UNDERSTANDING THE BREAKDOWN CHARACTERISTICS OF NANO MINERAL OIL UNDER NON-STANDARD TRANSIENT VOLTAGES

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***Abstract**: This paper conducts an experimental exploration about the breakdown in transformer oil under the action of impulse voltages for the insulation of the transformer in the field may be endangered to the lightning and switching overvoltage. There is a lack of research on the influences of AC and DC mixed voltage on the oil- insulation characteristics. In this paper a needle-plate electrode model is designed, and different values of AC, DC and transient voltage are levied on the oil surrounded needle-plate electrode model to learn the differences of breakdown characteristics. Liquid Insulation that is mineral oil is taken for AC, DC voltage profile and measured transient voltage breakdown strength of lightning impulse for both positive and negative polarity. After that mineral oil with Nano particle is prepared using TIo2 and surfactant as CTAB. The AC, DC and lightning impulse breakdown strength are measured for both mineral oil and Nano oil which results have been compared. It is observed that the corona inception voltage (CIV) in Lightning impulse having high break down strength when compared to AC and DC. The CIV was measured and the magnitude of discharged particles high in Nano mineral oil increases the breakdown voltage of transformer oil.*

***Key words:** Mineral Oil, Nano Oil, AC, DC, Lightning Impulse Voltages,CIV*

1. Introduction

In practice the system components may be stressed with the overvoltage of non-standard impulses and it is very important cause of transformer failure. Accordingly, it is necessary to study of non-standard impulses on insulating materials. Transformers are measured as the major equipment in power system, which in field may be subjected to the lightning and switching overvoltage and insulation coordination is generally considered the behavior of insulation under standard lightning and switching impulses [1]. There is a negative correlation between relative dielectric constant and volume resistivity that determines the field distributions of AC and DC voltages applied, in the medium respectively [2]. Transmission and distribution transformers are critical, highly loaded and classy part of the electricity generation and distribution network. Electric transformers rely on the high dielectric strength and cooling properties of insulating oil to achieve normal operation [3]. On the other hand, the good environmental property for higher fire safety guarantee, vegetable-based oils (natural esters) are considered today as a potential replacement of mineral and synthetic liquids for electrical insulation; the characteristics of these natural esters have been described in several papers [4-9]. The HV power transformers requires the knowledge of behavior of vegetable oil in the pressboard insulating systems regarding the discharges that can be originated at the interface of both the insulating materials and the propagation of which can lead to flashover and hence to the failure of insulating systems [10-15]. The Nano fluids were fictitious by engaging nanoparticles with different dielectric properties as modifiers to improve the dielectric strength of the mineral oil. Breakdown voltages under AC, DC and lighting impulse stresses were measured to evaluate breakdown strength of these Nano fluids [16]. An experimental investigation about the breakdown in transformer oil under the deed of impulse voltages with different waveform parameters of the transformer in field may be exposed to the lightning and switching overvoltage. The report of discharge and breakdown in the oil gap is found by the measurement of impulse voltage and transient current method. Meanwhile, the breakdown voltage and breakdown time for impulse voltages with changed waveform parameters are obtained. The results show that the breakdown voltage is closely related to the front time of the impulse voltage, the gap distance and the radius of curvature of the needle electrode. The propagation time of the streamer rises with the increase of the impulse front time, also the breakdown time delay has the same characteristic. The factors that inspiration the gap breakdown voltage are finally analyzed and discussed [17]. The consistency and life of transformers depend on operating condition and insulation design [18]. The transformer insulation is a amalgamation of oil impregnated pressboard (OIP) material and the transformer oil. It has been devoted to improve the dielectric strength and thermal conductivity of the transformer insulating system, in order to cover the lifetime of transformers and to increase the load capacity. The local electric fields indoors the transformer is extremely non-uniform. The transformer oil with nanoparticles such as Fe_3O_4 , Al_2O_3, SiO_2, TiO_2, the insulating and heat transfer possessions will be improve drastically indicated that titania nanoparticles detached in transformer oil have high breakdown strength [19]. The following aspects to understand the characteristics of nanoparticles dispersed transformer oil (a) To measure the steadiness of nanoparticles in transformer oil based on viscosity measurement and particle size analysis (b) To comprehend the characteristic variation in CIV and breakdown voltage of transformer oil and titania nanoparticles dispersed transformer oil.(c)To realize the impact of surfactant on CIV and breakdown voltage enhancement. (d)To know the impression of a barrier on the enhancement of CIV and breakdown strength with transformer oil under AC and DC voltages. (e) Investigation of breakdown voltage variation of electrode gap through normal distribution revisions. (f) Analysis of frequency innards present in the UHF signal generated from corona discharges in both transformer oil and titania nanoparticles dispersed transformer oil under AC and DC voltages. (i) To portray UHF signals by using Ternary plot. (j) The disparity in magnitude of discharges in transformer oil and nanoparticles detached transformer oil [20]. Semi conductive nanoparticles can be increased the AC, DC and Lightning impulse breakdown voltages of SNFs up to more than 1.2 times compared with mineral oils. Especially, the time to impulse breakdown of SNFs is prolonged by as much as 53% [21]. Depending on sole operating characteristics that valve side windings of transformer would tolerate combined AC-DC voltage, an investigational platform was established to test gas generation characteristics of transformer oil in the variety of voltages. Then 65 kV peak voltages in 5 different AC and DC voltage blends were applied to the needle plate electrode model for 2 hours. The test results showed that the expanses and generation rates of fault characteristic gases in oil under pure DC voltage and combined AC-DC voltage were many more than those under pure AC voltage. This data support for the standards about gas chromatography analysis for transformer [22]. The vegetable oil and mineral oil is observed due to two phenomena that equally compensate: (i) the permittivity between vegetable oil and pressboard being smaller than mineral oil and pressboard, the electric field at the slant of point electrode is smaller with vegetable oil. Then, one supposes that the creeping discharges will be shorter in presence of vegetable oil than in mineral oil (ii) the streamers in mineral oil are slightly shorter than in vegetable oil [23]. The tenure "nanofluids" was first proposed by researchers at Argonne National Laboratory and states to a two phase mixture, tranquil of liquid medium and solid nanoparticles in suspension. One method of attractive the thermal conductivity of a fluid is to add nanoparticles to the fluid, thus producing such a nanofluid. In this study, titania nanoparticles were detached into mineral oil in order to inspect the upshot on the thermal conductivity of the congregation fluid.

2. Experimental Setup

In this paper experimental study is on short gap between the needle plane electrode with different voltage profiles such as AC, DC, and transient voltages under mineral oil and Nano fluids .The transient voltage should be compared with AC and DC voltage profile.

The experimental setup for breakdown voltage under AC, DC and transient voltage shown in figure 1. This setup is sectioned into four divisions (a) High voltage transformer (b) Trigger circuit(c) voltage doublers circuit and test cell (d) Digital storage oscilloscope. The Corona inception voltage was restrained by generating different harmonics of AC with low and high frequencies, DC and triangular wave using trek amplifier. This generated voltage was restrained using a UHF sensor with a higher bandwidth digital storage oscilloscope. The needle plane electrode based test cell was used to measure the lightning impulse for both polarities. The plane electrode is a circular steel plate of 25cm radius. The gap between needle planes with esteem to ground electrode varies from 2cm to 7cm diameter. The electrode photograph has shown in figure 2. The same needle-plane configuration was used for generating corona inception voltage for both transformer oil and nano fluids with a needle gap distance from 2Cm to 5Cm.

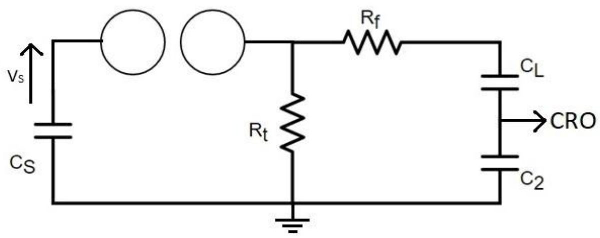

Fig 1. Experimental setup

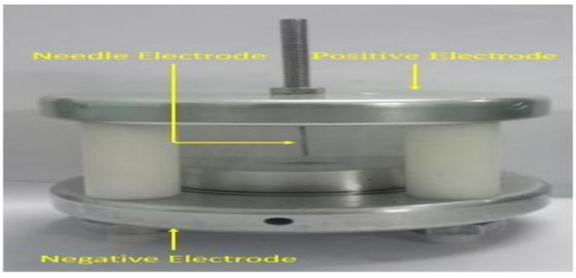

Fig 2. Test cell snapshot.

Test cell containing a point – plane electrode arrangements and an optical system enabling the conception and recording of creeping discharge which is shown Figure 2. The test cell consists of a cylindrical core of 90 mm high and 110 mm inner diameter and two flats circular cover. The upper cover was of PMMA (transparent material) to enable the conception of discharge and to support the point electrode; the lower one which constitutes also the electrode plane made up of brass.

The point electrode is made of tungsten, the radius of curvature rp of which is 10 µm. The cylindrical core of the test cell consists of two screwed parts, the upper part of 60 mm high made of Teflon and a bottom part is Plexiglas of 30 mm high allowing us to control the contact between the point electrode and the solid insulator.

3. Experimental Test Results

A. Comparison of Transient Voltage with AC and DC in Mineral Oil

In mineral oil insulation breakdown is mainly influenced by the electric field strength. However, it indicates that when imposing different kind of voltages, the breakdown voltage is different. The breakdown voltage under LI voltage is higher than that AC and DC voltage both positive and negative polarity in mineral oil as shown in fig.3 and fig 4. It seems that LI voltage has a significant effect on breakdown strength.

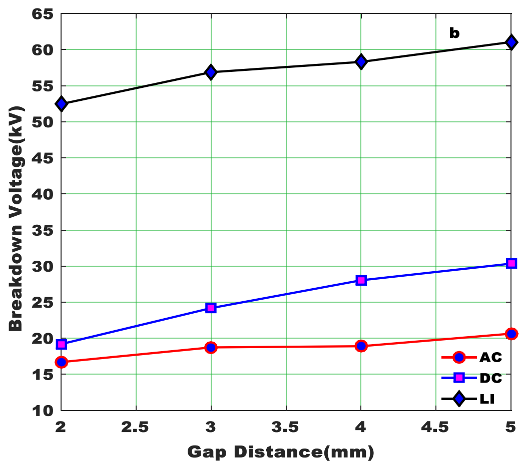

Fig 3. Breakdown voltage characteristics with Positive polarity of AC, DC and transient voltage in Mineral oil

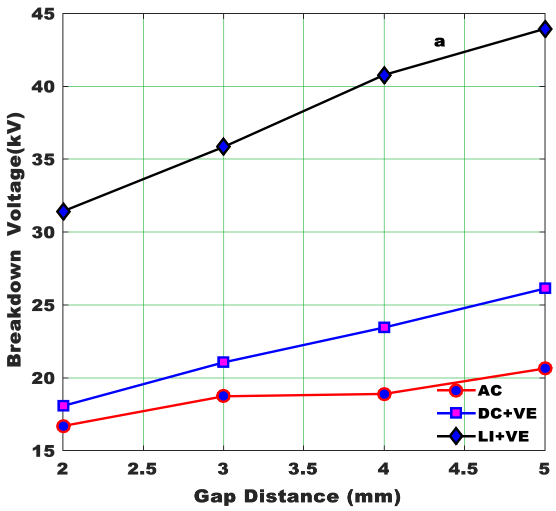

Fig 4. Breakdown voltage characteristics with Negative polarity of AC, DC and transient voltage in Mineral oil

B. Comparison of Transient Voltage with AC and DC with Nano Mineral Oil

In Nano mineral oil insulation breakdown is compared with mineral oil by the electric field strength. It indicates that the breakdown voltage in AC,DC and LI is got higher valve than mineral oil in both positive and negative polarity in Nano oil as shown in fig.5 and fig 6. It was observed that LI voltage has a substantial effect on breakdown strength.

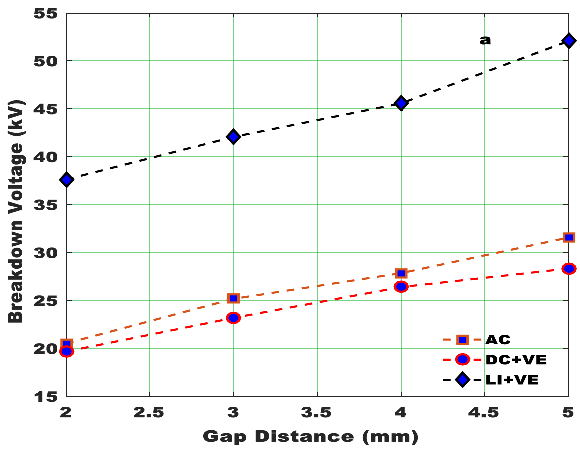

Fig 5.Breakdown voltage characteristics with positive polarity of AC, DC and transient voltage in Nano Mineral oil

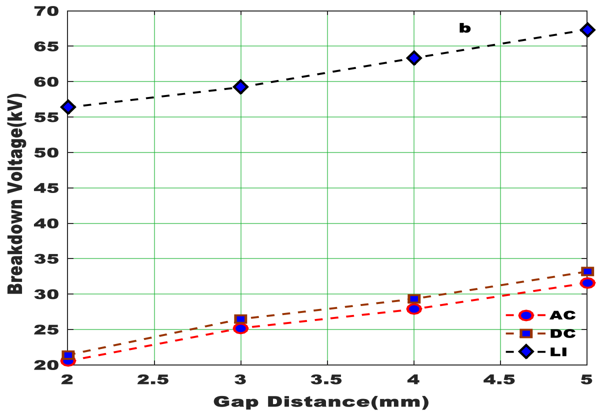

Fig 6. Breakdown voltage characteristics with Negative polarity of AC, DC and transient voltage in Nano Mineral oil

4. Analysis of Corona Inception Voltage

Figure 7 shows the variation in corona inception voltage of transformer oil with different weight % of titania nanoparticles under AC and DC voltages. Corona inception was stately based on the voltage at which UHF signal generated from the first discharge originated with the needle plane electrode gap filled with transformer oil. Corona inception voltage was in warded based on 20 measurements. The deviation from the mean of the measurements was very less and hence the deviation was not indicated. It was observed that the corona inception voltage increases with an increase in the weight % of titania nanoparticles in transformer oil. A fringe reduction in CIV was observed under AC and DC voltages. The cause for it could be the accumulation of nanoparticles.

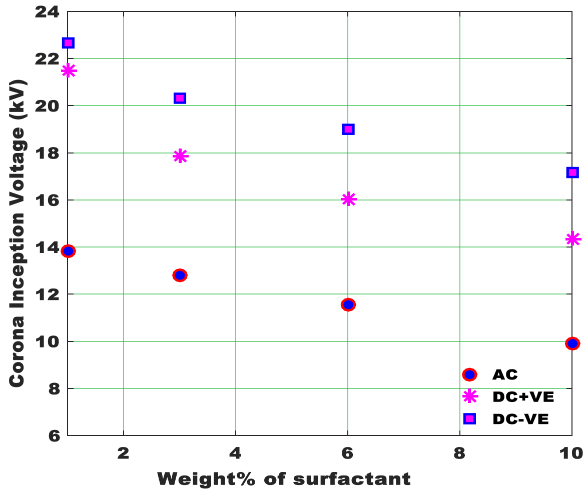

Fig 8.Variation in Corona Inception Voltage of different weight % of surfactant in transformer oil under AC and DC voltages

The Figure 8 shows the variation in CIV with changed weight % of the surfactant in 0.0061 weight % of titania nanoparticles in transformer oil. It was detected that 1 weight % of the surfactant added to 0.0061 weight % of titania shows the maximum CIV. The improved value of the weight % of the nanoparticle and the surfactant required to achieve firm nanofluid trusts basically on the size of the particle. When the surfactant is added to the transformer oil, it forms a coating done the nanoparticle, beginning reduced van der Waals force forming a stable nano fluid. This nanoparticle in stable colloidal solution gets the injected electrons and forms space charge field countering the applied electric field, thus attractive the corona inception voltage with nanoparticle filled transformer oil.

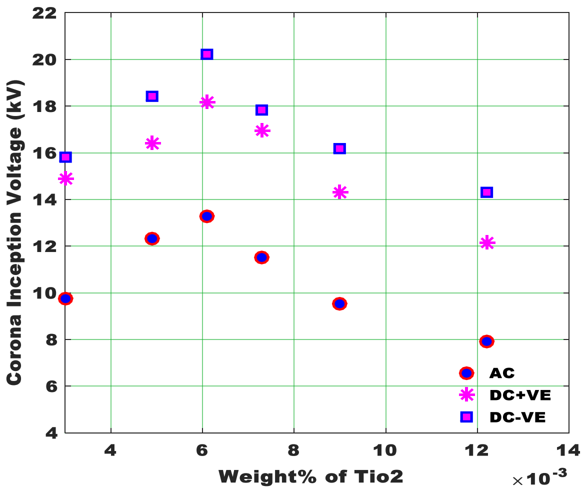

Fig 7. Variation in Corona Inception Voltage of different weight % of TiO2 nanoparticles dispersed in transformer oil under AC and DC voltages

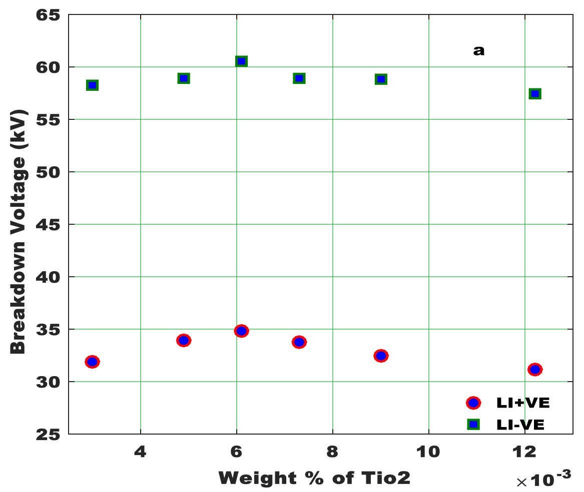

Fig 9. Variation in Corona Inception Voltage of different weight % of TiO2 nanoparticles dispersed in transformer oil under LI voltages

Corona inception was imposing based on the voltage at which UHF signal generated from the first discharge originated with the needle plane electrode gap filled with transformer oil. Corona inception voltage was in warded based on 20 measurements same procedure is followed by AC and DC methods. It was observed that the corona inception voltage increases with an increase in the weight % of titania nanoparticles in transformer oil. A fringe reduction in CIV was observed under LI voltages than AC and DC voltages as shown in fig.9

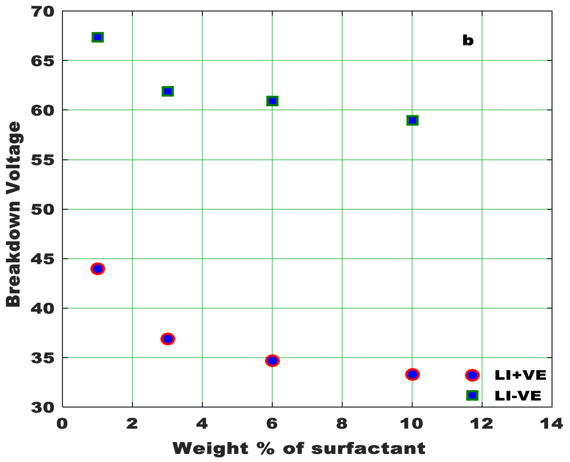

Fig 10 .Variation in Corona Inception Voltage of different weight % of surfactant in transformer oil under LI voltages

The improved value of the weight % of the nanoparticle and the surfactant obligatory to achieve firm nanofluid trusts basically on the size of the particle. When the surfactant is added to the transformer oil the LI negative breakdown voltage got maximum as shown in fig.10.

5. Analysis of Probability plot

C. Probability Plot for AC

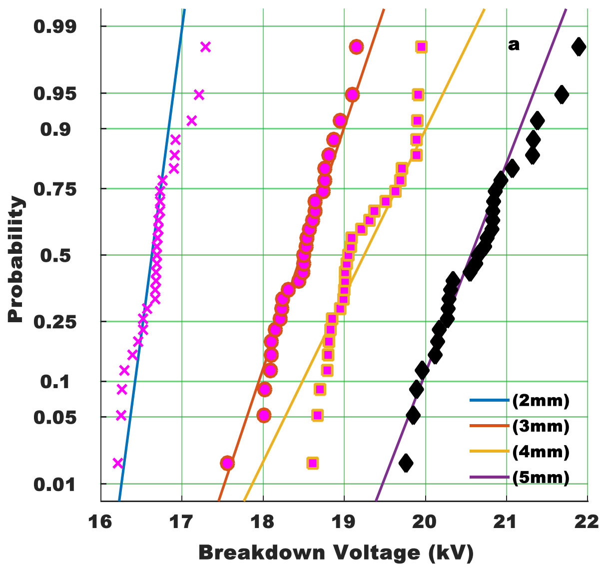

Fig 11(a). Normal Probability plot for different tested oil, Mineral oil

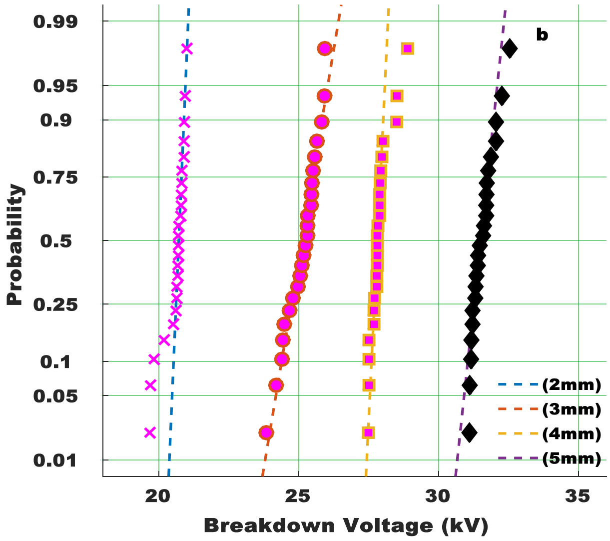

Fig 11(b). Normal Probability plot for different tested oil, titania nanoparticles dispersed transformer oil under AC voltages.

Figure 11 (a and b) shows the normal probability plot for both the transformer oil and titania nanoparticles dispersed mineral oil under AC voltage. It was observed that in case of the mineral oil got more scattered in the data is large when compare to nano mineral oil.

D. Probability plot for DC –Mineral Oil

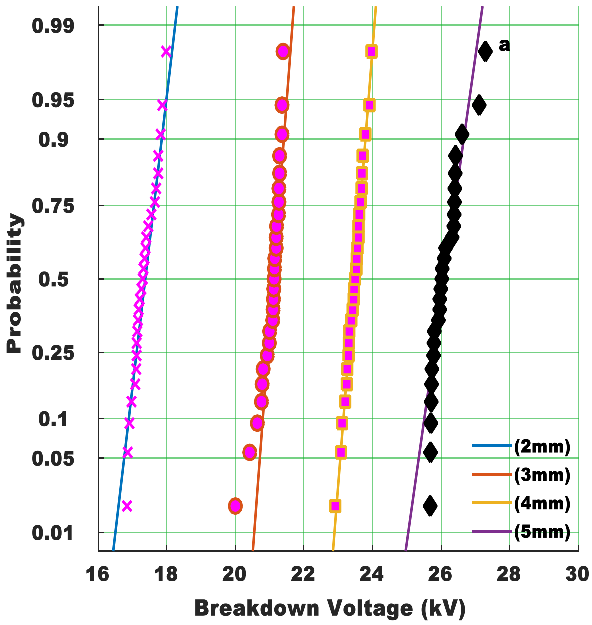

Fig 12(a). Normal Probability plot for DC Mineral oil, Positive

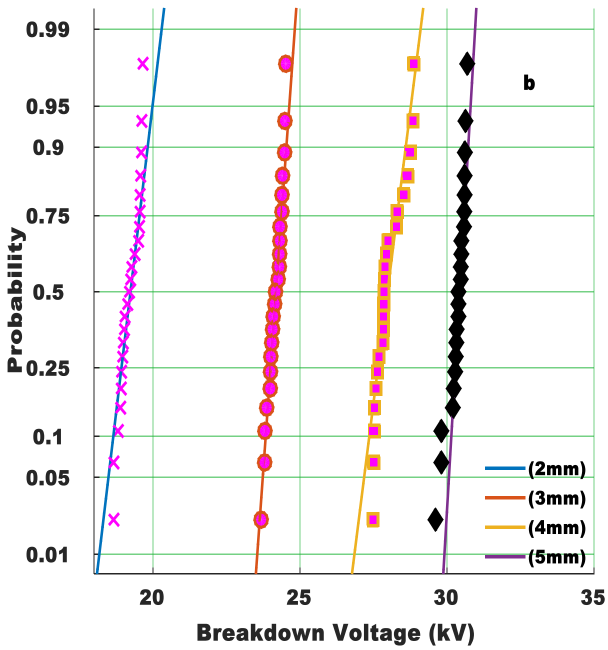

Fig 12(b). Normal Probability plot for DC Mineral oil, Negative

Under DC mineral oil, a noticeable deviation was observed from the negative DC voltages, the scattering in the data is high as shown in fig.12.It was noticed that under DC positive and AC mineral got same kind of scattered present.

E. Probability plot for DC-Nano Mineral Oil

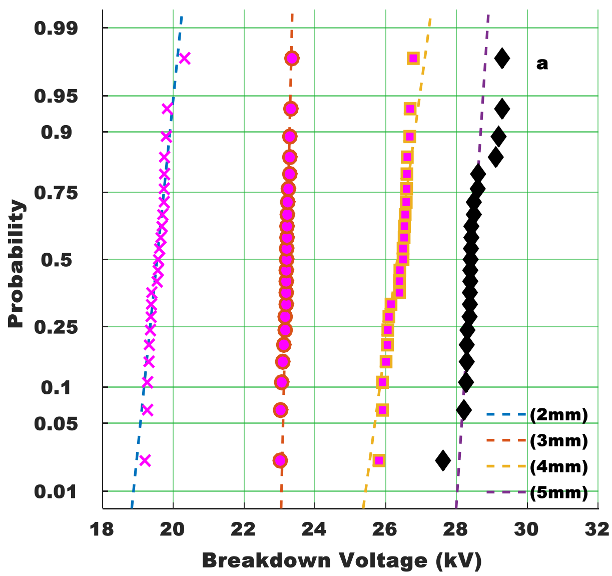

Fig 13(a). Normal Probability plot for DC Nano Mineral oil, Positive

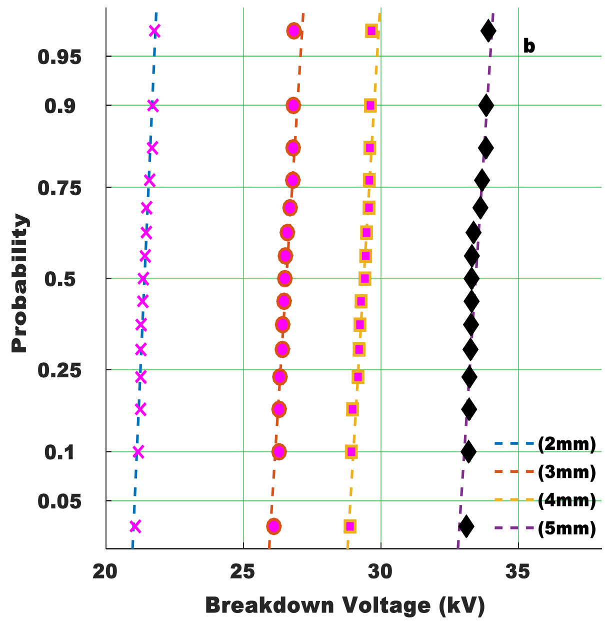

Fig 13(b). Normal Probability plot for DC Nano Mineral oil, Negative

A characteristic change in the color of the mineral oil was observed in a few breakdowns compared with AC and positive DC voltages but in nano mineral there is no color change. It is well known that the area of the breakdown path is high under AC and positive DC voltage in mineral oil and a huge discharge occurs under negative DC voltage as shown in fig.13.

F. Probability plot for Transient Voltage-Mineral Oil

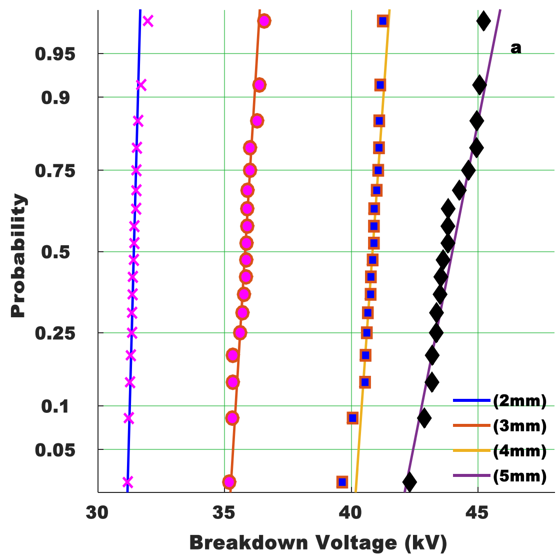

Fig 14(a). Normal Probability plot for LI Voltage in Mineral oil, Positive

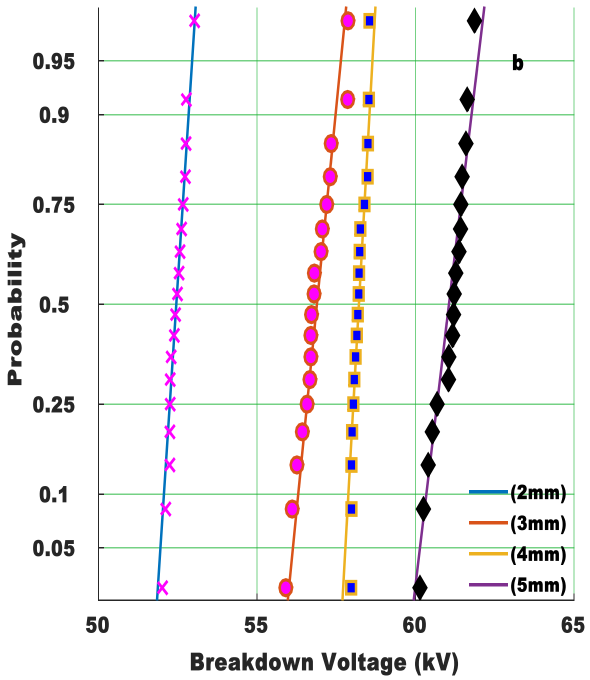

Fig 14(b). Normal Probability plot for LI Voltage in Mineral oil, Negative

It is understood that the area of the breakdown path is high under LI negative in mineral oil than positive impulse voltage and a huge discharge occurs under negative LI voltage as shown in fig.14.

Table 1. Voltages corresponding to probabilities of 5, 25, 50 and 90% of breakdown for normal probability for TO-Transformer Oil and NO-Nano Titania Dispersed Transformer Oil under AC and DC voltages with the gap distance 5 mm.

Type of Voltage Profile	Type of Oil	Normal Distribution			
		V5%	V25%	V50%	V90%
AC	TO	19.85	20.27	20.65	21.38
	NO	31.11	31.21	31.59	32.05
DC+ve	TO	25.69	25.78	26.02	26.61
	NO	28.1	28.3	28.44	28.67
DC-ve	TO	29.81	30.28	30.39	30.61
	NO	33.1	33.21	33.29	33.82
LI+ve	TO	42.3	43.25	43.81	45.06
	NO	51.62	51.74	52.2	52.59
LI-ve	TO	60.14	60.68	61.22	61.63
	NO	66.7	67.08	67.42	67.91

G. Probability Plot for Lightning Impulse –Nano Oil

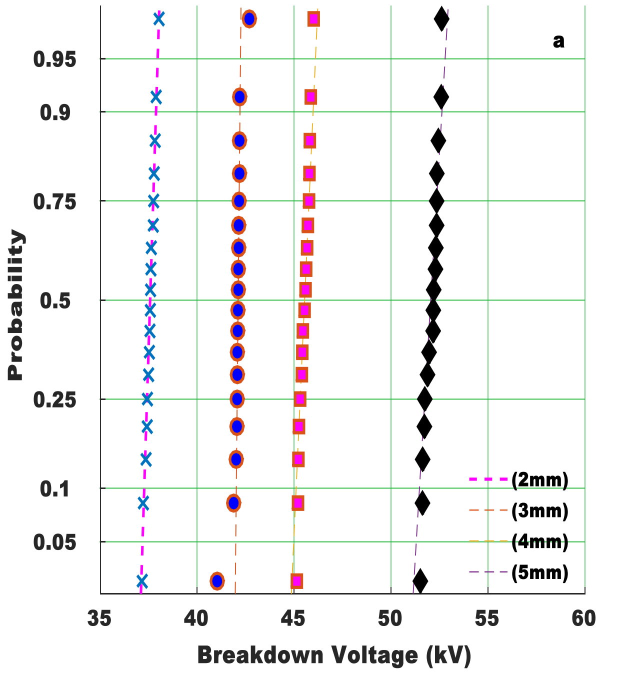

Fig 15(a). Normal Probability plot for LI Voltage in Nano Mineral oil, Positive

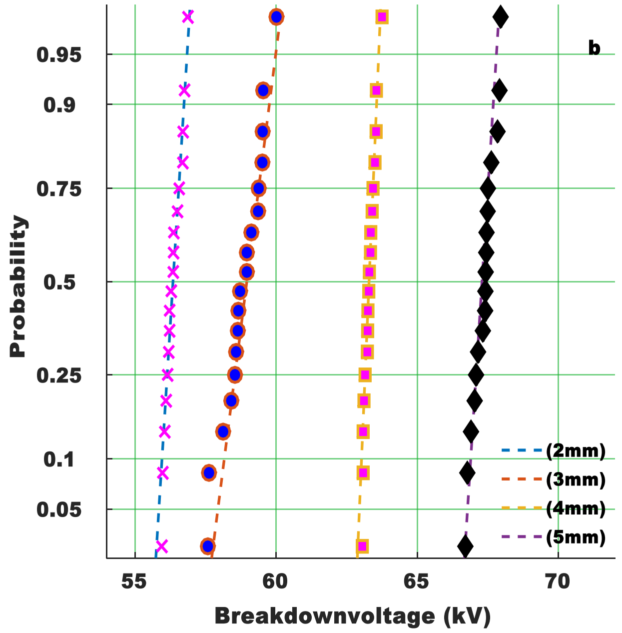

Fig 15(b). Normal Probability plot for LI Voltage in Nano Mineral oil, Negative

It is clearly understood that the area of the breakdown path is high under LI both positive and negative in nano mineral oil than mineral oil and a vast discharge occurs under negative LI voltage as shown in fig.15.

Under positive DC voltages the experimental values deviate from normal probability fitted line at probabilities less than 15% and more than 80% for transformer oil, 5% and 95% for titania nanoparticles dispersed transformer oil. The predicted voltages corresponding to the probabilities of 5, 25, 50, 90% of breakdown for normal probability for both transformer oil and titania nanoparticles dispersed transformer oil are listed in Table 1.

Based on the statistical analysis, V5%, V25%, V50% and V90% can be compared with the actual breakdown voltages to appraise the efficiency of the insulation design. Addition of nanoparticles in the transformer oil improves its breakdown voltage. This is due to the fact that the nanoparticles act as electron searchers, converting reckless moving electrons into negatively charged particles with reduced propagation speed and protracted propagation time of streamer between the electrode gaps

Conclusion

The Nano oil had improved the breakdown characteristics for AC , DC and LI voltages and observed marginal variation. In transient voltages, the DC voltage got higher breakdown voltage than Ac voltage. The performance of LI voltages with Nano fluids when compared with virgin mineral oil got increased and for LI positive got less breakdown voltage than LI negative Voltage. The observation from the nano oil, lightning impulse voltage got more breakdown voltage than AC and DC voltages. The CIV and breakdown voltage is highest for weight % in surfactant in Tio2 depressed transformer oil. The CIV/breakdown voltage is high 20% of electrode gap from needle tip and a marginal reduction is observed when the barrier is moved away from the needle tip. The LI breakdown voltage is higher for nano mineral oil as compared to AC and DC voltages. From a statistical analysis of breakdown data that deviation of mineral oil is more compared to nano mineral oil under AC,DC and LI voltages and highest for negative LI voltages

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