DISTRIBUTION TRANSFORMERS: A STUDY OF THE RELATIONSHIP OF THEIR OIL DIELECTRIC STRENGTH AND THEIR PREVIOUS HISTORY

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ABSTRACT

This paper is concerned with the correlation of the oil dielectric strength and the previous history of a number of distribution transformers of the P. P. C. (Public Power Corporation) from the region of Eastern Macedonia and Thrace. Our samples come from distribution transformers from the Xanthi area and from the broader region of Macedonia and Thrace, Northern Greece. In the Xanthi area there are 1631 distribution transformers. In the broader region of Macedonia and Thrace 39963 distribution transformers are in the network. Our work is a continuation of the work reported in CIRED 2001.Our effort is concentrated on the establishment of a statistical model which would relate the dielectric strength with the electric stresses to which a distribution transformer is subjected as well as its previous history. It is to be noted that the measurements of the dielectric strength were carried out with the aid of a Foster test cell according to the BS 148/78 standard.

INTRODUCTION

Transformer oil is a vital component of distribution transformers (15-20 kV). Its electrical behavior is determined by a variety of factors, such as, electric stress, transient phenomena, oil purity, filtering cycles, area and volume effect, viscosity, temperature and pressure [1-3]. These factors result in, what we call, ageing of the transformer oil and, consequently, of the distribution transformers. An aged oil presents a rather low dielectric strength; therefore it is unfit for further use.

For the control and measurement of the breakdown voltage of the transformer oil taken from the distribution transformers, a Foster test cell was used (BS 148/78) with Bruce profile electrodes of 50 mm diameter and a gap spacing of 2.5 mm. The breakdown measurements were carried out according to the P.P.C. distribution regulation No20[4,5]

TABLE 1

Transformer	Breakdown Voltage	Age of oil	Malfunctions
M-3629	25,5	3	4
M-5077	24,5	29	0
M-2822	17	5	1
M-2782	28,5	7	4
M-1412	30,5	5	20
M-7090	26	9	0
M-5281	28,5	4	4
M-7155	54,5	27	2
M-788	45	26	4
M-6387	43,5	8	12
M-3868	41	7	1
M-1927	51	27	0
M-5975	39	6	1
M-5153	50	30	2
M-6500	24,5	26	14
M-1798	32,5	6	0
M-3993	47,5	28	6
M-4015	50,5	9	3
M-2610	28	6	24
M-4377	37	24	7
M-7352	48,5	15	0
M-623	36,5	15	4
M-681	37	24	0
M-2339	24	24	3
M-2208	42	28	4
M-2360	61,5	6	13
E-1521	20,5	6	2
M-185	60	14	2
M-139	38,5	18	3
M-3922	48	5	1
M-3810	37,5	26	1
M-303	56	10	2
M-5282	49,5	30	0
M-2903	49	4	1
M-25571	33	4	22
E-1101	47,5	18	1
M-4208	46	8	1
M-576	26,5	4	10
M-5514	37	24	9
M-5166	62,5	3	1

M-3972	42,5	8	0
K-5497	24,5	4	3
M-6079	25	5	0
M-6455	60,5	11	1
M-7020	48,5	23	5
M-3577	30	9	1
M-6126	63	21	2
M-6127	20	20	1
M-40148	30	27	1
M-21661	21,5	3	3
M-40320	25,16	4	2
M-20077	20,92	31	7
M-16864	28,25	6	1
M-41031	25,92	6	4
M-4513	18,25	6	2
Π-4034	21,92	8	0
Θ-1291	28,33	1	5
M-1767	28,5	1	3
M-6229	28,16	8	10
E-2330	38,08	7	1
M-11760	27,33	3	0
E-2526	29,08	2	1
M-25675	27,83	0	0
M-6107	27,83	9	8
M-7488	24,66	9	3
Θ-2066	29,74	11	7
M-5206	24,08	12	5
M-664	27	0	3
E-622	27,66	0	5
M-2971	27,66	18	6
M-4121	27,66	15	4
Θ-82	26,5	14	3
M-6993	26,33	5	8
M-1228	27,33	1	3
M-35010	35,25	4	4
Π-5704	29,16	1	5
M-450	38,92	0	17
M-6539	25,66	1	5
M-1969	26,33	1	3
M-5355	38,25	4	1
Θ-744	31,16	26	0
M-7717	40,25	22	1
M-11704	39,33	13	3
M-6840	31,5	7	2
M-7149	28,25	3	3
M-8277	22,08	2	13
M-37382	31,92	8	2
M-42386	27,5	0	0
M-25052	23,08	5	1
M-25700	28,75	3	7
M-21303	25,33	8	0
M-20907	30	6	25

M-41946	25	9	0
M-23001	24,5	3	0
M-1490	35	9	0
M-10248	33,83	30	6
M-18539	27,16	7	15
M-6503	27,25	17	0
K-10090	26,8	16	1
M-17080	44,9	19	0
M-17080	44,9	19	3
M-37381	33,1	5	2
M-11494	40,9	23	8
M-11494	40,9	23	1
M-08547	32,6	27	0
M-08547	32,6	27	9
M-46478	25,8	1	3
M-46476	28,9	1	2
M-22648	22,3	1	1
M-26739	36,5	11	5
M-08651	24,4	27	0
M-08651	24,4	27	10
M-21453	21,4	11	3
M-10565	38,2	17	0
M-10565	38,2	17	0
M-08774	18,9	24	0
M-08774	18,9	24	4
M-40177	24,6	26	1
M-10302	21,6	12	6
M-42147	32,5	3	1
M-33249	25,7	2	1
M-26739	36,5	11	1
M-36573	39,8	6	0
M-38969	48,5	5	11
M 43123	27,2	5	2
M 49430	31,9	2	2
M 27283	24,5	13	16
M 39376	24,1	7	1
M 39229	31,5	7	9
M 45910	31,8	3	20
M 36767	30,7	8	16
M 46283	26,2	3	8
M 42608	29,7	5	4
M 502000	31,5	2	8
M 9121	15,5	18	0
M 19390	28,6	19	1
M 11007	24	13	2
M 17302	18.6	21	13
M 32769	29.9	6	9
M 30185	37.2	11	1
M 16580	22.7	15	3
M 27093	33.8	12	0
M 26647	23.2	12	9
M 18991	32.4	25	13

M 37816	43.4	7	0
M 37772	37.6	7	8
M 15125	26.6	22	1
M 10565	15.5	19	15
M 11186	14.7	7	11
M 16174	34.9	1	
M 15465	26.6	1	
M 16097	32.8	1	
M 043896	28,5	4	
M 042287	40,8	5	
M 031484	26	9	
M 031289	32,5	7	
M 016383	25,3	19	
M 014192	24,5	15	
M 014346	27,7	11	
M 022051	28,3	17	
M 016391	22,4	7	
M 016410	30	20	
M 031525	27	10	
M 042207	36	5	
M 016460	30,2	3	
M 018169	17,5	19	
M 040862	32,5	3	
M 043556	45	5	
M 016398	19,5	18	
M 031580	23,9	10	
M 042517	21,2	5	
M 042263	37	5	
M 030767	29,2	10	
M 023606	23,3	15	
M 015328	28,8	6	
M 031582	30,5	10	
M 017921	17,5	4	
M 020758	28,8	18	
M 042388	43,5	15	
M 017602	19,6	17	
M 022460	28,2	16	
M 040708	34	2	
M 032047	24,2	6	
M 046609	48	3	
M 036926	27,8	8	
M 043927	32	4	
M 018450	23,8	19	
M 032864	27,5	8	
M 039894	35	6	
M 047570	52,5	3	
M 020752	24,7	18	
M 022518	21,5	6	
M15500	28,4	4	
M 12054	40,1	9	
M 12529	5,9	27	
M 14022	18,6	23	
M 16267	15,18	10	
M 11061	29,8	26	
M 15789	28,6	22	
M 18083	25,32	20	
M 16866	19,2	4	
M 15869	22,3	3	
M 16510	14,7	4	
M 6440	25,6	4	
M 16224	17,3	7	
M 18243	31,3	3	
M 15677	30,5	3	
M 17965	25,9	10	
M 18404	27,5	5	
M 17621	21,3	5	
M 11612	19,2	8	
M 15804	16,6	4	
M 9314	11,4	19	
M 42232	22,8	2	
M 34169	9,6	10	
M 11603	8	22	
M 16284	13,7	1	
M 49727	10,9	3	
M 16036	9	2	
M 16403	40,8		
M 8412	28,3		
M 17042	11,9		
M 9177	14,9		
M 8922	9		

DEVELOPING A STATISTICAL APPROACH

The brief presentation of the results of the measurements which were realized in the sample of the 219 transformers regarding ageing (Y) and breakdown voltage (Z) and in the sample of the 149 transformers regarding the number of malfunctions (X), 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 II Frequency distribution of x

x_i	Frequencies of x_i f_i	Cumulative frequencies of x_i F_i
0	19	29
1	30	59
2	15	74
3	17	91
4	11	102
5	7	109
6	4	113
7	4	117
8	6	123
9	5	128
10	3	131
11	2	133
12	1	134
13	4	138
14	1	139
15	2	141
16	2	143
17	1	144
20	2	146
22	1	147
24	1	148
25	1	149
	$\sum_{i=1}^{22} f_i = 149$	

TABLE III frequency distribution of y

Classes	Frequencies of y f_i	y_i	Cumulative frequencies of y F_i
[0,5)	60	2,5	60
[5,10)	65	7,5	125
[10,15)	24	12,5	149
[15,20)	29	17,5	178
[20,25)	19	22,5	197
[25,30)	18	27,5	215
[30,35]	4	32,5	219
	$\sum_{i=1}^{7} f_i = 219$		

TABLE IV Frequency distribution of z

Classes	Frequencies of z f_i	z_i	Cumulative frequencies of z F_i
[5,10)	5	7,5	5
[10,15)	7	12,5	12
[15,20)	17	17,5	29
[20,25)	37	22,5	66
[25,30)	66	27,5	132
[30,35)	32	32,5	164
[35,40)	23	37,5	187
[40,45)	14	42,5	201
[45,50)	12	47,5	213
[50,55)	5	52,5	218
[55,60)	1	57,5	219
[60,65)	5	62,5	224
	$\sum_{i=1}^{12} f_i = 224$		

TABLE V Parameters of central tendency

Arithmetic mean	The mode	Median	100p-percentiles	Asymmetric index
$\bar{x} = 4,4$	$t_x = 1$	$M_x = 3$	Q_{1x}= 1, Q_{3x}= 6, D_{1x}= 0, D_{2x}= 1, D_{3x}= 1, D_{4x}= 2, D_{6x}= 3, D_{7x}= 5, D_{8x}= 8, D_{9x}= 13	$S_{k(x)}$ = 0,2
$\bar{y}$ = 11,4	t_y = 5,54	M_y = 8,81	Q_{1y}= 4,56, Q_{3y}= 17,63, D_{1y}= 1,83, D_{2y}= 3,65, D_{3y}= 5,44, D_{4y}= 7,12, D_{6y}= 11,33, D_{7y}= 15,74, D_{8y}= 19,52, D_{9y}= 25,09	$S_{k(y)}$ = 0,35
$\bar{z}$ = 30,22	t_z = 27,3	M_z = 28,49	Q_{1z}= 23,65, Q_{3z}= 35,87, D_{1z}= 18,06, D_{2z}= 22,14, D_{3z}= 25,09, D_{4z}= 26,79, D_{6z}= 30,38, D_{7z}= 33,88, D_{8z}= 38,30, D_{9z}= 45,25	$S_{k(z)}$ = 0,21

TABLE VI Dispersion

Variance	Standard	Relative Standard Deviation
$S_x^2 = 27,68$	$S_x = 5,26$	CV(x)= 119,55%
$S_y^2 = 71,5$	$S_y = 8,46$	CV(y)= 74,21%
$S_z^2 = 114,75$	$S_z = 10,71$	CV(z)= 35,44%

Figure 1: Bar chart of x

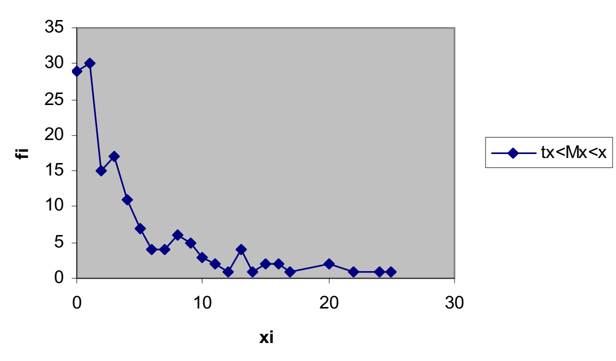


figure 2: Frequency histogram and polygon of y

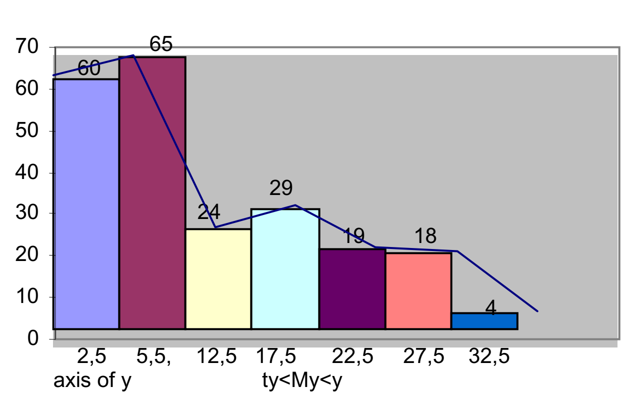


Figure 3: Frequency histogram and polygon of z

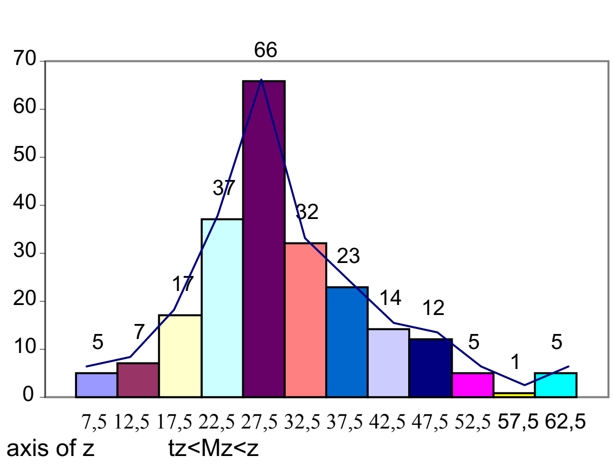
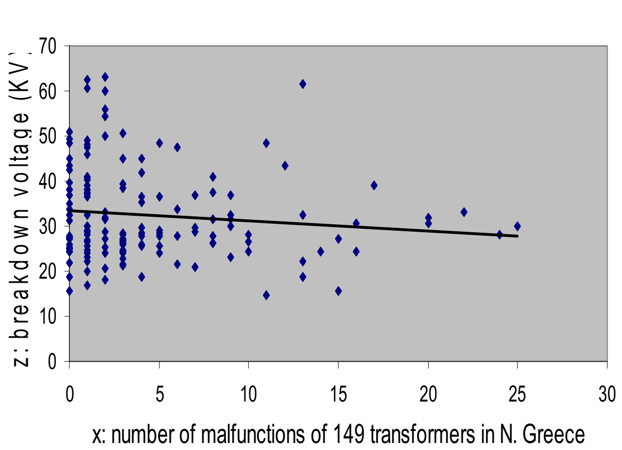


Figure 4: Linear Regression of z = -0,226x + 33,458



DISCUSSION

In this paper, a number of distribution transformers is investigated w.r.t. their oil breakdown strength, their past history which includes phenomena that might overstress the transformer insulation. This work is an extension of previous efforts [6,7] regarding distribution in the northern region of Greece (Macedonia and Thrace).The results show that we should concentrate to the linear relationship which seems to relate the number of malfunctions(x) to the breakdown voltage (z).

CONCLUSIONS

As shown above ,from the study of linearity of the relationship z=-0,226x + 33,458, in case of malfunctions, the breakdown voltage of the 149 transformers –the lifetime of which is between 0 and 35 years- tends to stabilize around 33kv which approaches the limit of the acceptable breakdown value according to the IEC 296/82 standard.

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