RESULTS OF MEASUREMENTS OF THE DIELECTRIC STRENGTH OF DISTRIBUTION TRANSFORMERS OIL DUE TO A STOCHASTIC MODEL

G.P. Andreou
Public Power Corporation
A. Sigala 6
67100 Xanthi (Greece)
Tel: +30-541-23180
Fax: +30-541-28108

S.I.Spartalis
Democr.Univ.Thrace
Dept. of Civil Engineering
67100 Xanthi (Greece)

M.G. Danikas
Democritus University Thrace
Dept. of Electrical & Computer Engineering
Electric of Energy Systems Labaratory
67100 Xanthi (Greece)
Tel: +30-541-79979 Fax: +30-541-27954
E-mail: mdanikas@xanthi.cc.duth.gr

ABSTRACT

In this paper the oil from distribution transformers of the P.P.C (Public Power Corporation), is investigated. The distribution transformers are stressed (electrically, thermally e.t.c.) and this results in the degradation of their insulating properties.
For the measurement of the breakdown voltage a FOSTER apparatus has been used, according to BS 148/72 The sampling has been done according to IEC 475/74 and BS 148/78. The condition of the treated oil is considered acceptable, when its breakdown voltage is bigger or equal to 30KV, according to IEC 296/82. The breakdown voltage of a new oil for a distribution transformer must by greater or equal to 50 KV.
In this article, measurements were taken in transformers, which work properly and transformers, which have presented malfunctions.
The measurements of the breakdown voltage of all the transformers oil are related to the previous history of each transformer to the distribution network as operating conditions, maintenance e.t.c. Problems connected with the condition of distribution transformers are lightning phenomena, breakdown high voltages e.t.c. When these phenomena occur the oil must have the capability to protect the transformer from any damages.
This is only the first step in the direction of developing a statistical model relating the breakdown voltages to the above quantities for the distribution transformers of the region of Xanthi.

INTRODUCTION

The collecting of oil specimens was done in distribution transformers (15kV) of the P.P.C. network of the region of Xanthi. The transformers had been removed from the network either due to a malfunction or due to a change of the distribution voltage (from 15 kV to 20 kV).
As far as distribution transformers are concerned, the oil control includes only the measurement of their dielectric strength. The sampling was performed according to the IEC 475/74 and BS 148/78 standard.
A FOSTER device according to the BS 148/78 standard (“Bruce” electrodes with a 50mm diameter and a gap spacing of 2.5 mm) was used for the measurement of the breakdown voltage and the measurements were carried out according to the P.P.C. distribution order No 20 [1].
The oil condition of an operating transformer is considered satisfactory, when its breakdown voltage, according to the IEC 296/82 standard is greater or equal to 30kV. The breakdown voltage of an oil (new or refined), which will be used to fill a transformer, must be greater or equal to 50kV.
The results of all these measurements are shown in the Tables I and II. In the first column you can see the P.P.C. serial number of the transformers used in this sampling. In the second column is the breakdown voltage of the specimens measured in KV. In the third column you can find out the last checking date of the oil breakdown voltage, that was found to be over 50 kV. In the last table column with the heading “malfunctions”, you can find the number of any possible damages of medium voltage (M.V.) and of low voltage (L.V.) of each substation from the P.P.C. records in the region of Xanthi and the history of each transformer.
In this paper, an effort is being made to relate the previous history of the transformers with their respective oil breakdown voltage. This is only the first step in the direction of developing a statistical model relating the above quantities for the distribution transformers of the region of Xanthi.

RESULTS OF THE MEASUREMENTS OF THE BREAKDOWN VOLTAGE FROM THE DISTRIBUTION TRANSFORMERS OIL

The results regarding the breakdown voltage of oil presented in Tables I, II.

TABLE I

Transformer	Breakdown Voltage	Checking date of oil	Malfunctions	
			L.V.	M.V.
M-3629	25,5	6/67	4	-
M-5077	24,5	3/89	-	-
M-2822	17	9/89	1	-
M-2782	28,5	7/81	-	-
M-1412	30,5	8/77	19	1
M-7090	26	5/90	-	-
M-5281	28,5	1/70	3	1
M-7155	54,5	11/85	2	-
M-788	45	4/65	2	2
M-6387	43,5	2/92	-	12
M-3868	41	5/91	1	-
M-1927	51	12/77	-	-
M-5975	39	1/88	-	1
M-5153	50	8/91	2	-
M-6500	24,5	10/71	14	-
M-1798	32,5	3/92	-	-
M-3993	47,5	9/87	3	3
M-4015	50,5	10/91	3	-
M-2610	28	7/90	24	-
M-4377	37	2/85	7	-
M-7352	48,5	11/72	-	-
M-623	36,5	5/86	-	4
M-681	37	3/74	-	-
M-2339	24	5/75	3	-
M-2208	42	6/92	2	2
M-2360	61,5	4/66	6	7
E-1521	20,5	7/90	2	-
M-185	60	8/88	1	1
M-139	38,5	8/90	-	3
M-3922	48	11/86	-	1
M-3810	37,5	3/91	1	-
M-303	56	11/68	2	-
M-5282	49,5	1/70	-	-
M-2903	49	1/88	1	-
M-25571	33	11/88	16	6
E-1101	47,5	3/68	-	1
M-4208	46	8/89	1	-
M-576	26,5	8/65	8	2
M-5514	37	1/70	7	2
M-5166	62,5	1/90	-	1
M-3972	42,5	12/67	-	-
K-5497	24,5	5/86	2	1
M-6079	25	1/90	-	-
M-6455	60,5	10/71	-	1
M-7020	48,5	8/80	5	-
M-3577	30	6/80	-	1
M-6126	63	6/71	1	1
M-6127	20	6/71	1	-

TABLE II

Transformer	Breakdown voltage	Checking date of oil	Malfunctions	
			L.V.	M.V.
M-40148	30	19/4/96	-	1
M-21661	21,5	10/1/94	-	3
M-40320	25,16	2/9/96	-	2
M-20077	20,92	4/3/97	7	-
M-16864	28,25	13/9/96	-	1
M-41031	25,92	10/7/96	2	2
M-4513	18,25	25/6/93	2	-
Π-4034	21,92	8/6/71	-	-
Θ-1291	28,33	5/3/75	4	1
M-1767	28,5	18/8/84	3	-
M-6229	28,16	6/7/90	8	2
E-2330	38,08	12/10/94	1	-
M-11760	27,33	2/6/95	-	-
E-2526	29,08	24/1/90	1	-
M-25675	27,83	16/5/97	-	-
M-6107	27,83	22/4/92	-	8
M-7488	24,66	8/7/94	1	2
Θ-2066	29,74	24/1/90	6	1
M-5206	24,08	26/2/92	-	5
M-664	27	11/10/88	-	3
E-622	27,66	10/5/94	1	4
M-2971	27,66	14/6/88	5	1
M-4121	27,66	15/2/68	-	4
Θ-82	26,5	10/12/90	2	1
M-6993	26,33	18/6/80	6	2
M-1228	27,33	17/5/70	2	1
M-35010	35,25	19/4/94	2	2
Π-5704	29,16	12/8/93	1	4
M-450	38,92	19/6/66	1	16
M-6539	25,66	25/7/91	2	3
M-1969	26,33	29/5/91	3	-
M-5355	38,25	14/11/91	1	-
Θ-744	31,16	1/11/89	-	-
M-7717	40,25	18/6/96	-	1
M-11704	39,33	20/3/96	-	3
M-6840	31,5	25/7/89	-	2
M-7149	28,25	17/8/90	3	-
M-8277	22,08	11/4/94	12	1
M-37382	31,92	16/5/95	2	-
M-42386	27,5	19/8/97	-	-
M-25052	23,08	22/7/88	1	-
M-25700	28,75	1/2/89	7	-
M-21303	25,33	16/6/86	-	-
M-20907	30	1/4/85	19	6
M-41946	25	7/7/97	-	-
M-23001	24,5	20/8/97	-	-
M-1490	35	13/6/79	-	-
M-10248	33,83	23/4/82	2	4
M-18539	27,16	23/3/83	12	3
M-6503	27,25	16/7/92	-	-

DEVELOPING A STATISTICAL APPROACH

The brief presentation of the results of the measurements, which were realized in the sample of the 98 transformers regarding the malfunctions (x), ageing (y) and the breakdown voltage (z), is being made with the aid of frequency tables.

In other words, for the independent variable, a frequency table of discrete variable is used, whereas for y and z frequency tables of a continuous variable. Moreover, with the aid of these tables, the arithmetic mean, the median, the mode, the percentiles, the variance, the standard deviation, the relative standard deviation are calculated and useful conclusions are drawn. Finally, the bar chart of x, the frequency histograms and the frequency polygons of y, z are given and investigated w.r.t. the positive and negative asymmetry.

Table III Frequency distribution of x

X_i	f_i	F_i
0	20	20
1	19	39
2	10	49
3	13	62
4	8	70
5	6	76
6	3	79
7	4	83
8	2	85
9	1	86
10	2	88
12	1	85
13	2	21
14	1	92
15	1	93
17	1	94
20	1	95
22	1	96
24	1	97
25	1	98
	$\sum_{i=1}^{98} f_i = 98$	

Table IV Frequency distribution of y

classes	Frequencies f_i	y_i	Cumulative frequencies F_i
0-5	19	2,5	19
5-10	29	7,5	48
10-15	16	12,5	64
15-20	8	17,5	72
20-25	5	22,5	77
25-30	10	27,5	87
30-35	9	32,5	96
	$\sum_{i=1}^{98} f_i = 98$		

Table V Frequency distribution of z

classes	Frequencies f_i	z_i	Cumulative frequencies f_i
15-20	3	17,5	3
20-25	15	22,5	18
25-30	36	27,5	54
30-35	8	32,5	62
35-40	12	37,5	74
40-45	6	42,5	80
45-50	9	47,5	89
50-55	3	52,5	92
55-60	2	57,5	94
60-65	4	62,5	98
	$\sum_{i=1}^{98} f_i = 98$		

Table VI Parameters of central tendency

Arithmetic mean	The mode	Median	100p-percentiles	Asymmetric index of bowley
$\bar{x}$ =4,14	t_x=0	M_x=2	Q_{1x}=1,Q_{3x}=5,D_{1x}=0,D_{2x}=0,D_{3x}=1,D_{4x}=2,D_{6x}=3,D_{7x}=4,D_{8x}=6,D_{9x}=12	$S_{k(x)}$=0,50
$\bar{y}$ =13,11	t_y=7,17	M_y=10,31	Q_{1y}=5,95,Q_{3y}=21,5,D_{1y}=2,58,D_{2y}=5,12,D_{3y}=6,79,D_{4y}=8,48,D_{6x}=13,37,D_{7y}=17,87,D_{8x}=25,7,D_{9x}=30,66	$S_{k(y)}$=0,08
$\bar{z}$ =33,61	t_z=27,14	M_z=29,3	Q_{1z}=25,9,Q_{3z}=39,8,D_{1z}=22,3,D_{2z}=25,2,D_{3z}=26,6,D_{4z}=27,9,D_{6z}=33,D_{7z}=37,7,D_{8z}=43,6,D_{9z}=49,5	$S_{k(z)}$=0,11

We denote by Q_I=100p-persentile, where (i,p) $\in$ {(1, 0,25), (2, 0,50), (3, 0,75)} and D_j=100p-persentile, where (j,p) $\in$ {(1, 0,10), (2, 0,20),… (9, 0,95)}. It is obvious that Q_2=M=D_5.

Table VII Dispersion

Variance	Standard	Relative Standard Deviation
S^2_x=28,2	S_x=5,3	CV(x)=132,5%
S^2_y=66,53	S_y=8,16	CV(y)=62,24%
S^2_z=121,67	S_z=11,03	CV(z)=32,82%

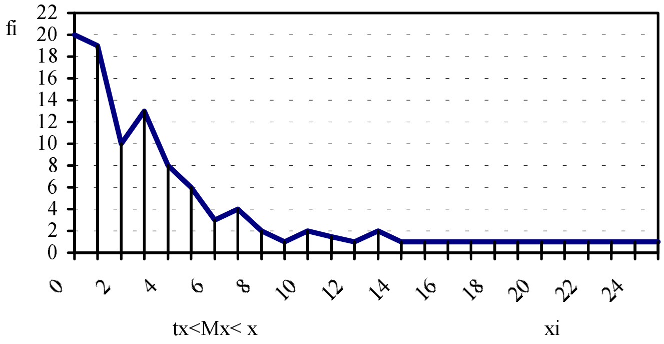

Figure 1 Bar chart of x

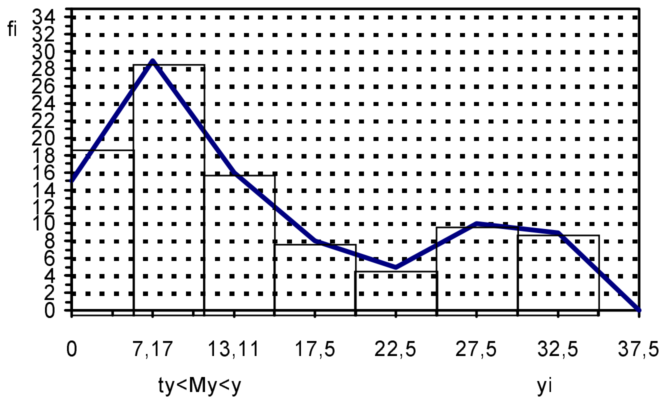

Figure 2 Frequency histogram and polygon of y

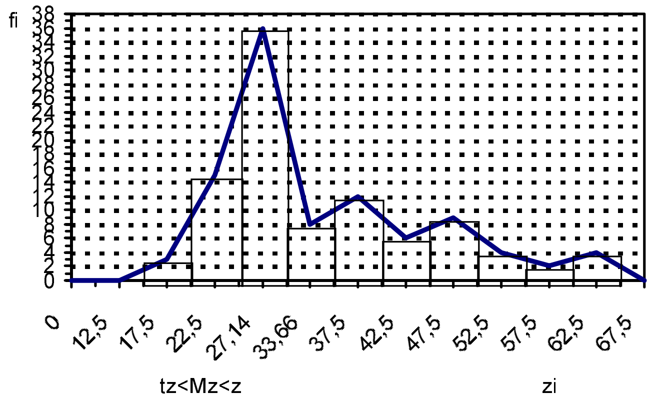

Figure 3 Frequency histogram and polygon of z

DISCUSSION

The present study represents a first approach to the matter of the dielectric strength of the distribution transformers' oil.

The good state of a transformer oil is of great importance to its good function and in a wider sense to the good operation and reliability of the whole system.

The oil's breakdown voltage depends on many factors.

A temperature rise, the presence of humidity, foreign particles and aromatic hydrocarbons (in large quantities) affects negatively the breakdown voltage of the insulating oil. Moreover various factors (that are of industrial significance) like the increase of the electrodes' surface and the duration of the voltage, bring about negative consequences to the breakdown voltage.

An increased breakdown voltage appears in cases of impulse voltages. The frequency increase of the voltage is followed by an increase of the breakdown voltage up to the maximum and all this leads to a downfall. High work function materials result in a high breakdown voltage. The admixture of some organic compounds results in the improvement of the breakdown voltage whereas oils with molecules, which hold a larger amount of carbon atoms, produce a better breakdown voltage [4,5,6].

In every-day practice and with the time passing, the transformer oil undergoes an oxidation, which leads to the ageing and the degradation of its insulating properties (a reduction of the dielectric strength).

The normal function of a transformer is affected by various irregularities, which occur on a daily basis in the transportation and in the electric energy distribution systems. Such irregularities are over voltages of all sorts [7,8].

The specimens, which showed greater breakdown voltage than its lowest allowable limit, present variability, as expected, in the field of breakdown voltage values. This variability is caused by the statistic nature of the breakdown effect and depends on all the previous factors (ageing, load, thunders e.t.c.). The presence of all those factors alone cannot reduce – in several cases - the breakdown voltage of the insulating oil under the 30 KV limit.

We could say it is normal to expect that with the passing of time and the gradual oxidation and ageing of the oil, its breakdown voltage is reduced and this results in the degradation of the insulating properties of the oil. That makes the transformer more susceptible to damages, which in their turn bring about a further reduction of the oil breakdown voltage.

CONCLUSIONS

The results presented in this paper as well as the statistical analysis performed indicate that relation between ageing and the breakdown voltage of oil samples taken from distribution transformers in use exists.

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