Effect of Mixing Insulating Mineral Oil in Transformer at Different Rations on its Breakdown Voltage

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Abstract:

Mixing different types of insulating mineral oil has an effect on the breakdown voltage of the mineral oil. In this study, the main aim is evaluating the effect of mixing different types of transformer oil at different rations on the breakdown voltage, we measured the breakdown voltage of three types of transformer oils with IEC60156 standard, using an electrical device to measure the breakdown voltage, and indicated the negative effect of this process on the value of the breakdown voltage , the result of 50% mineral oil with 50% new mineral oil has been selected as the optimum mixing ratio for the insulating mineral oil in transformer. In this case, our transformer (0.4-20) kV, and the studied samples are new mineral oil and used mineral oil samples taken from transformers in operation.

Key words: Breakdown voltage, High voltage, Mineral oil, Transformer oil.

Introduction:

A Transformer is one of the important equipment in electric power transmission and distribution system. The quality of oil in a transformer plays an important role in the insulation. Breakdown voltage of insulating oil is the most important factor to assess the insulating property of dielectric transformer oil. Researchers studied how to improve the properties of the mineral oil by mixing some materials. The most commonly used liquid in power transformers is mineral oil (T. O. Rouse 1998). The insulation fluid in power transformers performs two main functions; insulating and cooling. The highly refined mineral oils (transformer oils), typically used as insulating fluids, have low thermal conductivity and thus perform low cooling efficiency (H. G. Erdman. 1996). Optimization of power transformer insulation happen by the improvement of the characteristics of the most commonly used insulating liquid, i.e., mineral oil. For that purpose, mixtures consisting of mineral oil and other insulating.

liquids (namely silicon and synthetic ester oils) are investigated. (C.Perrier, et. 2006). However, they didn't draw clear roles about mixing different types of transformer oil and left it for the laboratory studies. In our research we studied the effect of this issue on the breakdown voltage for different types of mineral transformer oil. In general, the breakdown state of insulating liquids is explained by three different theories.

Firstly, pollutant and especially humid particles at the micro level in the insulating oil move towards electric field. Thus, these micro particles create a large dipole and a conductive bridge between occurred electrodes. If the particle radius is r (mm) and applied electric field is E (kV/mm), the force (F) which moves the particles towards the maximum of electric field, is defined in Eq. (1) as follows:

$$F= \frac{1}{2} \cdot r^3 \frac{(\varepsilon_2 - \varepsilon_1)}{2 \cdot \varepsilon_1 + \varepsilon_2} \cdot grad(E^2) \quad (1)$$

Where $\varepsilon 1$and $\varepsilon 2$are dielectric permittivity of the insulating liquid and particle, respectively. On the assumption that there is a fiber particle in oil having r radius. The charges at both ends of this fiber particle is described in Eq. (2). If the moving fiber or solid particle reach the electrode, they form a chain ring between the electrodes, and the local electric field starts to increase. These chain rings create a conductive bridge and so they cause breakdown in insulating oil.

$$\pm q = \pi \cdot r^2 \cdot (\varepsilon_2 - \varepsilon_1) \cdot \varepsilon_0 \cdot grad(E^2) \quad (2)$$

Secondly, air or gas bubbles in the insulating oil are some of the causes of the breakdown. The electric field strength in a spherical gas bubble in the uniform field can be calculated as follows in Eq (3):

$$E_b = \frac{1}{(\varepsilon_2' - \varepsilon_1')} \times \left\{ \frac{2 \cdot \pi \cdot \sigma \cdot (2 \cdot \varepsilon_2' - \varepsilon_1')}{r} \left[\frac{\pi}{4} \sqrt{\left(\frac{V_b}{2 \cdot r \cdot E_0} \right) - 1} \right] \right\}^{1/2} \quad (3)$$

Where ε' and ε' are relative permittivity of the gas inside the bubble and the insulating liquid, respectively. σ is the surface tension of the insulating liquid, r and Vb are the radius and voltage drop of the gas bubble, respectively. $E0$ is described the electric field intensity in the absence of gas bubble in the insulating liquid.

Thirdly, electrons in the insulation liquids have an average energy and show a Gaussian distribution due to electric field occurring between electrodes. These electrons share their energy by colliding with atoms of liquid molecules. The effect of the collisions causes local heating in this area. If enough energy during these collisions is released, the electrons can cause the impact ionization and thereafter streamers occur in low-intensity area of the liquid. Once the voltage rises to a sufficient magnitude, the density of streamers increases and eventually leads to the breakdown of insulating liquid by reaching the other electrode (Wadhwa. (2007), Al- Arainy ,et. (2005)). Mixing of different refiners brands of inhibited oil demands very much greater caution. The compatibility of different additives is not known and much more likely to cause problems. BS 148:1984 standard for unused mineral insulating oils for transformers and switchgear advises that if mixing of inhibited oils is contemplated a check should be made to ensure that the mixture complies with the requirements of this standard. To carry out such a check properly would be a time- consuming exercise and would hardly be justified simply for the purposes of topping- up existing equipment with oil from an inappropriate source (Martin J. Heathcote .1998).

Although mineral insulating oils may be mixed with other types of dielectric fluids, it is advisable to use dedicated processing and handling systems for each different type of fluid (IEEE Std C57.106-2006). The dielectric breakdown voltage of an insulating liquid is the measure of the liquid's ability to withstand voltage stress (W. Lick, et.2008). Low values of breakdown voltage indicate the presence of moisture and conducting substances within the oil (Y.Hadjadj, et. 2013). A high voltage breakdown voltage of oil is influenced by the different percentage of mineral oil with vegetable oils, the higher percentage of vegetable oil in the mixture will provide higher breakdown voltage (Muhammad bin Yahya,et 2017)

Materials and Methods

The experimental phases have been done at the Laboratory of Transformers (Ministry of Electrical-Damascus –Syria). The breakdown voltage of the samples was measured at room temperature according to the IEC 60156 standard using breakdown voltage device (MEGGER) with 2.5 mm gaps as show in fig1:

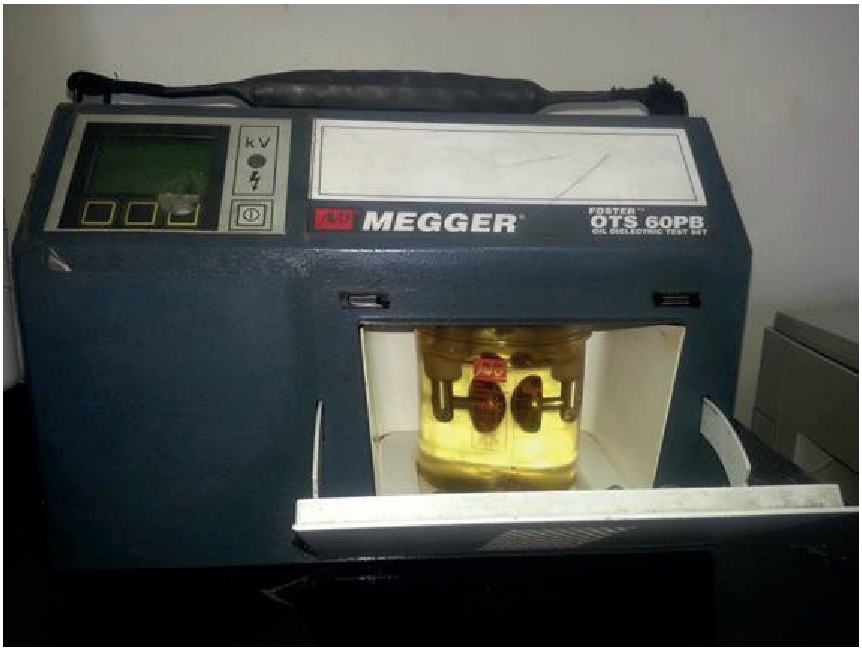

Figure.1Picture of the device used to measure the breakdown voltage.

For the experiment, transformer oil was filled in the vessel of the testing device, after that two standard-compliant test electrodes with a typical clearance of 2.5 mm were surrounded by the dielectric oil .We applied a test voltage to the electrodes and continuously increased up to the breakdown voltage with a constant value 2 kV/s. At a certain voltage level breakdown occurs in an electric arc, leading to a collapse of the test voltage. The transformer oil testing device measured and reported the root mean square value of the breakdown voltage. After the transformer oil test was completed, the insulation oil was stirred automatically and the test sequence was performed repeatedly. According to the standard 5 repetitions are performed. As a result, the breakdown voltage was calculated as mean value of the individual measurements shown in the **table (5)** and **table(6)**.

Preparation of the samples:

The transformer oil samples used in this study were three types of mineral oils, description of this samples **(Table1)**, and mixing process of the samples has been done in the (High Education laboratory at the faculty of Science-University of Damascus).

Name of the Sample	Sample Description
Sample1-A	used transformer mineral oil for 6 month (imported from China),in transformer (0.4-20)kV under operation
Sample2-B	new transformer mineral oil (imported from India), Ministry of Electricity warehouses
Sample3-C	used transformer mineral oil for one year (imported from Lebanon) in transformer (0.4-20)kV under operation

Table 1: Description of samples.

First experiment:

In this case, we have mixed the first sample **(A)**, with second sample **(B)** at different ratio as follow in the **table 2:**

Type(A)	Type(B)
20%	80%
40%	60%
50%	50%

Table 2. Ratio of mixing oil at first experiment.

Second experiment:

In this case, we have mixed the first sample **(B)**, with second sample **(C)** at different ratio as follows in the **table 3.**

Type(B)	Type(C)
20%	80%
40%	60%
50%	50%

Table3. Ratio of mixing oil at second experiment.

Third experiment:

In this case, we have mixed the first sample (A), with second sample (C) at different rations as follow in the table 4.

Type(A)	Type(C)
20%	80%
40%	60%
50%	50%

Table 4. Ratio of mixing oil at third experiment

After mixing process the obtained samples as shown **fig 2**.

Figure.2 Picture of the samples after the mixing process.

Results and Discussion:

For the three types of transformer oil before mixing the results of the value of their breakdown voltage as follow in **tables 5**.

Types	Test1	Test2	Test3	Test4	Test5	Test6	Calculating the value of BDV	Result of Testing	Test Method
A	38	37	41	36	37	39	228/6	38 kV	IEC60156
B	44	47	49	44	45	47	276/6	46 kV	IEC60156
C	30	36	37	32	33	36	204/6	34 kV	IEC60156

Table 5. Result of testing three types before mixing

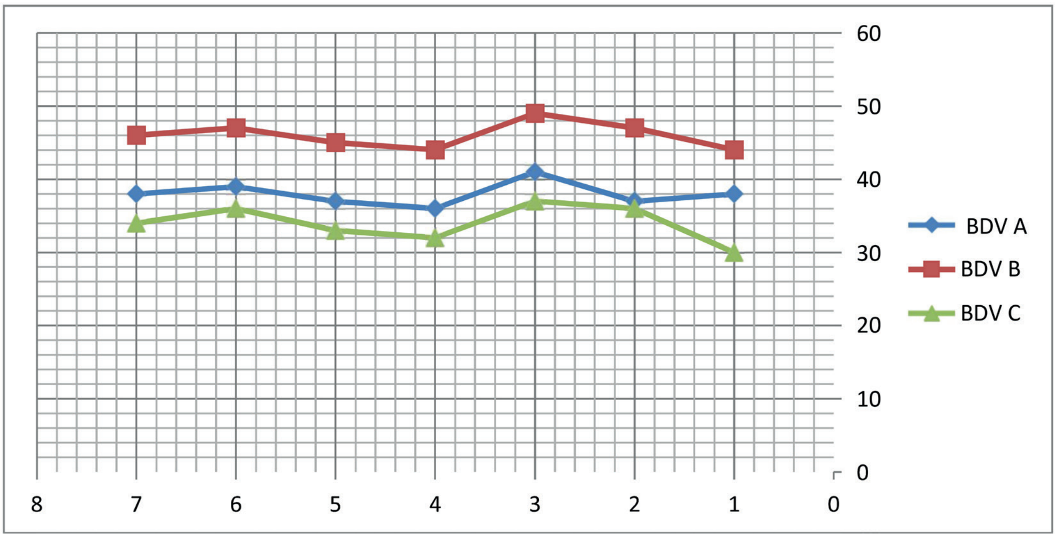

Fig 3. Diagram of breakdown voltage of the studied samples

After mixing the three types with the different ratio mentioned above, we can see the effect of the mixing on the breakdown voltage, the results are shown in **table 6:**

Sample	Rations	Test1	Test2	Test3	Test4	Test5	Value of Breakdown voltage
1	20% (A)+80%(B)	20	21	23	22	24	23 kV
2	40% (A)+60%(B)	18	23	22	19	21	21 kV
3	50% (A)+50%(B)	39	44	45	45	40	42 kV
4	20% (B)+80%(C)	20	41	30	27	25	29 kV
5	40% (B)+60%(C)	20	20	24	21	23	22 kV
6	50% (B)+50%(C)	35	29	36	31	32	33 kV
7	20% (A)+80%(C)	21	39	32	25	27	29 kV
8	40% (A)+60%(C)	19	20	22	21	23	22 kV
9	50% (A)+50%(C)	28	31	33	30	29	31 kV

Table 6. Results of testing the sample after mixing process

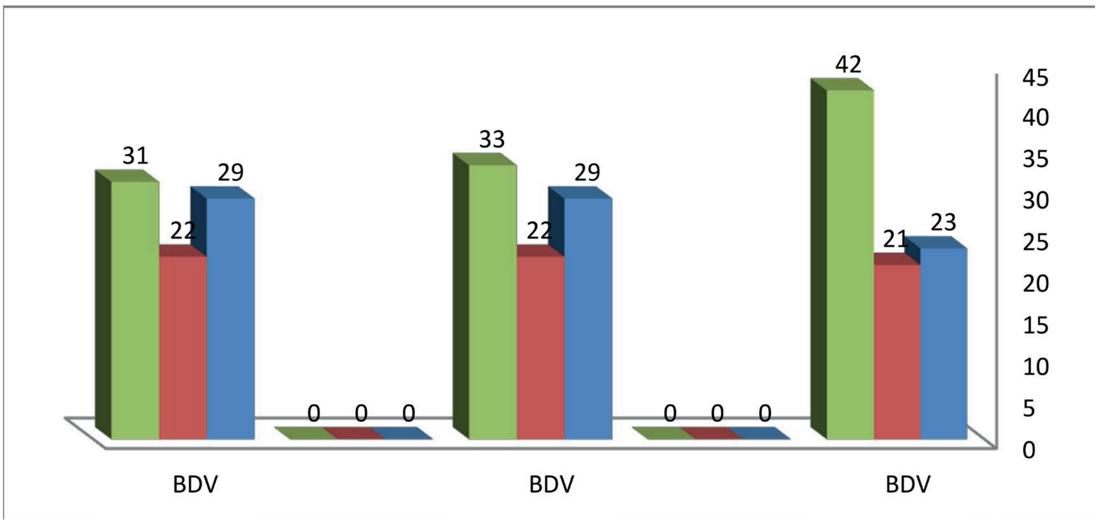

Fig 4. Graph show the value of breakdown voltage after mixing process

Conclusion :

Results obtained from the present study indicated that the breakdown voltage of new samples after mixing process has been decreased. The experiment of measuring breakdown voltage of mineral oil was performed, considering various operating conditions and the obtained results were described. It is revealed that the breakdown voltage decreases with the ratio from 20% to 80% and from 40% to 60% the values were between 21kV to 29kV. And all the ratio 50% with 50% breakdown voltage of the oil mixture was above 30kV, starting 31kV to 42kV, which fulfilled the IEC standard. The breakdown voltage value shows the estimated lowest dielectric strength obtained from 40% to 60%. Comparisons between mixtures of mineral oil with Synthetic Esters and vegetable oils reported by past researchers have shown that the dielectric strength for all ratios are far superior than mineral oil where all the breakdown voltage of oil mixture has exceeded the breakdown voltage of mineral oil. In the light of our results it can be proposed that the results indicated the negative effect of the mixing process on the breakdown voltage. To summarize, in this paper we find that 50% used mineral oil with 50% new mineral oil, is the optimum mixing ratio for the new insulating mineral oil with used mineral oil in transformer. In the future, we will study the effect of mixing process on other factors which play main role in the quality of transformer oil as acidity, viscosity, temperature, etc..

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تأثير مزج الزيوت العازلة المعدنية في المحولات بنسب مختلفة على جهد انهيارها

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الملخص:

إن مزج أنواع مختلفة من الزيوت المعدنية العازلة له تأثير على جهد انهيار الزيت المعدني. في دراستنا هذه، الهدف الرئيس هو تقييم أثر مزج أنواع مختلفة من زيوت المحولات بنسب مختلفة على جهد الانهيار، حيث قمنا بقياس جهد الانهيار لثلاثة أنواع مختلفة من زيوت المحولات حسب المواصفات القياسية العالمية IEC60156، باستخدام جهاز كهربائي لقياس جهد الانهيار، وبيَّنَّا الأثر السلبي لعملية المزج على قيمة جهد الانهيار، وقد تم اختيار النسبة ٥٠٪ زيت معدني مستعمل مع٥٠٪ زيت معدني جديد كنسبة مثلى لمزج الزيوت المعدنية العازلة في المحولات. في حالتنا المحولة المدروسة (0.4-20) kV والعيِّنات المدروسة هي زيت معدني جديد، ونوعان من الزيوت المستعملة أخذت من محولة قيد الخدمة.

الكلمات المفتاحية: جهد الانهيار، الجهد العالي، الزيوت المعدنية، المحولات الزيتية.