فحوص معملية على محول توزيع قدرة فعلى معزول بالزيت حول ظاهرة تيار الإزاحة

EXPERIMENTAL INVESTIGATIONS OF THE STREAMING CURRENT PHENOMENON IN A PRACTICAL OIL-INSULATED DISTRIBUTION POWER TRANSFORMER

By

M. M. I. El-SHAMOTY

Electrical Power & Machine Department
Faculty of Engineering
Mansoura University
EGYPT

الخلاصة: يقدم هذا البحث نتائج فحوص معملية تم اجراؤها على محول توزيع قدرة فعلى مقننه ٢٠٠ ك.ف.أ. – ٣,٣ ك.ف./٣٨٠ فولت معزول بالزيت وذلك لتحديد ومعرفة العوامل المؤثرة على ظاهرة تكهرب الزيت التى تؤدى إلى تيار إزاحة تحت ظروف التحميل المختلفة، وذلك مثل سرعة سريان الزيت وجهد التغذية للمحول وتيار الحمل ودرجة حرارة الزيت.

لإجراء هذه الفحوص على المحول تم عمل تعديل خاص لمسار الزيت فى المحول ليس فقط للتمكن من تسخين الزيت واختبار تأثير درجة الحرارة وإنما أيضاً للتمكن من عمل سريان ذو سرعة متحكم فيها للزيت. وقد أظهر البحث النقاط الهامة التالية التى يجب على المصنعين والمستخدمين أخذها فى الإعتبار:-

- تيار الإزاحة السارى بالمحول يزداد كلما ارتفعت درجة الحرارة (أى كلما زاد الحمل بالمحول).
- زيادة سرعة الزيت القصرية (لرفع كفاءة تبريد المحولات) تؤدى إلى زيادة تيار الإزاحة نتيجة زيادة عوامل تكهرب الزيت.
- الزيت المتقادم نتيجة طول فترة الاستخدام يظهر ميولاً أكبر لتوليد تيارات إزاحة أعلى نتيجة التكهرب عن تلك التى تحدث فى الزيت الجديد.
- تيار الإزاحة السارى يزداد كلما زاد جهد التغذية للمحول.
- كفاءة سريان تيار الإزاحة بالزيت أكبر فى حالة تأريض نقطة التعادل عما لو كان وعاء الزيت فقط هو المتصل بالأرض.

Abstract:

This paper introduces the results of experimental investigations of the streaming current phenomenon in a practical oil-insulated 200 kVA, 3.3 kV/380 V distribution power transformer. A modification of oil path made it possible to investigate the most important factors affecting the static electrification of oil e.g. oil flow velocity, energization, loading current and temperature up to 50°C. The results are of great importance for both manufactures and utilities.

Introduction :

Recently, static electrification resulting of flowing oil in power transformers has become of a major importance for manufactures and users [1]. Numerous failures of power transformers as well as observed traces of erosion and discharges on the surface of insulating materials have been attributed to this phenomenon [2-4]. The contact of streaming high resistivity oil on the solid surface of the highly dried paper generates a static electrification which can produce discharges and then affect the insulation of the design [5]. This can be considered as a side effect to the forced circulation of oil in order to remove efficiently the heat generated by iron and copper losses.

Experimental investigations of some parameters affecting the static electrification phenomenon have been undertaken using simple closed and open cycle arrangements to enable the calculation of the electric field strengths additionally [6-10] The complexity of the transformer structure makes it difficult to investigate the static electrification which can be involved [11].

In this work, a modification of the oil path in an actual power transformer, made it possible to investigate the most important factors affecting this phenomenon. Thereby, oil flow velocity, energization, oil quality, temperature up to 50°C and loading current have been taken into consideration.

Experimental Procedure :

An actual power distribution transformer of 200 kVA, 3.3 kV/380 V rating has been used to investigate the streaming current produced by the static electrification of the transformer oil. A modification of the path made it possible to control the intentionally circulation of oil.

Figure (1) shows a schematic diagram of the transformer under test and the modified oil path. The oil flow velocity has been measured via a venturimeter and controlled by means of closing and opening the valves in the bypass. The transformer was electrically insulated from the rest of the cycle and ground.

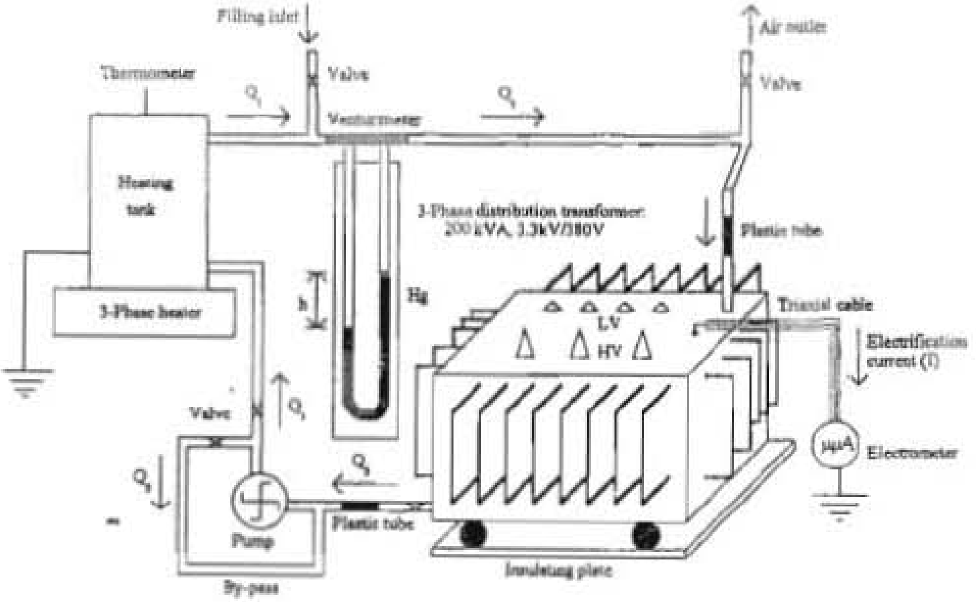

Fig.(1) : Schematic Diagram of The Transformer Under Test With Modified Oil Pass.

The electrification current is measured from tank and/or the neutral on the low voltage side. An electrometer capable of measuring down to 10^{-14} ampere has been used to measure the streaming current. Double shielding of the electrometer and connecting cable has been ensured to avoid any external interference by the measuring.

To take the influence of oil aging on the electrification current into consideration, fresh and aged oil have been individually used. The chemical and electrical prpperties of both oil types have been carefully investigated under the different operating temperatures. Table (1) indicates the results of property tests. The same results are elucidated in Figs.(2) & (3).

An electrical heater supplied from a three phase, 380 V, 50 Hz power supply has been used to heat the oil under test. Additionally to the heater, short-circuiting the low voltage side of the transformer at 250 ampere short-circuit current has been used to accelerate the oil temperature increasing.

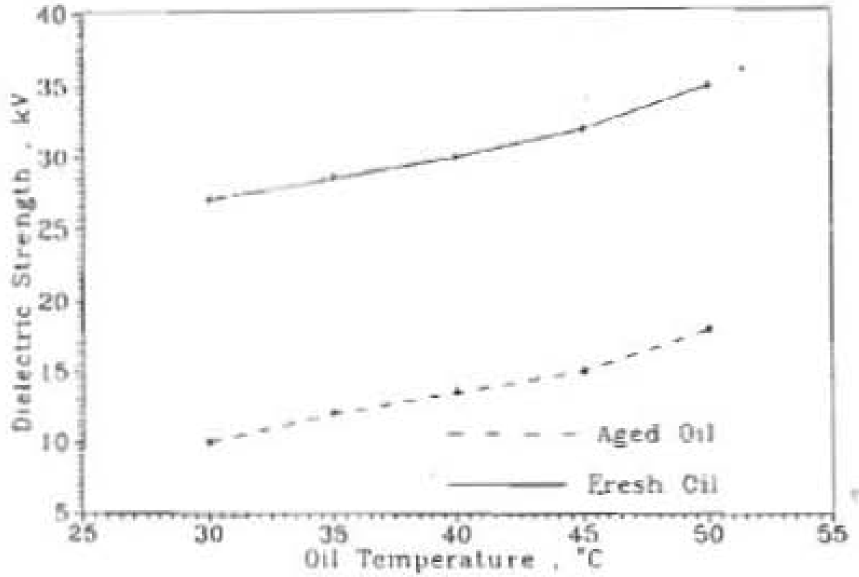

Fig.(2) : The Dielectric Breakdown Strength of Two Types of The Oil Used , Fresh and Aged , at gap 2.5 mm.

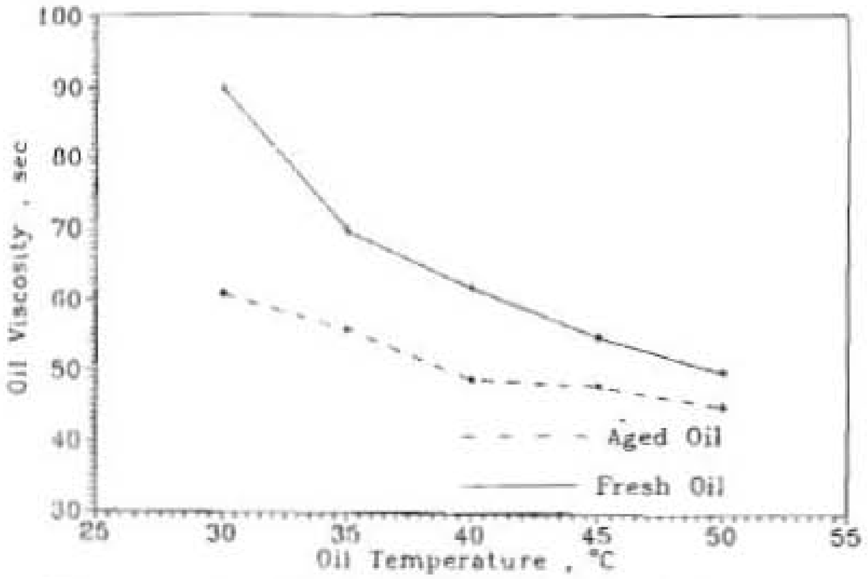

Fig.(3) : The Property of The Viscosity Oil with the Oil Temperature.

TABLE (1) : The Physical Properties of Aged and Fresh Oil used in the Power Transformer.

Property	Specification Values of Fresh Oil	Specification Values of Aged Oil
Dielectric Strength, 2.5 mm at 30 °C	27 kV	10 kV
35	28.5	12
40	30	13.5
45	32	15
50	35	18
Viscosity * at 30 °C	90 Sec	61 Sec
35	70	58
40	62	49
45	55	48
50	50	45
Flash Point **	180 °C min	145 °C min
Specific Gravity at 30 °C	0.875	0.870
Total Acid in mg of KOH	0.200	0.080

* The Viscosity is measured by REDWOOD Viscometer I.P. 70/48 British made.

** The Flash Point is measured by PENSKY-MARTEN Flash Point meter British made.

Results and Discussions :

It is well known that, the insulation of a power transformer is a complicated composite assembly of solid insulation and oil. This assembly of insulation is subjected to non-uniform field producing electrostatic charge generating conditions. The flow of the oil transports parts of this charge, formes and generates additionally free charges.

The transformer designer is interested to remove efficiently the heat generated by iron and copper losses to withstand higher loading conditions. Therefore, a forced oil circulation is usually undertaken. It is thus of great importance to clarify the influence of oil flow rate on the generating of streaming currents.

The effect of the velocity of oil flow on the streaming current for both types of oils used has been carefully investigated at different oil temperatures namely 30 °C , 40 °C and 50 °C and under AC energization ranged from 100 V up to 380 V. The obtained experimental results of the streaming current under these conditions are clearly illustrated in figures (4) , (5) and (6).

It is clear from the results that, aged oil gives higher values of streaming current than those of the fresh oil under the same operating conditions and the same energization voltages. The streaming current in all these tests was found to be in the order of few nano-amperes for velocity of oil flow up to 3.5 m/sec. This value of streaming current can be used as a parameter of aging process in the oil. For example, fresh oil gave 1.8 nA streaming current under 380 energization voltage and velocity of oil flow 2.5 m/sec, while aged oil gave 3 nA under the same conditions.

Temperature also affects the streaming current, higher temperature give higher streaming currents. This fact is clearly shown in Fig.(7) for the two types of oil tested in unenergized transformer. The same results is illustrated in Fig.(8) when the transformer is energized with AC voltage.

It is clear from the results that the streaming current increases with the increase of the energizing voltage for the same oil flow velocity (3.25 m/sec). Also, there is a significant increase in the streaming current by temperature rise.

Figure (9) illustrates the variation of streaming current with oil flow velocity, when the transformer is short-circuited (I_{sc}=250 A) , under various temperatures for both oil types. The same tendency is always found, namely, aged oil produces higher streaming currents than that of fresh oil. Also, by higher temperatures higher streaming currents are expected.

A rough comparison between both Figs. (8) and (9) shows that the applied voltage plays a dominant role by the generation of streaming currents. The higher the applied voltage the higher is the streaming current.

Figure (10) shows the variation of tank and neutral streaming current with the velocity of oil flow when the transformer is short-circuited and has S.C. current of 250 A under different temperatures namely at 35°C , 40°C and 45°C. It is clearly seen that the streaming current flowing between neutral to ground is higher than that flowing from tank to ground under the same conditions.

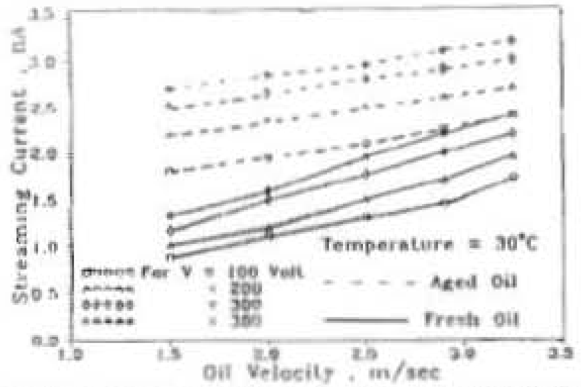

Fig.(4) : Variation of Streaming Current with Oil Flow Velocity under Various AC Energisation For Two Types of Oil and T = 30 °C.

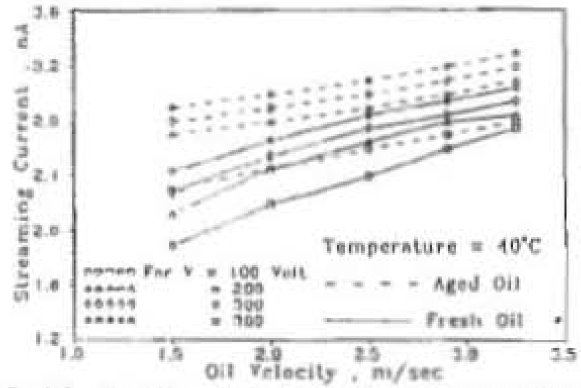

Fig.(5) : Variation of Streaming Current with Oil Flow Velocity under Various AC Energization For Two Types of Oil and T = 40 °C.

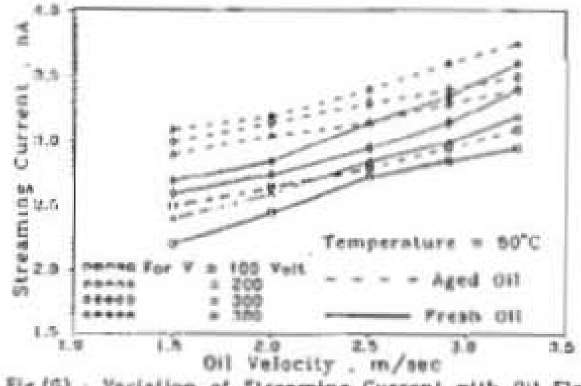

Fig.(6) : Variation of Streaming Current with Oil Flow Velocity under Various AC Energization For Two Types of Oil and T = 50 °C.

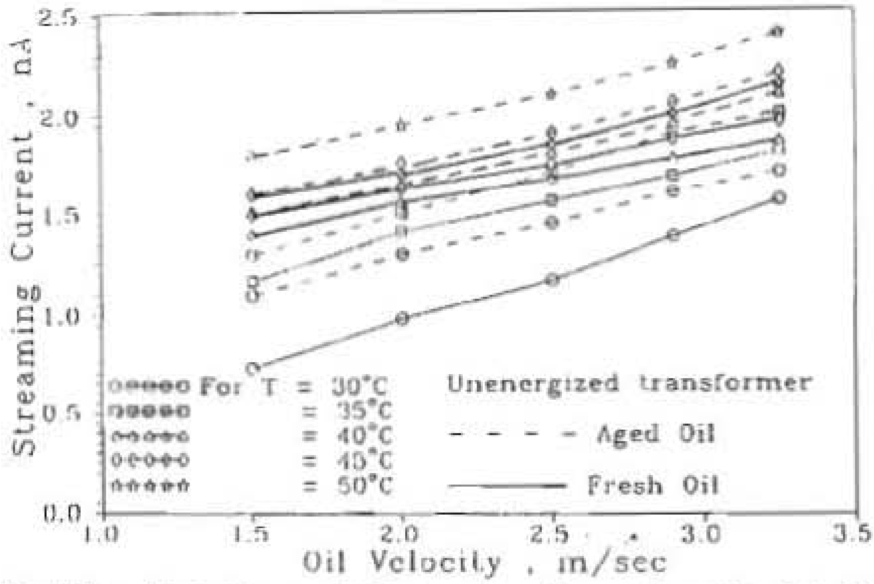

Fig.(7) : Variation of Streaming Current with Oil Flow Velocity Under Various Oil Temperatures for Two Types of Oil and Unenergized Case.

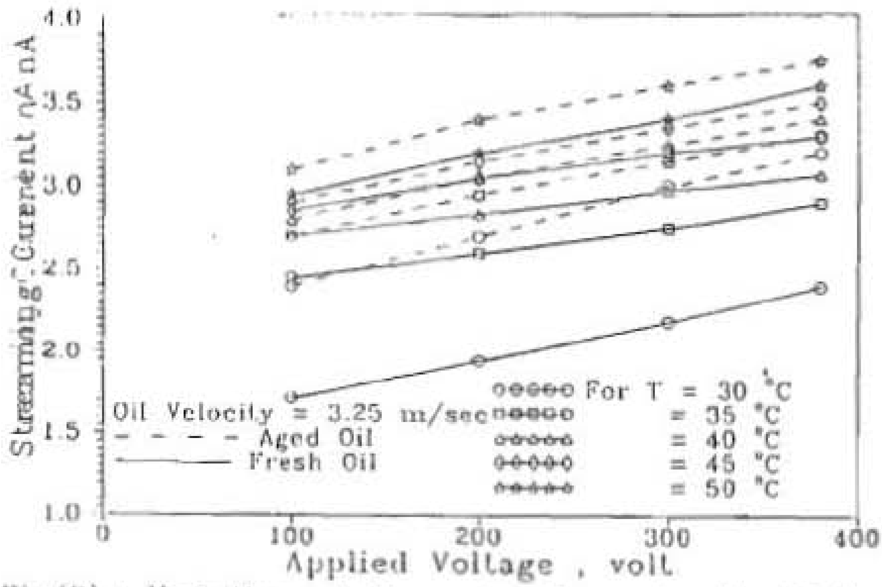

Fig.(8) : Variation of Streaming Current with AC Energization Under Various Oil Temperatures for Two Types of Oil at Flow velocity of Oil = 3.25 m/sec.

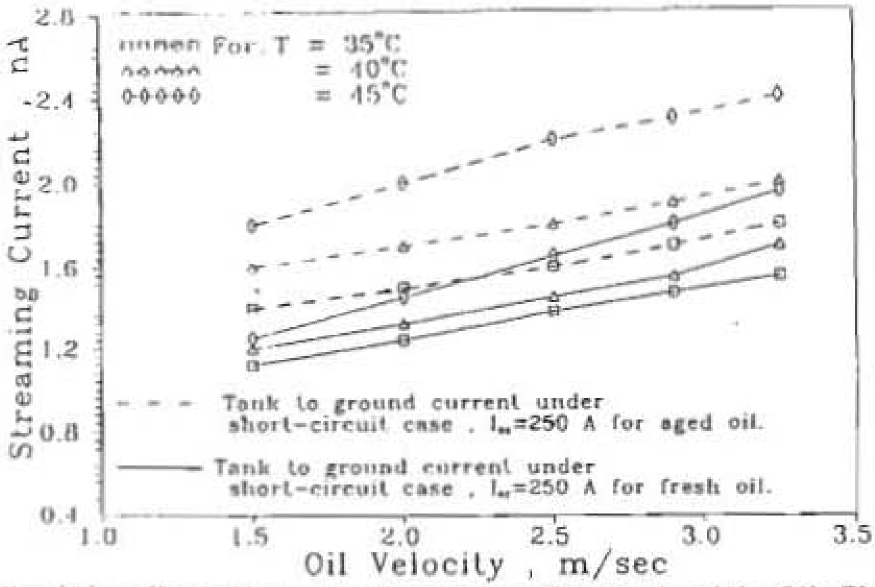

Fig.(9) : Variation of Streaming Current with Oil Flow Velocity When The Transformer is Short-Circuit , I_{sc} = 250 A , under Varipus Temperatures and Two Types of Oil.

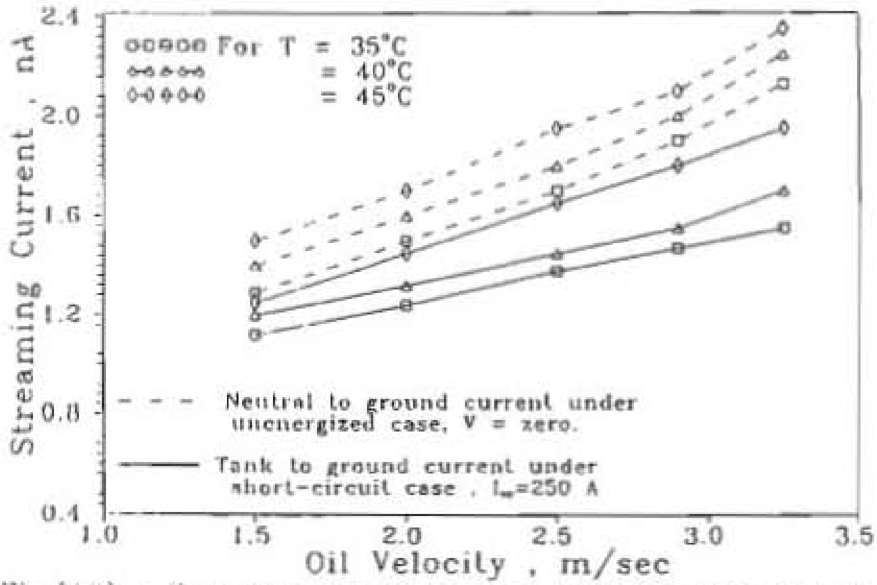

Fig.(10) : Variation of Tank and Neutral Streaming Current with Fresh Oil Flow Velocity When The Transformer is Short Circuit and unenergized for Various Temperatures.

Conclusion :

The ever growing tendency to remove efficiently the heat generated by iron and copper losses makes it necessary to force oil circulation in oil insulated transformers. Streaming currents due to static electrification can however appear as a side effect of such a procedure. To this extend the investigations carried out in this work lead to the following important conclusions :

1. Increasing oil temperature (due to higher transformer loading) increases the electrification current.

2. Increasing the oil flow velocity (to increase transformer cooling efficiency) increases the streaming current due to charging tendencies.

3. Aged oil shows higher charging tendencies than that of fresh oil.

4. Increasing the transformer energizing voltage increases the streaming current.

5. The flow of the generated streaming current to the earth can be more efficiently undertaken through neutral grounding than that of tank grounding.

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