CHARACTERISATION OF PARTIAL DISCHARGES IN OIL IMPREGNATED PRESSBOARD INSULATION SYSTEMS

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Abstract:

Partial discharge (PD) measurement and interpretation is one of the most useful diagnostic tools for quality assurance testing during the design, manufacture and life assessment of electrical equipments. Pressboard-oil insulation continues to be a major component in the insulation design of EHV transformers. As tests on practical systems are not always feasible due to cost and time factors, model systems tests are gaining importance. In the present work a model insulation system consisting of oil impregnated pressboard with uniform field electrode arrangement has been tested for its behaviour under PDs. It is shown that by defining a modified scale parameter for the Weibull distribution it is possible to take into account the effect of both smaller and larger magnitude PD pulses. The modified scale parameter serves as a good index for characterising PD behaviour in oil impregnated pressboard insulation system studied.

1 Introduction

Pressboard-oil insulation continues to be a major component in the insulation design of EHV transformers. Partial discharges are considered to be hazardous for the satisfactory performance of the insulation system. The gradual deterioration due to PDs can lead to premature failure of the system. Two or mixed parameter Weibull functions are conveniently used to fit the experimental data /1/. Model insulation systems are found to he convenient for the study of PD behaviour /2,3,4,5/. In the present work, oil impregnated pressbaord samples have been tested for their PD behaviour at predetermined stress levels. Records of PD pulse distribution patterns are acquired with the help of the multichannel analyser. The data has been analysed using Weibull statistics. A modified scale parameter of the mixed Weibull distribution is found quite useful for monitoring aging behaviour.

2 Experimental Procedure

2.1 Test Cell

A pair of $7\pi/12$ Rogowski brass electrodes of **30** mm overall diameter was used for the study of PD characteristics in a uniform field. A PMMA (Poly Methyl Methaacrylate) cell of volume **130** mm x **130** mm x 150 mm was used for conducting experiments. The pressboard samples were placed between electrodes in the PMMA cell filled with transformer oil.

2.2 Preparation of samples

Pressboard sheets with nominal thickness of **2.0** mm, mat finished on both sides were used for making samples of 50 mm diameter. Samples were vacuum dried at a temperature of 100 degree centigrade. Filtered and vacuum treated transformer oil was used for impregnation. The impregnated samples were stored in vacuum tight dissicator containing moisture absorbent.

2.3 Test Procedure

The voltage across the samples was raised gradually at an average rate of 2 kV/s till inception of PD. The inception voltage was noted. PD distributions were acquired using MCA (*EG&G ORTEC*), Model **921.** Further the voltage was raised to a predetermined stress level as explained in the following section.

2.4 Criterion for selecting the stress levels

Initially three samples were tested at a stress level of 12.0 kV/mm. The stress level of 12.0 kV/mm was close to the inception level (11.0 kV/mm average). PD pulse distributions were recorded continuously. It was found that failure of the sample took place only in one case after 230 minutes of application of overvoltage stress. The

Table 1
Results of PD tests at different stress levels

Sample number	Inception stress level kV/mm	Applied stress level kV/mm	Time to failure min.
1	11.60	13.0	92
2	11.00	13.0	120
3	11.10	13.0	67
4	11.00	13.0	113
5	11.10	13.0	80
6	10.40	13.0	92
7	11.00	13.5	65
8	11.80	13.5	78
9	11.10	13.5	35
10	12.50	13.5	52
11	11.00	13.5	64
12	11.10	13.5	206
13	10.50	14.0	40
14	10.50	14.0	21
15	12.50	14.0	60
16	11.00		24
17	11.10		60
18	11.80	14.0	52

other two tested samples did not fail cvcn after aging for **24** hours at which stage the cxpcriments were terminated. In order to accelerate the aging process due to PDs an overvoltage stress of 15.0kV/mm was tried for two samples. The failure times were 30 minutcs and 41 minutes which were found too short for observing the PD behaviour. Hence an intermcdiate overvoltage stress levels of 13.0kV/mm, 13.5kV/mm and 14.0kV/mm were selected for further experimentation. PD pulse distribution patterns were acquired continuously with each record containing pulses for 10 seconds duration.

3 Analysis **of** results

Weibull distribution was used for analysis of PD pulse distribution patterns. The Weibull distribution is given by

$$F(q) = 1 - e^{(\frac{-q}{\alpha})^{\beta}}$$

where F(q) is the cumulative Weibull distribution function. The a, known as scale parameter, defines **63.2%** probability for the group. The β, known as shape parameter. q is the discharge magnitude.

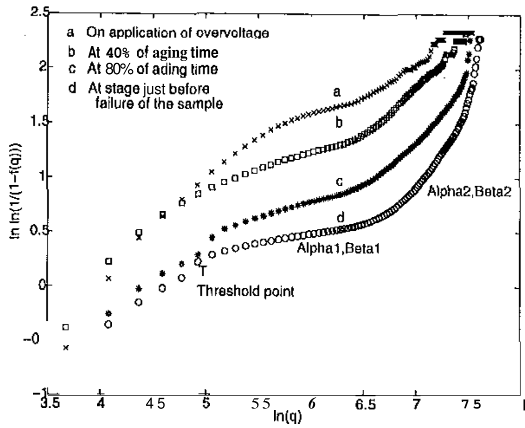

Figure 1: Typical Weibull plots for the samplc (no.8) at 13.5kV/mm

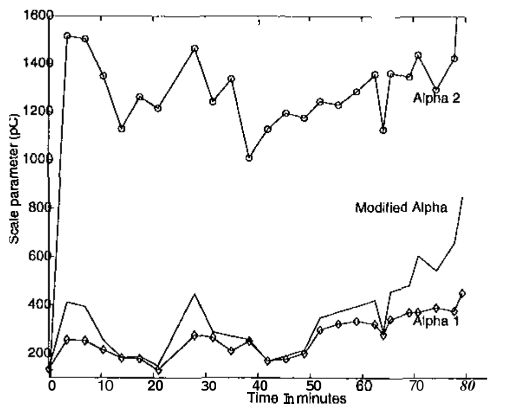

Figure 2: Variation of scale parameters α_0,α_1 and α_2 with aging time for a typical samplc (no.8) at 13.5kV/mm

A typical Weibull distribution plots are shown in figure 1. The distribution has bcen considered in two sections representing α_1,β_1 and α_2,β_2 parameters. **A** threshold discharge magnitude was decided and initial portions from Weibull plots were excluded. In order to explain the PD behaviour a modified scale parameter called α_0 has been defined as

$\alpha_0 = P_1\alpha_1 + P_2\alpha_2$ P_1 is the probability of the first scction of the distribution

P_2 is the probability of second section of thc distribution.

$P_1 and P_2$ are calculated as

$$P_1 = \frac{N_1}{(N_1+N_2)} \text{ and} P_2 = \frac{N_2}{(N_1+N_2)}$$

N_1 = total number of pulses in scction 1 and
N_2 = total number of pulses in section 2.

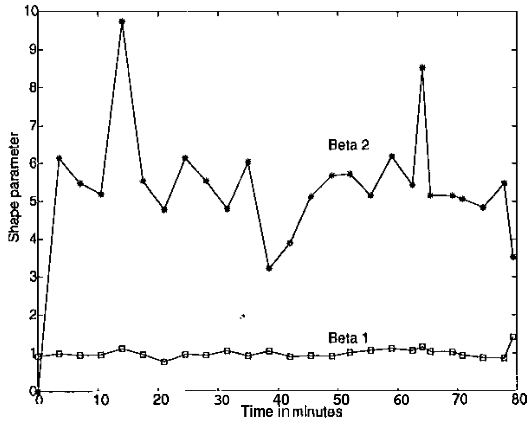

Figure **3:** Variation of shape parameters β_1 and β_2 with aging time for a typical sample (no.8) at **13.5** kV/mm

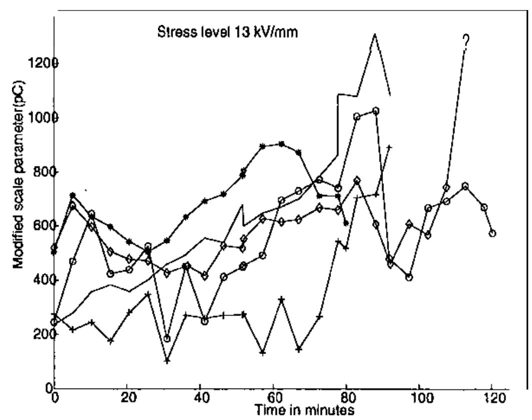

Figure 4: Variation of modified scale parameter α_0 with aging time at **13.0** kV/mm for all the samples

4 Discussion

Figure **2** shows the variation of modified Weibull scale parameter α_0 (Modified Alpha), α_1 (Alpha **1**) and α_2 (Alpha **2**) with time. It is seen that the transition just before the failure of the sample is indicated by the steep increase in the **value** of the modified scale parameter α_0. Hence the modified scale parameter α_0 can be considered as a better indicator of aging due to partial discharges as compared to α_2, the scale parameter of the higher magnitude discharge pulses only. Figure **3** shows the variation of Weibull shape parameters p~and p~with time. A modified shape parameter β_0 has not been defined in view of the fact that the large value of β_2 (in the range from **3** to 6) of the larger magnitude pulses is a better indicator of the aging rate than the value of β_1 (in the range from **1** to **2**) given for the smaller magnitude discharge pulses.

The variation in the modified scale parameter α_0 and shape parameter β_2 for all the system tested at different stress levels are shown in figures 4 to 9. It may he seen from figures **4, 6** and 8 that initial α_0 is significantly higher (**$\gg$ 500**) for the samples at **14** kV/mm. But at the end of aging period, just before the failure of the samples, the values of α_0 are in the range (**1000** to **1200** pC) for all the stress levels. **As** shown in figures **5,** 7 and **9,** the range of the β_2 values are **3.2- 5.5** at **13.0** kV/mm, **3.5- 6.5** at **13.5** kV/mm and 4.6- **6.5** at **14.0** kV/mm indicating **a** gradual increase in the rate of deterioration of the samples with increase in stress levels. This fact is also reflected in the time to failure (Table **1**).

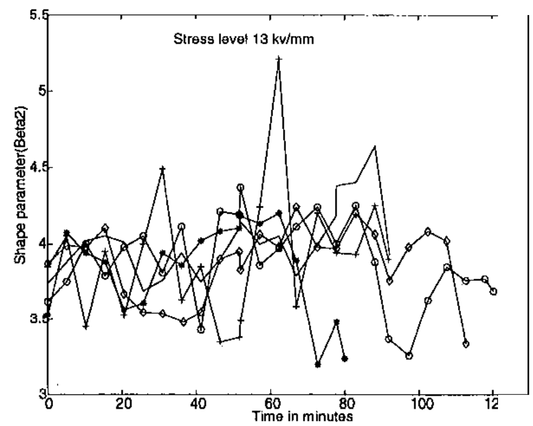

Figure **5:** Variation of shape parameter β_2 with aging time at **13.0** kV/mm for all the samples

5 Conclusions

It is shown that by defining a modified Weibull scale parameter the PD behaviour of pressboard insulation system can be studied more effectively than by just considering two modes of the distr-butions.

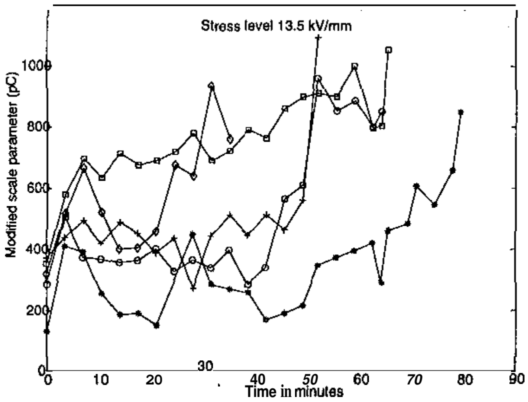

Figure 6 Variation of modified scale parameter α_0 with aging time at 13.5 kV/mm for **all** the samples

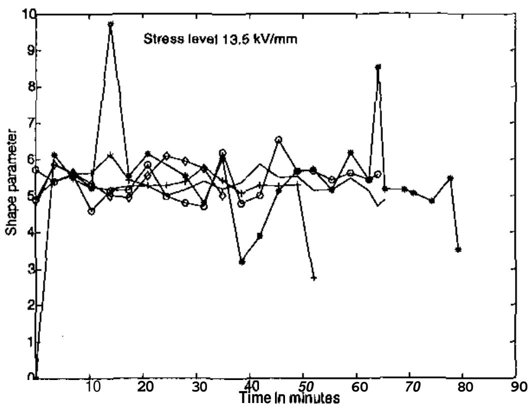

Figure **7**: Variation of shape parameter β_2 with aging time at 13.5kV/mm for all the samples

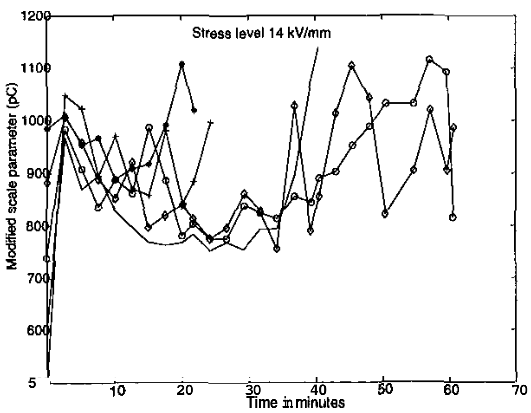

Figure 8: Variation of modified scale parameter α_0 with aging time at 14.0 kV/mm **for** all the samples

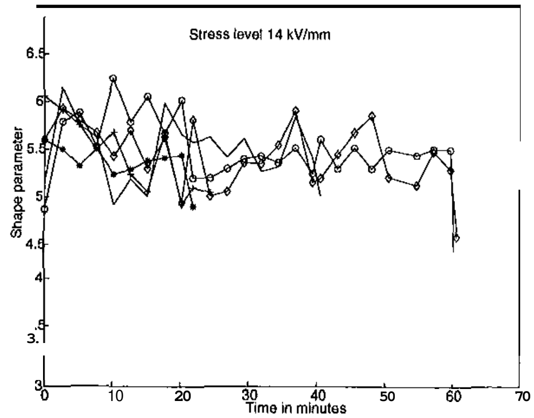

Figure 9: Variation of shape parameter β_2 with aging time at 14.0 kV/mm for all the samples

6 References

/1/ A.Contin,E.Gulski,M.Cacciari and G.C.Montanari "A Weibull approach to the investigation of partial discharges in aged insulation' system", Conference record of the IEEE International Symposium on Electrical Insulation, Montreal, Quebec, Canada, June 16-19,1996,pp. 416-419.

/2/ Palmer S and Sharpely W.A. " Electric strength of transformer insulation", IEE Proc., Vol.116, No.12, December 1969, pp.2029-2038.

/3/ Mohsin M.M., M.N.Narayanachar and R.S.Nema **"A study of** partial discharge characteristics in oil impregnated pressboard insulation",Conference record of the IEEE International Symposium on Electrical Insulation, Montreal, Quebec, Canada, June 16-19,1996, pp.79-82.

/4/ K.Raja, M.N.Narayanachar and R.S.Nema "A study of phase angle distribution of partial discharges in oil pressboard insulation system", Conference record of the IEEE International Symposium on Electrical Insulation, Montreal, Quebec, Canada, June 16-19,1996, pp.75-78.

/5/ Karlernst Giese "Electrical strength of presshoard and components for transformer insulations" IEEE Electrical Insulation Magazine, Vol 12,No.1, January-February,1996, pp.29-33.