DETERMINING THE OPERATING TIME OF THE ELECTROINSULATING OIL FOR POWER TRANSFORMERS

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ABSTRACT

This paper presents a way of assessing the durability of the electroinsulating oil used on medium/low voltage power transformers owned by the national electricity supplier (SDFE) in Oradea. Statistics about the operation durations, before replacing the electroinsulating material, reveal a Rayleigh non-exponential distribution, specific for the degradable products, exclusively due to aging.

Key words: durability, Rayleigh non-exponential distribution, statistics, degradable products.

INTRODUCTION

Surface tension of the electroinsulating oils represents a physical attribute of these products and indicate the force exerted per unit length of the oil-water layer. The level of the surface tension can reveal an image of the oxidized product quantity in the oil mass. The allowed value for the surface tension, according to the international quality norm, ASTM/D 3487, is 40 Dyn/cm (0,04 N/m) and corresponds to pure oil. Norms in Romania, NI Astra Romana 39/1999, 57/1999 indicate the same number.

The minimum level admitted is 0,0255 N/m. Below this value, the process of mud forming is amplified, in this case being recommended the improvement or replacement of oil.

Within SDFE Oradea, the corrective maintenance is exclusively practiced – replacing the oil when the surface tension is at the critical level: 0,014 – 0,022 N/m.

Figure 1 represents the graph of surface tension evolution during the operating time accepted.

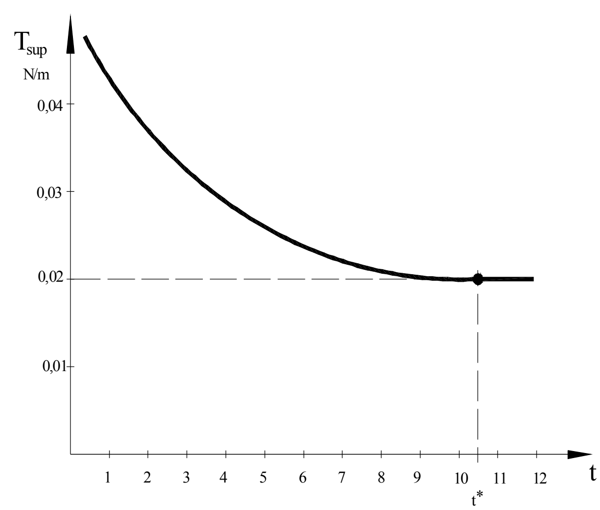

Fig.1

CASE STUDY

The analysis in this paper focuses on a group of seven medium/low voltage power transformers the operating time of which are revealed in table 1.

Table 1

i	1	2	3	4	5	6	7
τ_i *[year]*	11	9	8	13	10	13,5	9

• VALIDATION OF THE RAYLEIGH MODEL OF THE OPERATING TIME FOR ELECTROINSULATING OIL

The Rayleigh distribution represents a version of the Weibull distribution, meaning that the distribution function

$$F(t) = 1 - \exp(-\theta\, t^{\beta})) \qquad (1)$$

has the following form:

$$F(t) = 1 - \exp(-\theta\, t^{2})) \qquad (2)$$

(form parameter, β=2)

Table 2 is made to verify this model:

Table 2

i	***t_i***	***t_{i+1}***	***$\Delta M(z_i)$***	***l_i***
1	8	1	1,079055	0,92673682
2	9	0	0,591587	0,00000000
3	9	1	0,442789	2,25841202
4	10	1	0,387280	2,58211134
5	11	2	0,387714	5,15844153
6	13	0,5	0,480648	0,96129600
7	13,5	-	-	-
$\sum_i$				11,88699771

The values for the ΔM(z) quantile are extracted from table 2, based on statistical sample volume ***n*** and on the level of verisimilitude ***P***, extracted from table 3.

Table 3

r	***i***	***$\Delta M(z_i)$***	***P***	
			0,90	0,95
	1	1,216395		
3	2	0,863046		
	3	-	0,90	0,95
	1	1,150727		
	2	0,706698		
4	3	0,6795960	0,90	0,95
	4	-	0,67	0,76
	1	1,115718		
	2	0,645384		
5	3	0,532445	0,90	0,95
	4	0,583273	0,68	0,77
	5	-	0,79	0,86
	1	1,093929		
	2	0,612330		
	3	0,474330	0,90	0,95
6	4	0,442920	0,68	0,76
	5	0,522759	0,80	0,86
	6	-	0,66	0,73
	1	1,079055		
	2	0,591587		
	3	0,442789	0,90	0,95
7	4	0,387280	0,68	0,77
	5	0,387714	0,80	0,86
	6	0,480648	0,67	0,74
	7	-	0,74	0,80
	1	1,068252		
	2	0,577339		
	3	0,422889	0,90	0,95
8	4	0,356967	0,68	0,77
	55	0,334089	0,80	0,86
	6	0,349907	0,67	0,74
	7	0,449338	0,74	0,80
	8	-	0,65	0,71
	1	1,060046		
	2	0,566942		
	3	0,409157	0,90	0,95
	4	0,337763	0,68	0,77
9	5	0,304777	0,80	0,86
	6	0,297949	0,67	0,75
	7	0,322189	0,74	0,80
	8	0,424958	0,66	0,72
	9	-	0,71	0,76
	1	1,053606		
	2	0,559013		
	3	0,399100	0,90	0,95
	4	0,324470	0,68	0,77
10	5	0,286163	0,80	0,86
	6	0,269493	0,68	0,75
	7	0,271645	0,75	0,81
	8	0,300809	0,66	0,72
	9	0,405316	0,71	0,76
	10	-	0,61	0,69

The calculation of the l size is based on the following relation:

$$l_i = \frac{t_{i+1} - t_i}{\Delta M(z_i)} \qquad (3)$$

the following statistics is calculated:

$$S^* = \frac{\sum_{i=\left[\frac{n}{2}\right]+1}^{n-1} l_i}{\sum_{i}^{n-1} l_i} \qquad (4)$$

Where $\left[\frac{n}{2}\right]$ is the whole of the fraction;

so:

$$S^* = \frac{\sum_{i=3+1}^{5} l_i}{\sum_{i=1}^{6} l_i}$$

Results that :

$$S^* = \frac{8{,}70184}{11{,}88700} \Rightarrow S^* \cong 0{,}73$$

From table 3 the quantile of the $S_{n=7;\,P=0{,}95}$ test is taken

$$S_{n=7;\,P=0{,}95} \in [0{,}8 - 0{,}95]$$

The hypothesis of the model is confirmed by the inequality:

$$S^* < S_{n;P} \qquad (5)$$

Results that

$$S^* = 0{,}73 < S_{n=7;P=0{,}95} \in [0{,}80;0{,}95]$$

• CALCULATION OF THE OPERATING TIME OF THE ELECTROINSULATING OIL

According to this statistical distribution, the durability of a product is expressed by the formula:

$$M(T) = \theta\,\Gamma\left(\frac{1}{k}+1\right) \qquad (6)$$

or

$$M(T) = \theta\,\Gamma\left(\frac{1}{2}+1\right) \qquad (7)$$

($\beta = 2$ for Rayleigh distribution).

The gamma function $\Gamma\left(\frac{1}{2}+1\right)$ is deduced from table 4, depending on the parameter $\beta = 2$; so $\Gamma\left(\frac{1}{2}+1\right)$=0,8862

Table 4

k	V_k	g_k	***CV***
0,200	120,0000	1901,0000	15,8400
0,300	9,2610	50,0800	5,4080
0,400	3,3230	10,4400	3,1410
0,500	2,0000	4,4720	2,2360
0,600	1,5050	2,6450	1,7580
0,700	1,2660	1,8510	1,4620
0,800	1,1330	1,4280	1,2610
0,900	1,0520	1,1710	1,1130
1,000	1,0000	1,0000	1,0000
1,100	0,9649	0,8783	0,9102
1,200	0,9407	0,7872	0,8369
1,300	0,9236	0,7164	0,7757
1,400	0,9114	0,6596	0,7238
1,500	0,9027	0,6129	0,6700
1,600	0,8966	0,5737	0,6399
1,700	0,8922	0,5402	0,6056
1,800	0,8893	0,5112	0,5749
1,900	0,8874	0,4858	0,5475
2,000	0,8862	0,4638	0,5227
2,500	0,8873	0,3797	0,4279
3,000	0,8930	0,3246	0,3634
3,500	0,8997	0,2847	0,3165
4,000	0,9064	0,2543	0,2805
4,500	0,9126	0,2301	0,2521
5,000	0,9182	0,2103	0,2291
7,000	0,9354	0,1572	0,1680
10,000	0,9514	0,1145	0,1203

As for parameter θ, it will be calculated according table 5 data.

Table5

i	t_i	$\bar{t}$	$t_i - \bar{t}$	$(t_i - \bar{t})^2$
1	8		-2,5	6,25
2	9		-1,5	2,25
3	9		-1,5	2,25
4	10	10,5	-0,5	0,25
5	11		+0,5	0,25
6	13		+2,5	6,25
7	13,5		+3,0	9,00
$\sum_i$	73,5			26,50

Parameter θ – the failure rata– is deduced from the following formula:

$$\theta = \frac{\sigma}{\xi_k} \qquad (8)$$

Where σ is the standard deviation of the variable values from its mear value, $\bar{t}$:

$$\sigma = \sqrt{\frac{\sum_i \left(t_i - \bar{t}\right)^2}{n}} \qquad (9)$$

It's obtained:

$$\sigma = \sqrt{\frac{26{,}50}{7}} \Rightarrow \sigma \cong 1{,}9457$$

The value of ξ is deduced from table 4 depending on the variation coefficient, CV:

$$CV = \frac{\sigma}{\bar{t}} \qquad (10)$$

Results :

$$CV = \frac{1{,}9457}{10{,}5} \Rightarrow CV = 0{,}1853$$

By interpolation, $\xi_k \cong 0{,}18$ is set.

According to formula (8), the value for the θ parameter is obtained:

$$\theta = \frac{1{,}9457}{0{,}18} \Rightarrow \theta \cong 10{,}8$$

The durability of the electroinsulating oil is obtained from relation (7):

$$\tau = M(T) \cong 9{,}6 \text{ years}$$

CONCLUSIONS

● The durability of electroinsulating oil is influenced by a series of mechanical, electrical and chemical measures (properties), all of these conditioning the quality of the protective product.

● Knowing the limit values of these determinants factors, their temporal evolution, cause an accurate imagine to anticipate the critical moment of operation, and therefore the opportunity for improvement or replacement the electroinsulating material operational compromise.

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