THE EVALUATION OF THE ENDURANCE OF CABLE BOXES FOR 6kV CABLES IN THE CITY OF ORADEA

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Abstract - This paper presents a „case study" on determining the average endurance of one lot of cable boxes, built identically, from the 6 kV cables used for power supply of a consumption segment.
The endurance of these products depends on the distribution function of operational times (up to the failure of the products included in the statistic sample under analysis).

Key words: average endurance, distribution function, operational times

INTRODUCTION

The endurance of depends on the distribution function of operational times. The average endurance of products that cannot be repaired implies checking the exponential character of the function of endurance distribution for the elements of the lot under analysis. The checking of the statistical exponential distribution of the endurance will be made based in the following models: HANN-SHAPIRO-WILK, FINKELSTEIN – SHAFER t, HARTLEY. The volume of the entire lot the endurance of which is going to be determined is n = 30 products, and of those of the presented statistic is r = 10.

1. VALIDATING THE EXPONENTIAL DISTRIBUTION FOR THE ENDURANCE OF CABLE BOXES

Cable boxes under analysis in this „case study" have in their structure an electro insulating material - composite, silicone rubber.

The life time of these products varies between 2 – 15 years – according to the evidence supplied by the service departments.

We take a lot of 30 products, and from 10 of them we note the operation time until the wearing out of the last cable box – the tenth - of this „experimental" set. The endurance of cable boxes depends on the time of the life time distribution function for the 10 products studied.

The checking of the statistical exponential distribution of the endurance will be made based in the following models:

1.1. The HANN-SHAPIRO-WILK test

If this test doesn't confirm the hypothesis of the exponential character of the distribution function of the endurance, other two tests will be used; an exponential distribution of the endurance is accepted only if the solutions of both models lead to that conclusion.

The Hann-Shapiro-Wilk test validates the exponential distribution if the following inequality is met:

$$W_{r;P}^{inf} \langle W_0 \langle W_{r;P}^{sup} \qquad (1)$$

where W^{inf}, W^{sup} are the inferior, respectively superior of the test quantum;
r is the volume of the "experimental" set: ***r=10***, and P is the level of likelihood – complementary measure of the risk, α :

$$P = 1 - \alpha \qquad (2)$$

Frequently, P = 0,95 (α =0,05) is taken.

Measure W_0 – statistics calculation – is obtained from the relation:

$$W_0 = \frac{\sum_i (t_i - \bar{t})^2}{(\sum_i t_i)^2}, i = \overline{1;r} \qquad (3)$$

$\bar{t}$ being the average of the functioning time, t_i.

Table 1 gives the calculation model of this measure:

Table 1

i	t_i - year -	$\bar{t}$	$t_i - \bar{t}$	$(t_i - \bar{t})^2$
1	2,0	5,8	-3,8	14,44
2	2,5	5,8	-3,3	10,89
3	3,5	5,8	-2,3	5,29
4	4,0	5,8	-1,8	3,24
5	5,0	5,8	-0,8	0,64
6	6,5	5,8	+0,7	0,49
7	7,0	5,8	+1,2	1,44
8	8,0	5,8	+2,2	4,84
9	9,5	5,8	+3,7	13,69
10	10,0	5,8	+4,2	17,64
$\sum_i$	58,0	*	0	72,60

Table 2

r	P = 0,95	
	W^{inf}	W^{sup}
7	0,025	0,260
8	0,025	0,230
9	0,025	0,205
10	0,025	0,184
11	0,025	0,166
12	0,025	0,153
13	0,025	0,140
14	0,024	0,128
15	0,024	0,119
16	0,023	0,113
17	0,023	0,107
18	0,022	0,101
19	0,022	0,096
20	0,021	0,090
21	0,020	0,085
22	0,020	0,080
23	0,019	0,075
24	0,019	0,069
25	0,018	0,065
26	0,018	0,062
27	0,017	0,058
28	0,017	0,056
29	0,016	0,054
30	0,016	0,053

The statistics calculation – relation (3) - results:

$$W_0 = \frac{72,6}{58^2} \Rightarrow W_0 = 0,0216$$

Table 2 indicates the following values for the W^{inf} and W^{sup} quantum:

$W^{inf} = 0,025$;
$W^{sup} = 0,184$.

It turns out that inequality (1) is not met. According to this model, the distribution of the endurance is not exponential:

$$W^{inf}_{r=10;P} = 0,025 > W_0 = 0,0216 < W^{sup}_{r=10;P=0,95} = 0,184$$

1.2. The FINKELSTEIN – SHAFER Test

This test imposes the following condition for validating the exponential hypothesis of the distribution function:

$$S_0 < S^*_{r;P} \qquad (4)$$

where

S_0 is the statistics calculation:

$$S_0 = \sum_i \max_i |A_i ; B_i| \qquad (5)$$

$$A_i = \frac{i}{r} - F(t_i) \qquad (6)$$

$$B_i = F(t_i) - \frac{i-1}{r} \qquad (7)$$

$F(t_i)$ is the distribution function:

$$F(t_i) = 1 - \exp(\frac{t_i}{\bar{t}}) \qquad (8)$$

$S^*_{..}$ is the test quantile.

The data for calculating the test statistics is given in table 3, and the value of the S^* quantile is found in table 4.

It results:

$$S_0 = 1,42123 < S^*_{r=10;P=0,95} = 1,7$$

Table 3

i	t_i	$\bar{t}$	$\frac{t_i}{\bar{t}}$	$\exp(-\frac{t_i}{\bar{t}})$	$F(t_i)$	$\frac{i}{r}$	$\frac{i}{r} - F(t_i)$ (A)	$\frac{i-1}{r}$	$F(t_i) - \frac{i-1}{r}$ (B)	$\max_i \|A_i ; B_i\|$
1	2,0	5,8	0,34483	0,70834	0,29166	0,1	-0,19166	0,00000	0,29166	0,29166
2	2,5	5,8	0,43103	0,64984	0,35016	0,2	-0,15016	0,10000	0,25016	0,25016
3	3,5	5,8	0,60345	0,54692	0,45308	0,3	-0,15308	0,20000	0,25308	0,25308
4	4,0	5,8	0,68965	0,50175	0,49825	0,4	-0,09825	0,30000	0,19825	0,19825
5	5,0	5,8	0,86207	0,42220	0,57771	0,5	-0,07771	0,40000	0,17771	0,17771
6	6,5	5,8	1,120690	0,32605	0,67395	0,6	-0,07395	0,50000	0,17395	0,17395
7	7,0	5,8	1,20690	0,29912	0,70088	0,7	-0,00088	0,60000	0,10088	0,10088
8	8,0	5,8	1,37931	0,25175	0,74825	0,8	-0,05175	0,70000	0,04825	0,04825
9	9,5	5,8	1,63793	0,19438	0,80562	0,9	-0,09438	0,80000	0,00562	0,00562
10	10	5,8	1,72414	0,17833	0,82167	1,0	-0,17833	0,90000	-0,07833	-0,07833
$\sum_i$										1,42123

Table 4

r	$S^{*}_{r;P=0,95}$	r	$S^{*}_{r;P=0,95}$
2	0,96	12	1,82
3	1,13	13	1,87
4	1,23	14	1,92
5	1,32	15	1,98
6	1,40	16	2,02
7	1,48	17	2,08
8	1,56	18	2,12
9	1,62	19	2,16
10	1,70	20	2,21
11	1,75	25	2,42

Given that the condition (4) is met, it results that the endurance distribution of the cable boxes is exponential. This conclusion will be reconfirmed following the use of another model for checking the exponential character of the endurance distribution function for the products analyzed.

1.3. The HARTLEY test

This model is preferred if the sequence of the values of the independent variable – operating times – is characterized by fluctuating amplitudes of the following intervals:

$$\Delta t_i = t_i - t_{i-1} \qquad (9)$$

Table 5 evidences this state of events – oscillating Δt_i intervals:

Table 5

i	t_i	t_{i-1}	Δt_i
1	2	0	2
2	2,5	2	0,5
3	3,5	2,5	1
4	4	3,5	0,5
5	5	4	1
6	6,5	5	1,5
7	7	6,5	0,5
8	8	7	1
9	9,5	8	1,5
10	10	9,5	0,5

Statistics calculation of the test is deduced from the expression:

$$H_c = \frac{\max\limits_{i} \varphi(t_i)}{\min\limits_{i} \varphi(t_i)} \qquad (10)$$

where

$$\varphi(t_i) = [n - (i-1)\ \Delta t_i] \qquad (11)$$

Statistics $\mathbf{H_c}$ calculation is given in table 6:

Table 6

i	i-1	n-(i-1)	Δt_i	$\varphi(t_i)$	$\max\limits_{i} \varphi t_i$	$\min\limits_{i} \varphi t_i$
1	0	30	2	60,00	60,00	*
2	1	29	0,5	14,50	*	*
3	2	28	1	28,00	*	*
4	3	27	0,5	13,50	*	*
5	4	26	1	13,00	*	*
6	5	25	1,5	16,67	*	*
7	6	24	0,5	12,00	*	*
8	7	23	1	23,00	*	*
9	8	22	1,5	14,67	*	*
10	9	21	0,5	10,50	*	10,50

In Table 6, ***n*** represent the number of the cable boxes included in the entire lot : ***n=10***.

$$H_c = \frac{60,00}{10,50} \Rightarrow H_c \cong 5,7$$

The compatibility condition of the exponential hypothesis with the endurance distribution of the products imposes the following inequality:

$$H_c < H_{r;\,P} \qquad (12)$$

The values of the $H_{r=10;\ P=0,95}$ quantile are given in table 7:

Table 7

P	*r*	$H_{r;P}$
P=0,95	2	39,0
	3	87,5
	4	142
	5	202
	6	266
	7	333
	8	403
	9	475
	10	550
	...	...
	...	...
	...	〉〉5,7

As

$$H_c = 5,7 << H_{r=10;\,P=0,95} = 550,$$

It results that the statistical distribution of the endurance of cable boxes under analysis from the volume set ***r = 10***, is exponential.

2. ASSESSMENT OF THE AVERAGE ENDURANCE OF THE PRODUCTS IN THE LOT

The volume of the entire lot the endurance of which is going to be determined is n = 30 products, and of those of the presented statistic is r = 10.

The case being of an “incomplete sample” of type “r out of n”, the literature recommends in the case of the exponential model, the following relation for calculating the average endurance of products ($\tau_{r,n}$) pertaining to the statistical sample studied:

$$\tau_{r;n} = \frac{1}{r}\left[\sum_i t_i + (n-r)t_r\right] \qquad (13)$$

Based on the calculation data established, it results:

$$\tau_{r=10;\, n=30} = \frac{1}{10}\left[58 + (30-10)10\right] \Rightarrow$$

$\tau_{r=10;\, n=30}$ =26 years

calculation elements Σt_i and t_r are given in table 1.

3. CONCLUSIONS

- The average endurance of products that cannot be repaired implies checking the exponential character of the function of endurance distribution for the elements of the lot under analysis.
- Although the first model hasn’t confirmed the exponential nature for the lot under analysis, the use of the two tests has demonstrated the acceptance of an exponential distribution for the temporal evolution of the products.
- The average endurance of the entire lot – relation (13) – refers to the whole sample with volume n, under the hypothesis that any product out of order has been replaced. It results that there have permanently been 30 operational cable boxes, but the relation (13) targets only the initial statistic sample.

REFERENCES

[1]. V. Gh. Vodă - Controlul durabilității produselor industriale, Ed. Tehnică, Bucureşti, 1981
[2]. T. Baron – coordinator, Al. Isac-Maniu, L. Tövissi, ş. a. - Calitate şi fiabilitate. Manual practic, vol. 1+2, Ed. Tehnică, Bucureşti, 1988
[3]. V. Panaite, R. Munteanu - Control statistic şi fiabilitat, Ed. Didactică şi Pedagogică, Bucureşti, 1982
[4]. Al. Isac-Maniu, V. Gh. Vodă - Fiabilitatea – şansă şi risc, Ed. Tehnică, 1986