ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ANALYSIS OF HIGH FREQUENCY OSCILLATIONS IN SURFACE DISCHARGE FORMATION ON OIL IMPREGNATED PRESSBOARD

Palanki Pattabhi Saikumar and Mohamed Ghouse S
Department of Electrical Engineering Shanmugha Arts, Science, Technology and Research Academy University, India
E-Mail: saikumaar@outlook.com

ABSTRACT

The High voltage high frequency (HVHF) oscillations caused by the power electronics and non-linear loads, such as converter transformers, arc furnaces, welding machines, photocopiers, microwave ovens, etc, can pollute the supply voltage by generating the high frequency oscillations thereby causing surface discharge formation on the insulation of transformer. This work deals with the effect of high frequency oscillations in the surface discharge formation on oil impregnated pressboard used in the converter transformer. Converter transformers are a part of transmission system located near the converter station, where the occurrence of high frequency oscillations is high due to the presence of power electronic devices in it. These high frequency oscillations, if enters into converter transformer, can cause formation of surface discharges on the insulation, which is one the major causes for failure of transformer. The insulation materials in converter transformers are mainly oil impregnated pressboard and mineral oil. During operation, the oil/pressboard structure undergoes multistress ageing which results in surface discharge activity and cause gradual physical and chemical degradation. Surface discharge activity at the oil impregnated pressboard interface is studied by conducting tracking studies with high frequencies such as 85 KHz and 113 KHz and observed the surface degradation due to tracking. After the test, it is concluded that the tracking paths are formed due to surface discharges, which can produce degradation by-products which contaminate and degrade the transformer oil. The current and voltage patterns formed during the surface discharge process under tracking studies are recorded. Degraded zone of oil impregnated pressboard insulation due to surface discharges was analyzed using Attenuated Total Reflectance Fourier Transform Infra-red (ATR-FTIR) spectroscopy, which can provide a specific wavelength spectrum of any functional group formed due to characteristic changes that occur due to ageing. The tracking study and pressboard material characterization at the tracked zone give a clear inference about the by product formation and degradation mechanism of converter transformer insulation system.

Keywords: HVHF, oil impregnated pressboard, surface degradation, ATR-FTIR spectroscopy.

1. INTRODUCTION

The transformer is important component in the power system. Working, wear and tear of the transformer depends on design of insulation [1]. The transformer operation is subjected to multiple stress causes ageing and degradation. The presence of a contaminant in transformer oil, forming a multi dielectric medium, increases breakdown voltage of the medium [2, 3].

The failure of transformers is due to surface discharges occurring in pressboard.. It is known that these discharges cause surface carbonization of pressboard material [4]. The pressboard structure has multi-stresses which cause physical and chemical degradation, during transformer operation [5-7]. Surface discharge formation in transformer during operation is a challenge [8, 9]. Surface discharge characteristics work is going on in transformer insulation under 50 Hz AC voltages [10]. The mechanism of surface discharge formation in transformer insulation under AC voltages with high frequency oscillations, are plenty. Surface degradation analyses were carried out near the carbonized zone formed due to surface discharges. Degraded zone of oil impregnated pressboard insulation due to surface discharges were analysed using attenuated total reflectance fourier transform infra-red (ATR-FTIR) spectroscopy and XRD. Surface charge measurements can provide ageing condition of insulation material [11, 12]. Surface degradation is observed near the carbonized zone formed due to surface discharges. Degraded zone of oil impregnated pressboard insulation due to surface discharges were analysed using attenuated total reflectance fourier transform infra-red (ATR-FTIR) spectroscopy.

2. LABORATORY EXPERIMENTAL TEST SETUP

Apply voltage uniformly to the test electrodes from zero until breakdown occurs. Use the short-time test unless otherwise specified.

The block diagram for the test setup is shown in the Figure.1. The test setup consists of the following resources such as high voltage AC generation, test cell, oil impregnated pressboard, DSO, attenuated total reflectance fourier transform infrared spectroscopy (ATR-FTIR).

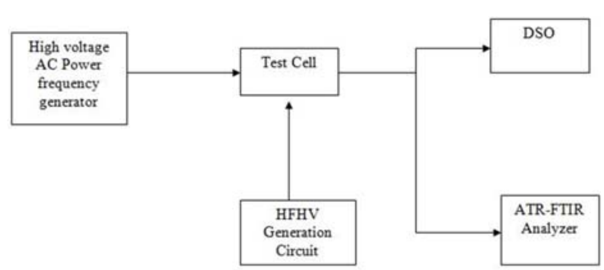

Figure-1. Block diagram.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

3. PREPARATION OF TEST SAMPLES

The test Set up consists of two electrodes. The upper electrode is made in the IEC(b) electrode configuration. The test is fabricated in rod to plane electrode configuration. One electrode is set in the bottom which is shown in Figure-2 and called as bottom electrode and the other situated at the top is called top electrode. The bottom electrode is made up of aluminum and the top electrodes are of copper, brass and aluminum. The bottom electrode is of 5mm thickness and 5cm in diameter. The upper electrode is 6mm in diameter. Teflon rods are used as insulation as well as support for the test cell. Teflon is the strongest material which is fire resistant and acts as an insulator for electrical and thermal purposes. Pressboard material, on which the test is being conducted, comes in between the two electrodes. It is cut in the exact dimension of the bottom electrode. It is seated on the bottom electrode. Pressboard is used fresh for every set of experiment. The test cell is as show in the Figure-3.

Figure-2. Bottom view.

Figure-3. Test cell.

4. SURFACE DEGRADATION STUDIES UNDER HFHV TEST

The double tuned resonant circuit is designed in order to obtain better coil factor (voltage magnification) at resonant condition. The laboratory experimental test setup comprises of…... The primary and secondary windings (L1 & L2) are wound on an air-cored arrangement which comprises the coil with facility to tap-off variable values of inductance. Tapping at various points of the coil provides an appropriate choice of inductance which in turn offers various choices of resonant frequencies. The two coil combinations are tuned to appropriate frequencies in the range of 40-150 kHz in conjunction with condensers C1 and C2. The output voltage is directly a function of the L-C combination (L1, L2, C1 and C2) and the mutual inductance of the coils. Since invariably the winding resistance is small it contributes only to the damping of the oscillations.

Figure-4. Laboratory setup for HFHV tracking test.

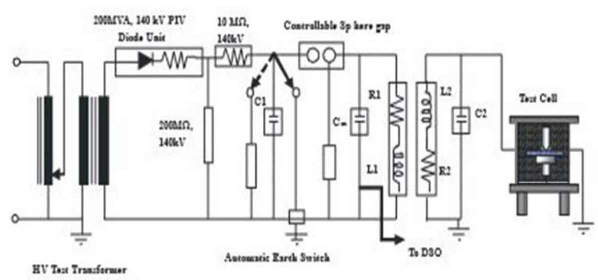

Figure-5. Circuit diagram of double tuned resonant test setup.

Figures 4 and 5 shows experimental setup and circuit diagram for surface degradation studies. A rod-plane electrode configuration was used the pressboard is inserted between the two electrodes. The supply voltage is maintained by at 6 kV (HVAC voltage). Fresh pressboard is shown in Figure-6. The degraded pressboard used for tracking studies is shown in the Figures 7 & 8. The test is done on pressboard of same material for different frequencies to understand the nature of the pressboard in the HFHV oscillations and the waveforms are observed and the pressboard is analyzed with ATR-FTIR. The degradation of pressboard and waveforms obtained after testing at 85 KHz and 113.6 KHz are shown below. The

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

leakage current waveforms of oil impregnated pressboard under High frequency are recorded. Figure-9 gives the understanding of leakage current waveforms while tracking and the peaks in Figures 10 & 11 represents the surface discharges while tracking at 85 KHz. Whereas, Figure-12 gives the understanding of leakage current waveforms while tracking at 113 KHz and the peaks in Figures 13 & 14 represents the surface discharges while tracking at 113 KHz.

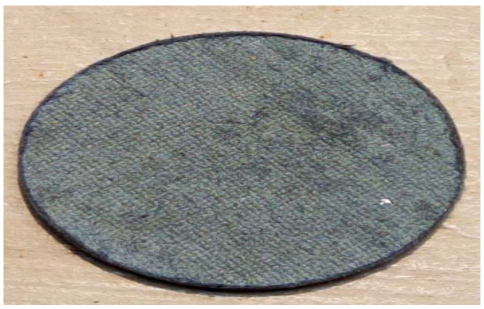

Figure-6. Pressboard before tracking.

Figure-7. Degraded pressboard at 85Khz.

Figure-8. Degraded pressboard at 85Khz.

Table-1. HFHV tracking test.

Frequency of HFHV transients	Double tuned circuit parameters		Test sample
	Parameters of primary circuit	Parameters of secondary circuit	
85khz	C1=26200pF (25000pF‖1200pF) L1=0.134mH	C2 =1200pF L2= 2.83 mH	pressboard
113khz	C1=13700pF (12500pF‖1200pF) L1=0.14mH	C2 =1200pF L2= 1.7 mH	pressboard
60kHz	C1= 25000pF L1= 0.265mH	C2 =2500pF (1200pF ‖1200pF‖ 100 pF) L2= 2.9 m	pressboard

ARPN Journal of Engineering and Applied Sciences

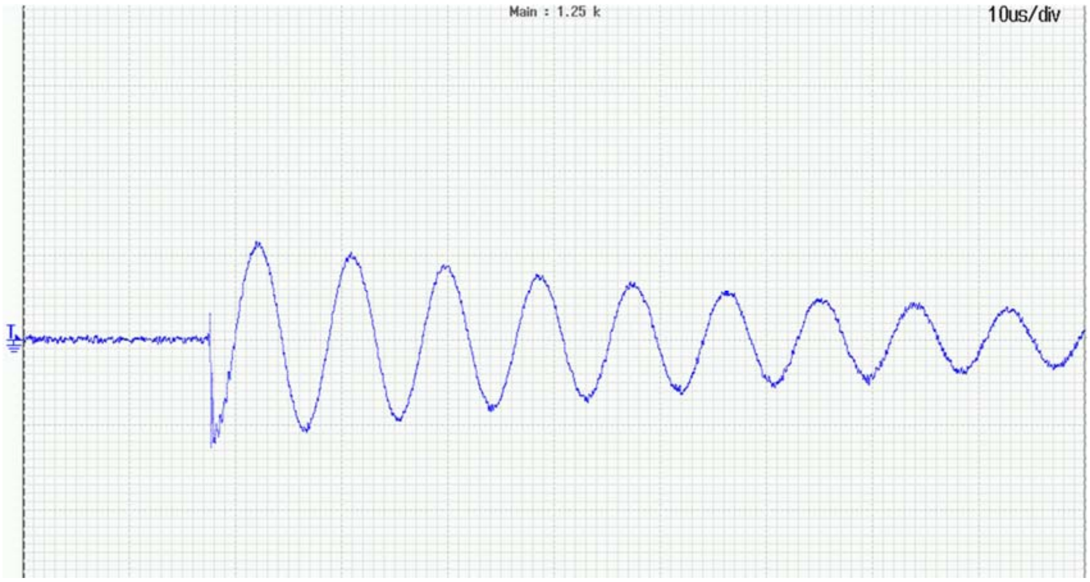

Figure-9. Waveform at 85 KHz frequency (before tracking).

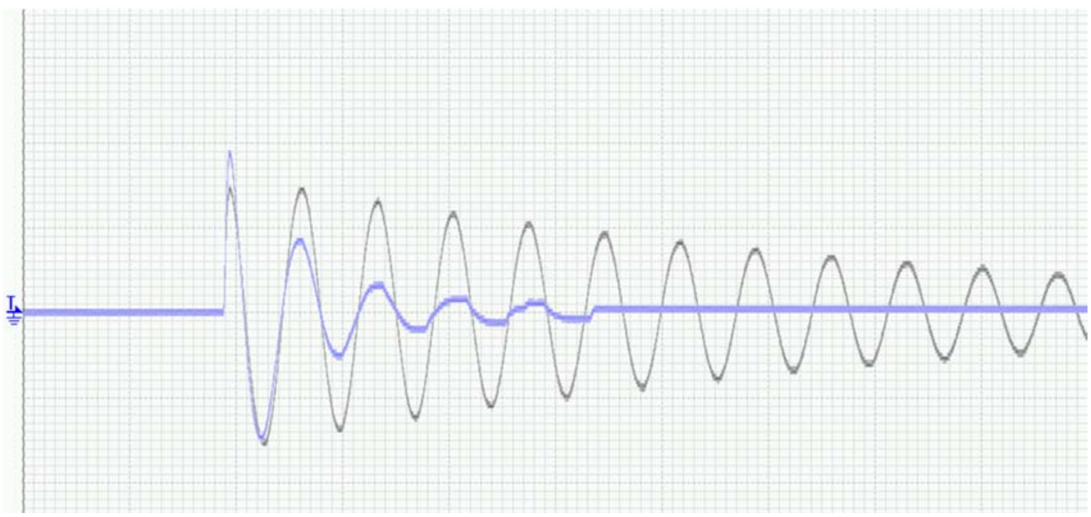

Figure-10. Waveform at 85 KHz frequency (while tracking).

ARPN Journal of Engineering and Applied Sciences

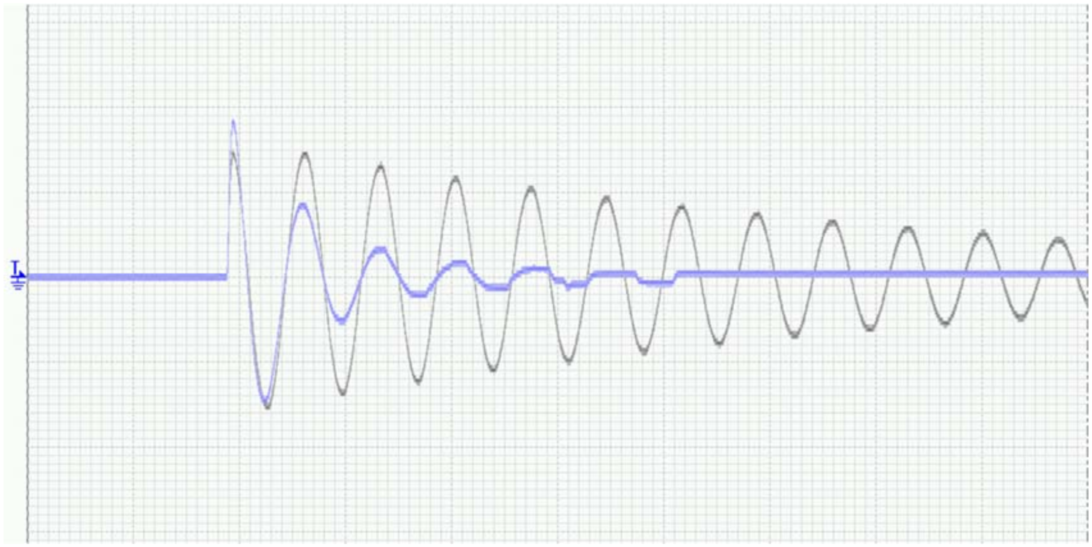

Figure-11. Waveform at 85 KHz frequency (while tracking).

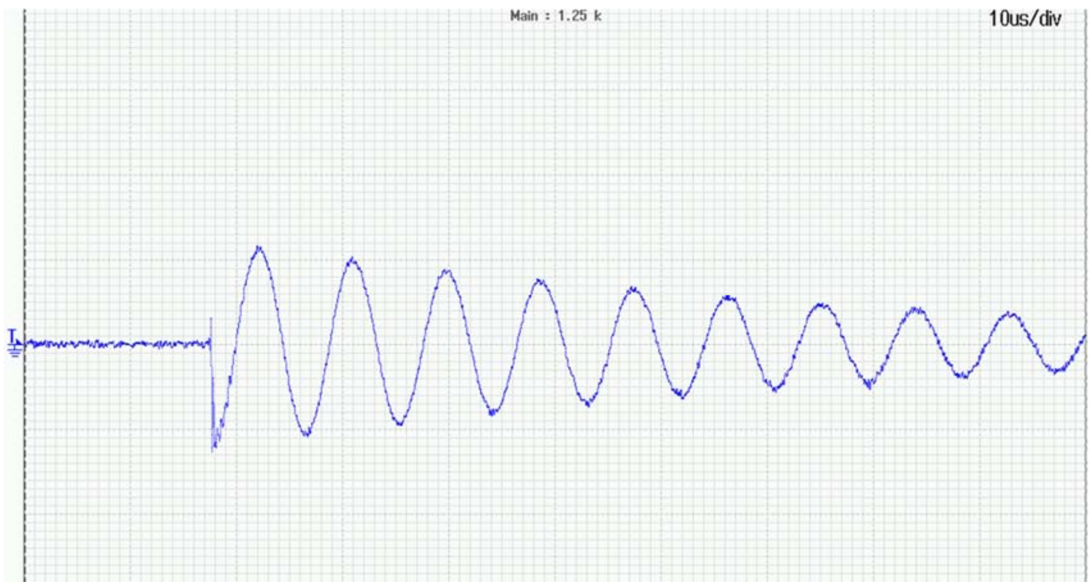

Figure-12. Waveform at 113 Khz frequency (before tracking).

ARPN Journal of Engineering and Applied Sciences

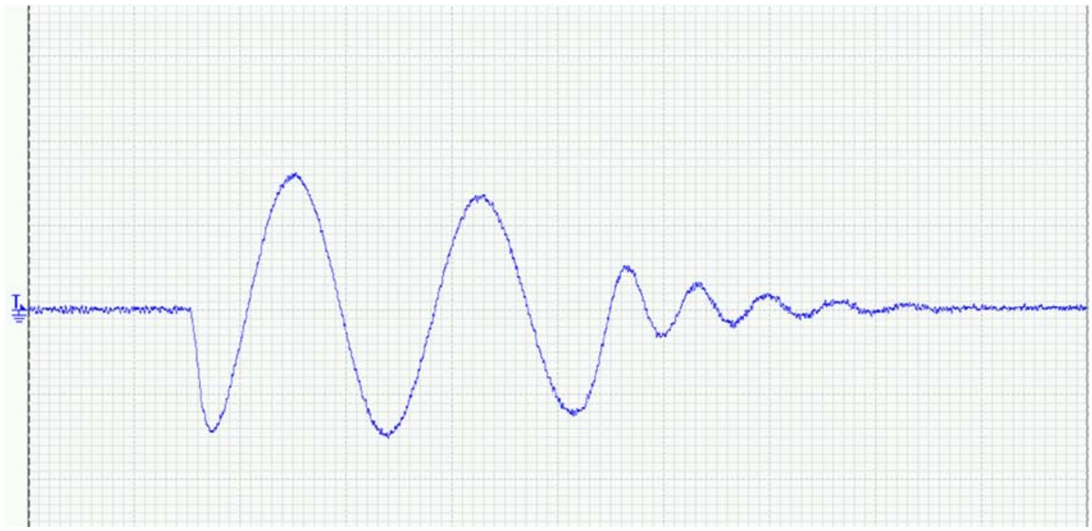

Figure-13. Waveform at 113 KHz frequency (while tracking).

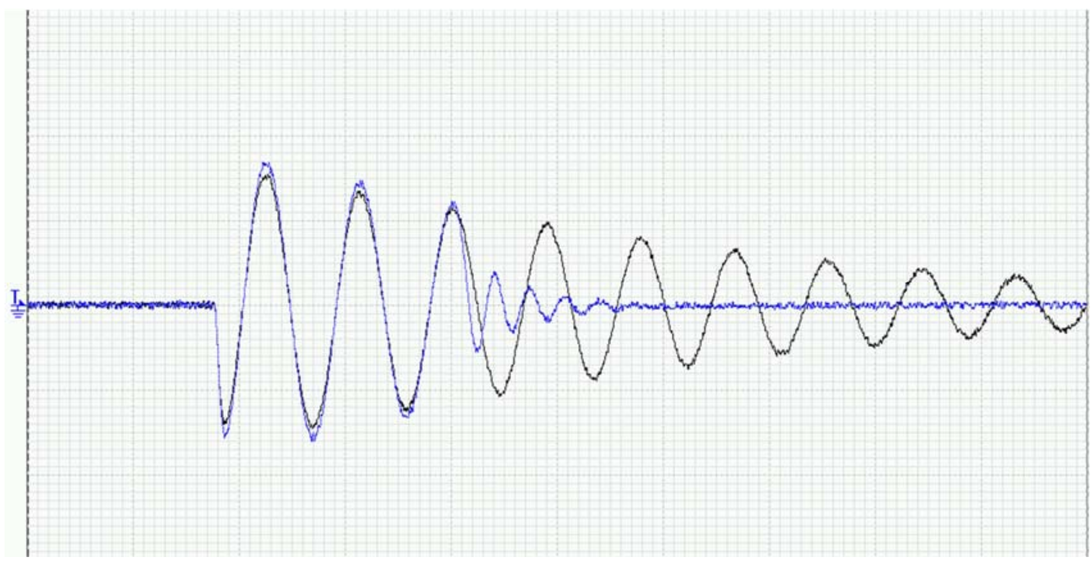

Figure-14. Waveforms obtained while tracking at 113 KHz frequencies.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

5. STUDY OF AGEING FROM ATR-FTIR ANALYSIS

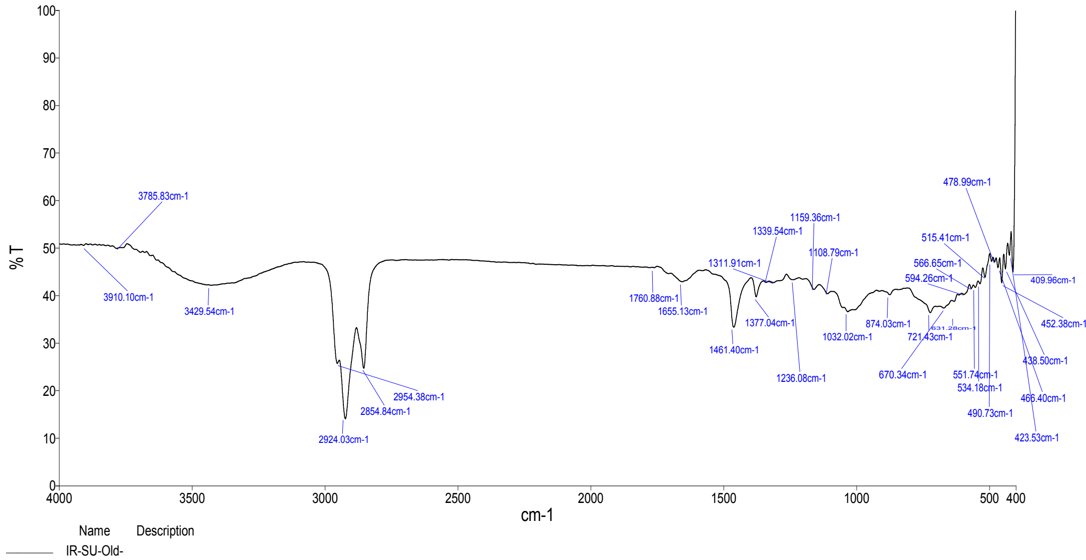

Figure-15. ATR-FTIR Analysis of fresh pressboard.

The Surface discharge degraded zone in aged Oil impregnated pressboard was analyzed through ATR-FTIR spectroscopy as shown in Figure-16. In general, the characteristic peaks for Alkanes and carboxylic acids formation appear in the range 2850 and 3000 cm-1, alcohols, carboxylic acids, esters, ethers are detected in the range 1600 and 1000 cm-1, alkenes are present in range 1000 and 650 cm-1, aromatic compounds, primary and secondary amines are detected in the range 900-675 cm-1 and alkyl halides are detected in the range 850-550 cm- and 700-610 cm-1

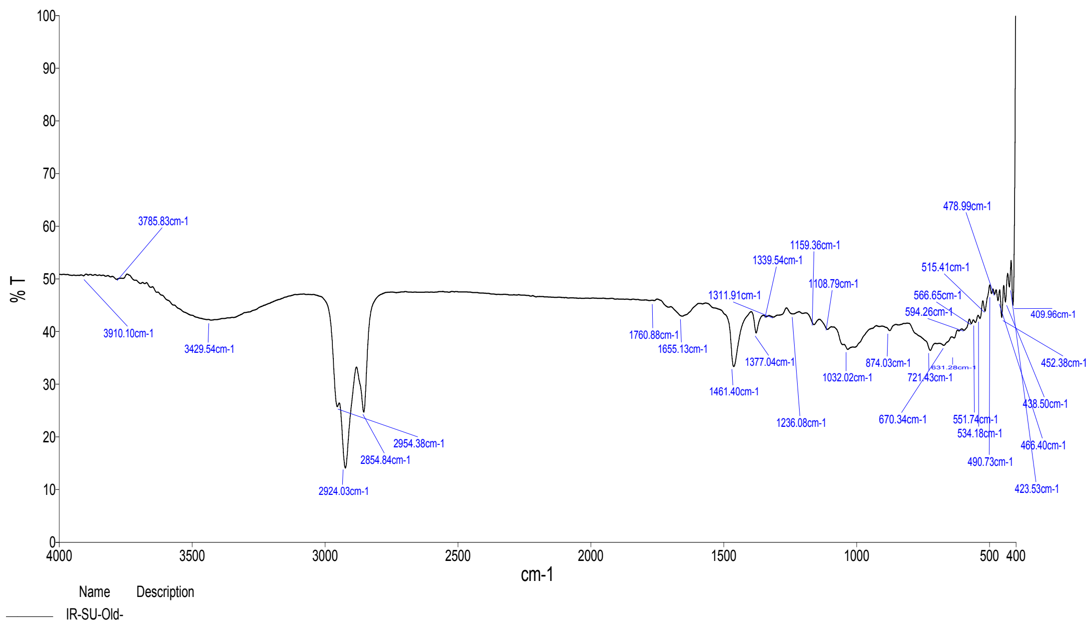

Figure-16. ATR-FTIR analysis of degraded pressboard.

The characteristic peaks for aldehyde and carboxylic acids formation appear in the range 1000 and 1650 cm-1, as shown in Figure-16. Aromatic compounds are detected in the 1450–1650 cm-1 and the –OH component can be detected near 3400 cm-1 range [32]. It is observed that C=O groups are generated due to the surface discharges and predominant peaks occur in the range of 1760-1200 cm-1 [48]. In the present study, to understand the impact of characteristic variation in surface discharge damaged zone, the oil impregnated samples

ARPN Journal of Engineering and Applied Sciences

were stressed for surface discharge activity for few hours. From Figure.16, it can be observed that the characteristic peaks are detected in the range of 650-1650 cm-1, confirming the presence of aldehyde, ketones and carboxylic acids, caused due to degradation by the surface discharge process [12].

6. XRD ANALYSIS OF FRESH PRESSBOARD

Fresh and degraded Pressboards are cut into a circular sample. On XRD analysis of the sample, the following results were obtained As shown in Figure-17, the XRD image for the fresh pressboard samples have the maximum intensity of 250 counts was obtained for a peak in the range 20 to 50 degrees and 5 visible peaks were also obtained. This shows the chemical structure of the fresh pressboard sample.

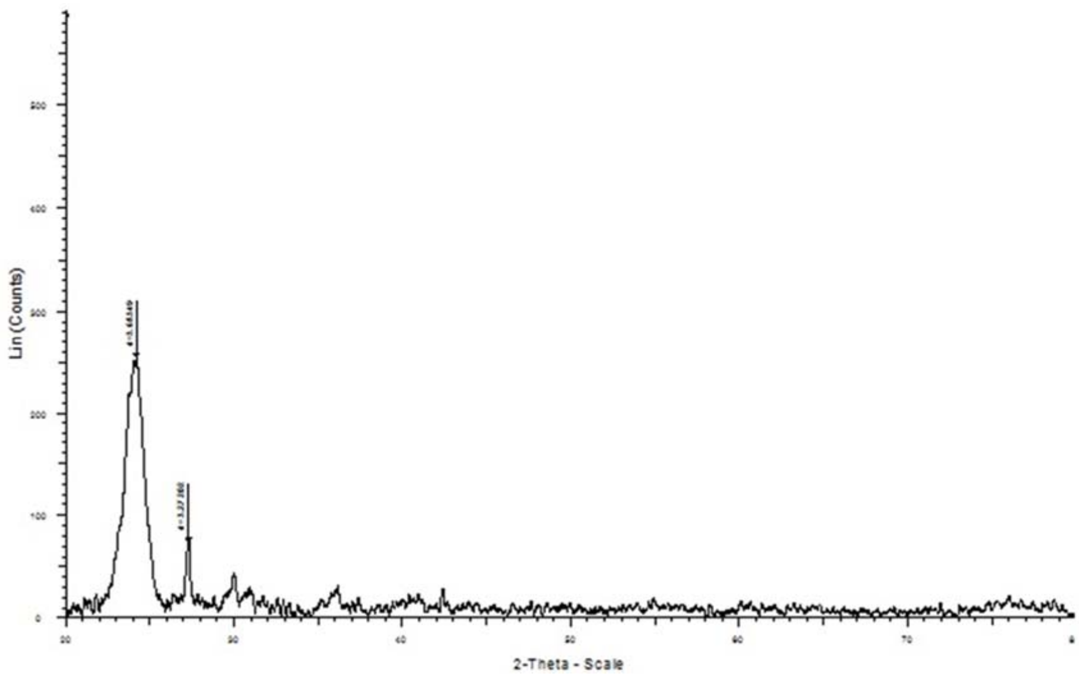

Figure-17. XRD Analysis of fresh pressboard.

As shown in the Figure-18, In the XRD image for the degraded pressboard sample which is tested by passing HFHV Oscillations, the maximum intensity of 1200 counts was obtained for a peak in the range 20 to 40 degrees and 7 visible peaks were also obtained. This shows there is a significant change in the chemical structure of the degraded sample after tracking when compared to fresh pressboard sample. The effect of high frequency oscillations on oil impregnated pressboard is too intense and this might cause the damage of insulation as well as the transformer itself.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

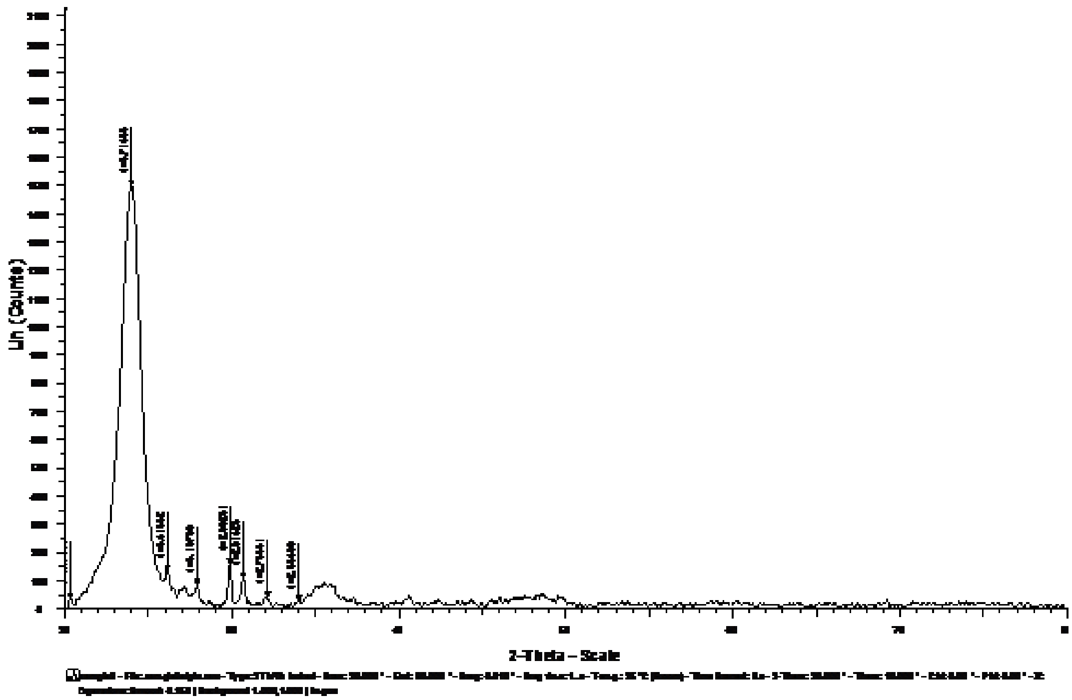

Figure-18. XRD analysis of degraded pressboard (HFHV test).

7. CONCLUSIONS

The HFHV oscillations test is done on the pressboard insulation, which is inserted in the test cell to observe the surface discharge formation. The voltage and current patterns on the pressboard insulation due to surface discharges are observed and recorded. ATR-FTIR (Attenuated Total Reflectance Fourier Transform Infra-Red) spectroscopy analysis and XRD analysis is done on the degraded zone of the pressboard insulation to understand the material behavior of the insulation. It is concluded from the above analysis that surface degradation of pressboard occurred while tracking and with increase in frequency, surface degradation also increases. The HFHV test revealed that the effect of tracking on pressboard is too intense and happened at multiple regions when the frequency is increased.

REFERENCES

[1] S.V. Kulkarni and S.A. Khaparde. 2012. Transformer Engineering, Design, Technology and diagnostics. Second Edition, CRC press, Taylor and Francis group, New York.

[2] F. Guerbas, M. Zitouni, A. Boubakeur and A. Beroual. 2010. Barrier effect on breakdown of point-plane oil gaps under alternating current voltage. IET Generation, Transmission Distribution. 4(11): 1245-1250.

[3] I. S. Jacobs and C. P. Bean. 1963. Fine particles, thin films and exchange anisotropy. in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic. pp. 271-350.

[4] T. Tanaka. 1986. Characteristics of composite insulation: liquid impregnated insulation. IEEE Trans. Electr. Insul. 21(6): 881-888.

[5] V. Sokolov, Z. Berler and V. Rashkes. 1999. Effective Methods of Assessment of Insulation System Conditions in Power Transformers: a View Based on Practical Experience. IEEE Electr. Insul. Conf. Electr. Manufacturing & Coil Winding. pp. 659-667.

[6] J. Li, W. Si, X.Yao and Y. Li. 2009. Measurement and simulation of partial discharge in oil impregnated pressboard with an electrical aging process. Measurement Sci. Techn. 20(10): 17.

[7] J. Li, W. Si, X. Yao and Y. Li. 2009. Partial Discharge Characteristics over Differently Aged Oil/pressboard Interfaces. IEEE Trans. Dielectr. Electr. Insul. 16(6): 1640-1647.

[8] M.D.L. del Casale, R. Schifani and J.T. Holboll. 2000. Partial discharge tests using CIGRE method II. IEEE Trans. Dielectr. Electr. Insul. 7(1): 133-140.

[9] W. Hui, L.I. Cheng-rong, S. Kang and M. Yinyin. 2009. Experimental Study on the Evolution of Surface Discharge for Oil-Paper Insulation in Transformers. Conf. Electr. Insul. Dielectr. Phenomena. pp. 405-409.

[10] J. Yan, R. Liao, L. Yang and M. Zhu. 2011. Measurements and analysis of surface damage on oil-impregnated insulation paper caused by partial discharge. Measurement Sci. Techn., IOP. 22(5).

[11] I. Fofana, A. Bouaicha and M. Farzaneh. 2011. Characterization of aging transformer oil-pressboard insulation using some modern diagnostic techniques. European Transactions on Electr. Power. 21: 1110-1127.

[12] J. Yan, R. Liao, L. Yang, J.Li and Bin. 2011. Product analysis of partial discharge damage to oil-impregnated insulation paper. Applied Surface Science. 257: 5863-5870.

[13] R. Sarathi, I. P. Merin Sheema, P. Sundara Rajan and M G Danikas. 2014. Influence of Harmonic AC Voltage on Surface Discharge Formation in Transformer Insulation. IEEE Transactions on Dielectrics and Electrical Insulation. 21(5).