NUMBER-INTERFACIAL TENSION AND SLUDGE FORMATION IN OIL FILLED TRANSFORMERS		
Neutralization Number vs Sludge (A)		
NN mg/KOH/g	Percent of 500[1]	Units Sludged
0.00-0.10[2]	0	0
0.11-0.20	38	190
0.21-0.60	72	360
0.60 and up	100	500
Interfacial Tension vs Sludge (B)		
IFT Dynes/cm	Percent of 500[1]	Units Sludged
1) Below 14	100	500
2) 14-16	85	425
3) 16-18	69	345
4) 18-20	35	175
5) 20-22	33	165
6) 22-24	30	150
7) Above 24	0	0
[1] ASTM - 11 year test on 500 transformers(1946-57).		
[2] Realistic value of 0.03-0.10.		

TABLE II: Comparison of standard method results with Entropy method results

Sl No	Standard method			Entropy method					
	Sample ageing year	NN in mg KOH/grm	tanδ	Entropy value	Sample ageing year	NN in mg KOH /grm	IFT	tanδ	Power factor
1	1	0.013	0.002	3.36	1	0.013	< 24	0.002	0.002
2	3	0.05	0.006	3.48	2.6	0.043	< 24	0.005	0.005
3	9	0.1	0.018	3.85	10.65	0.151	< 24	0.022	0.179
4	12	0.15	0.024	3.92	12.82	0.179	18 – 20	0.026	0.024
5	14	0.2	0.029	4.01	14.15	0.196	18 – 20	0.029	0.028
6	16	0.25	0.108	4.1	16.08	0.268	18 – 20	0.115	0.107
7	17	0.27	0.12	4.19	18.02	0.3	14 – 16	0.129	0.119
8	18	0.3	0.125	4.205	18.26	0.3	14 – 16	0.131	0.124
9	21	0.3	0.155	4.41	21.15	0.3	14 – 16	0.152	0.153
10	25	0.3	0.179	4.97	24.34	0.3	14 – 16	0.175	0.176

From the TABLE II it can be observed that Entropy value is directly proportional to age of the oil. tanδ value increase 0.002 per year for the period of 0 to 14 years, so k in equation (4) is taken as 0.0020. After 14 years oil reaches critical acid value, so rapid enhancement in tanδ. This prompts us to take another constant for15 to 25 years period. Increase in ageing increases the tanδ, which is clearly illustrated in figure 3. According to TABLE II, power factor is directly proportional to tanδ. Oil samples image which is used during experiment is shown in figure 3.

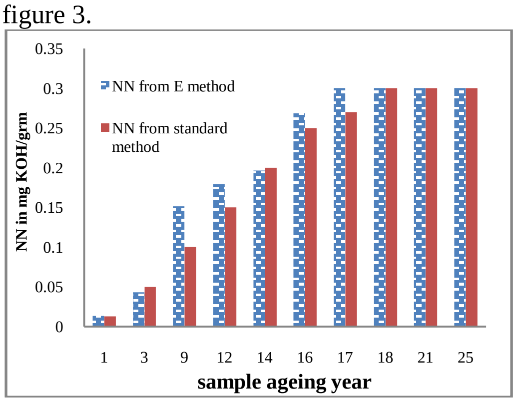


Fig 2: NN V/s samples ageing year graph

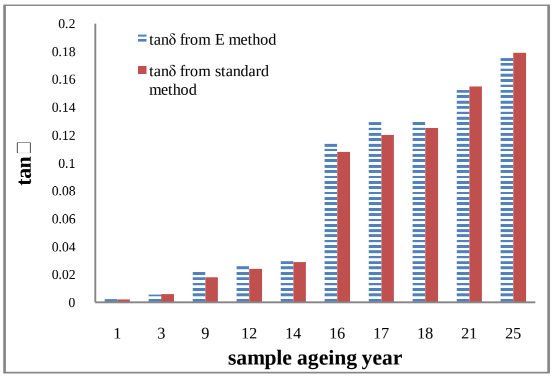
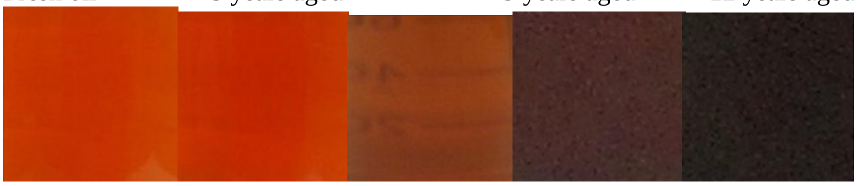


Fig 3: tanδ v/s samples ageing year graph



Fresh oil 3 years aged 9 years aged 12 years aged 14 years aged



16 years aged 17 years aged 18 years aged 21 years aged 25 years aged

Fig 4: Experimental oil sample images

V. CONCLUSION

This work has made an effort to reveals the change in acidity, Interfacial Tension, power factor and tanδ properties of the transformer oil. Further, it emphasizes the inference as the outcome of experimentation. It enhances the acidity with respect to increase of tanδ. Image processing technique texture entropy yielded better results of transformer oil properties evaluation. In the sequence, it notices as quick and viable criteria as compared with conventional practices. Here, the proposed strategy works through statistical parameter such as entropy features of oil image. Subsequently, image processing complete procedure is employed to analysis of transformer oil quality.

REFERENCES

[1] Endah Yuliastuti, *Analysis of dielectric properties comparison between mineral oil and synthetic ester oil.*, Delft University of Technology, Netherland, June 2010.
[2] Dr. J Spencer, *Optical detection of the degradation of transformer oil*., University of Liverpool, 2009.
[3] Sherif S. M. Ghoneim, Sayed A., Taif ,Dissolved gas analysis as a diagnostic tool for early detection of transformer faults, *Advances in Electrical Engineering Systems*, *1(3)*, 2012, 152 – 156.
[4] G. J. Pukel, H. M. Muhr, W. Lick, *Transformer diagnostics: Common used and new methods*, Graz University of Technology Austria.
[5] Naveen Kumar Sharma, Prashant Kumar Tiwari, and Yog Raj Sood, Review of Artificial Intelligence Techniques Application to Dissolved Gas Analysis on Power Transformer, *International Journal of Computer and Electrical*, *Engineering, 3(4)*, August 2011, 577- 581.
[6] Amritpal Singh, and P. Verma, A Review of Intelligent Diagnostic Methods for Condition Assessment of Insulation System in Power
Transformers, *IEEE International Conference on Condition monitoring and Diagnosis, Beijing, China*, 2008.
[7] W. Xu, D. Wang, Z. Zhouand and H. Chen, Fault Diagnosis of Power Transformers: Application of Fuzzy Set Theory, Expert
Systems, and Artificial Neural Networks, *IEEE Proceedings of Science, Measurement and Technology, 144(1),* 1997, 39-44.
[8] M.H. Wang, Extension neural network for power transformer incipient fault diagnosis, Generation, Transmission and Distribution,
IEEE Proceedings 2003, *150(6)*, 2003, 679 – 685.
[9] Hong-Tzer. Yang, and Yann-Chang. Huang, Intelligent Decision Support for Diagnosis of Incipient Transformer Faults Using Self- organizing Polynomial Networks,Power Industry Computer Applications, *20th International Conference*, 1997, *60 – 66*.
[10] *A guide to transformer oil analysis* (I.A.R. Gray Transformer Chemistry Services)
[11] Umashankar Babuparamashiva, Sushi I Chaudhari, Anil Kumar Bhatia, Experimental Investigation of Iso-Paraffinic Oil for Application in High Voltage Power Transformers, *2012 IEEE 10th International Conference on the Properties and Applications of Dielectric Materials Bangalore, India* , July 2012, 24-28.
[12] Suwarno and Fadli Salim, Effects of Electric Arc on the Dielectric Properties of Liquid Dielectrics. , *IEEE International Conference,*
2006, 483-485.
[13] G. Daemisch, Geriatrics of transformer.