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Reliability functions of low voltage electrical terminals made from bare wires, insulated and cables

Streszczenie. *W artykule przedstawiono wyniki oceny podstawowych funkcji określających właściwości niezawodnościowe przyłączy nN, jakimi są funkcja intensywności awarii, funkcja niezawodności oraz funkcja zawodności. Na podstawie wieloletnich obserwacji przyłączy nN eksploatowanych w sieci dużej spółki dystrybucyjnej energii elektrycznej w kraju, określono przebiegi empiryczne wymienionych funkcji. Przeprowadzono także analizę zgodności rozkładu empirycznego z założonym rozkładem teoretycznym. Wyznaczono wartość oczekiwaną czasu poprawnej pracy przyłączy nN do uszkodzenia.* ***(Funkcje niezawodnościowe przyłączy elektroenergetycznych nN)***

Abstract*. The article presents the results of the evaluation of basic functions determining reliability characteristics of LV connections, they are a failure intensity function, function reliability and unreliability function. Based on years of follow-up LV connections operated in large electricity distribution company in the country were defined empirical waveforms mentioned features. It was also carried out an analysis of the empirical distribution of compliance with the assumed theoretical distribution. In paper was determined the expected value of lifetime to damage of LV connections.*

Keywords: distribution network, low-voltage terminals, reliability, failure intensity, reliability functions
Słowa kluczowe: sieci dystrybucyjne, przyłącza niskiego napięcia, niezawodność, intensywność awarii, funkcje niezawodnościowe.

Introduction

The issue of reliability of electrical equipment is very important in terms of ensuring uninterrupted supply of electrical power to a considerable group of recipients. In many cases, lapses in power supply create a real threat for human life or health, e.g. in case of people using professional life-support medical equipment. Therefore, in order to establish methods of proper operation and undertake all possible actions to eliminate such failures in the future, it is necessary to supervise work of power networks and analyze occurring failures.

Determination of parameters and functions defining reliability features of the individual network elements is a very important issue. In many cases, obtaining full information is impossible due to the lack of data from operation. Therefore, reliability factor *q* and average failure intensity λ are most often given as characteristic parameters.

This article includes a method of determination of reliability and unreliability functions and functions of damage intensity for bare and insulated overhead and cable terminals. The analysis was made according to data collected over 10 years of observations. Assumed level of significance α =0,05.

"Dynamic test" method for determining reliability functions for electrical equipment

In order to fully determine the reliability features of unrepairable electrical plants, their functions of reliability $R(t)$, unreliability $F(t)$ and failure intensity $\lambda(t)$ have to be determined. In case of restored plants, it is necessary to additionally define restoration distribution and stochastic process data characterizing its work. Process characteristics such as: constancy of failure and restoration intensity, etc. should be tested. In practice, obtaining full and detailed information concerning reliability is very difficult and labor-intensive and impossible in many cases due to a lack of reliable operation data. Therefore, average values of failure intensity λ_{av} and average restoration times t_a are usually used in approximate analyzes and calculations.

In case there is a necessity of determining reliability functions ($R(t)$, $F(t)$ or $\lambda(t)$), estimation method depends on the available statistical sample.

In case of simultaneous introduction of *N* elements and testing their reliability/time *t* characteristics, a full random sample is applied. In such case, reliability function *R(t)* is estimated by estimator $R^*(t)$:

$$R^*(t)=\frac{n(t)}{N} \tag{1}$$

where: $n(t)$ – number of elements which were not damaged within a period of (*0*, *t*>, *N* – number of tested elements.

Similarly, reliability function $F^*(t)$ has the following estimator:

$$F^*(t)=\frac{m(t)}{N} \tag{2}$$

where: $m(t)$ – number of elements which were damaged within a period of (*0*, *t*>.

It is much less probable for a considerable population of electrical equipment to be put into operation simultaneously. Pieces of equipment are usually introduced in small numbers and within different timeframes. In such case, it is not possible to use a full random sample method.

Publication [7] includes a presentation of the dynamic random sample method, consisting in simultaneous observation of plants in various stages of operation:

1. Assessment of plant reliability is performed by analyzing a population of plants in various stages of operation,
2. Reliability properties of the plant is defined by the reliability function $R(t)$,
3. Plant restoration process does not change its reliability features because its purpose is limited to elimination of failure in a particular device installed in this plant,
4. Plant failure time is much shorter in relation to its operation time and can be omitted in the aforementioned analysis.

Analysis is performed on a statistical sample of plants in various stages of operation. Number of plants in a particular year of observation j (j = 1,2,3, ..., l) is a sum of plants in the i-th year of operation (i = 1,2,3, ..., k):

$$n_j = \sum_{i=1}^{k} n_{ij} \tag{3}$$

where: n_j – number of plants in the j – th year of observation, n_{ij} – number of plants in the j - th year of observation and the i – th year of operation.

Similarly, a number of plant failures that occurred in j - th year of observation is a sum of plant failures in various years of operation i:

$$m_j = \sum_{i=1}^{k} m_{ij} \tag{4}$$

where: m_j – number of failures in the j – th year of testing, m_{ij} – number of plant failures in the j – th year of observation and the i – th year of operation.

Often, in order to increase the size of statistical sample, results are taken from several years of observation. It is equivalent to averaged parameters obtained during these years. In such case, the total number of plants and the number of plant failures in the i – th year of operation are determined from the following equation:

$$n_i = \sum_{j=1}^{l} n_{ij} = n_{i1} + n_{i2} + ... + n_{il} \tag{5}$$

$$m_i = \sum_{j=1}^{l} m_{ij} = m_{i1} + m_{i2} + ... + m_{il} \tag{6}$$

where: i = 1,2,3, ..., k – consecutive years of operation, j = 1,2,3, ..., l – consecutive years of tests.

Estimator of average failure intensity in the i – th year of operation is equal to:

$$\hat{\lambda}_i = \frac{2 \cdot m_i}{n_i + n_{i+1}} \tag{7}$$

whereby:

$$\frac{n_i + n_{i+1}}{2} = n_{śr} \tag{8}$$

is the substitute number of objects in the i – th year of operation, provided that the number of plants introduced into operation changes linearly throughout the year.

Knowing a plant failure intensity function in a form of discrete values λ_i, we are able to determine the average failure intensity [7]:

$$\lambda = \frac{1}{k} \cdot \sum_{i=1}^{k} \lambda_i \tag{9}$$

In theory of reliability, it is very important to know the frequency of failures f_i and the cumulative distribution function F_i. Basing on discrete values λ_i in particular years of plant operation, f_i^*, F_i^* and R_i^* estimators can be determined:

$$f_i^* = \hat{\lambda}_i \cdot \prod_{k=1}^{k=i-1} \left(1 - \hat{\lambda}_k\right) \tag{10}$$

$$F_i^* = \sum_{k=1}^{k=i} f_k^* \tag{11}$$

$$R_i^* = 1 - F_i^* \tag{12}$$

whereby a standardization condition has to be maintained:

$$\sum_{i=1}^{i=\infty} f_i^* = 1 \tag{13}$$

Discrete values f_i^*, F_i^* and R_i^* determined from formulas (18) to (20) are realizations of probability density function $f(t)$, unreliability function $F(t)$ and reliability function $R(t)$ for particular years of operation i (i = 1, 2, 3, ..., k). Therefore, determination of failure intensity, reliability nor unreliability function does not solve a problem of estimation of reliability parameters. Analysis of empirical distribution type compliance with a chosen theoretical distribution is also very important. Such analysis is made in accordance with nonparametric estimation rules. In many cases, estimation of unknown function can be done with sufficient accuracy with the use of a functional grid [6,7]. Distribution hypothesis can be verified by a test of characters, Kolmogorov test λ, Pearsone test χ^2 or Wald-Wolfowitz test also known as the test of series [6,7,8].

Assessment of reliability functions of overhead electrical LV terminals made of bare wires

Statistical test of electrical LV terminals is a dynamic sample from reliability testing point of view, which means that it includes terminals in various stages (years) of operation. Failures of electrical LV terminals were grouped into samples of amounts n_i – number of terminals in i – th year of operation and m_i – number of terminals damaged in i – th year of operation.

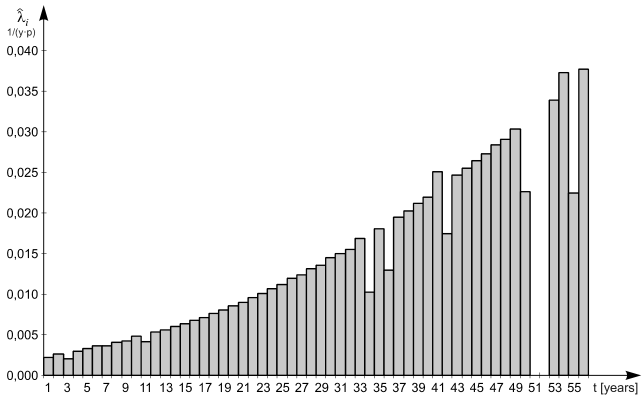

Fig. 1. Empirical intensity of failures of overhead LV terminals made of bare wires

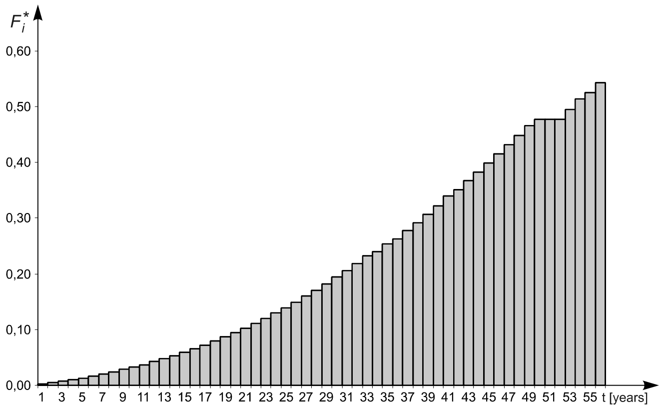

Fig. 2. Empirical function of unreliability of overhead LV terminals made of bare wires

Empirical values of failure intensity $\hat{\lambda}_i$, failure frequency f_i^*, reliability function R_i^* and unreliability (durability) function F_i^* were calculated in accordance with equations (7), (10), (11) and (12). Results of calculations were listed in table 1 and shown graphically in figure 1 and 2.

Empirical distribution type compliance with a chosen theoretical distribution of failure intensity was analyzed. According to a detailed analysis of the obtained results, it was assumed that a function of failure intensity of overhead LV terminals made of bare wires is subject to normal truncated distribution and is defined with the following equation:

$$\lambda(t) = \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}} \cdot \frac{\exp\left[-\frac{(t-m)^2}{2 \cdot \sigma^2}\right]}{0{,}5 - \Phi\left(\frac{t-m}{\sigma}\right)} \tag{14}$$

where: m – expected value of random variable t; σ – standard deviation of random variable t, $\Phi(x)$ – Laplace integral.

Values of distribution (14) determined with the use of Statistica and Excell software equal: m = 50,53 and σ = 25,08.

Table 1. Results of statistical calculations concerning intensity, frequency of failures, distribution of durability and reliability for overhead LV terminals made of bare wires

Year of operation	$\hat{\lambda}_i$	f_i^*	F_i^*	R_i^*
	$\frac{1}{year \cdot piece}$	---	---	---
1	0,0022	0,0022	0,0022	0,9978
2	0,0026	0,0026	0,0048	0,9952
3	0,0020	0,0020	0,0068	0,9932
4	0,0029	0,0029	0,0097	0,9903
5	0,0033	0,0033	0,0130	0,9870
6	0,0036	0,0036	0,0166	0,9834
7	0,0037	0,0036	0,0202	0,9798
8	0,0041	0,0040	0,0242	0,9758
9	0,0042	0,0041	0,0284	0,9716
10	0,0048	0,0047	0,0331	0,9669
11	0,0042	0,0040	0,0371	0,9629
12	0,0053	0,0051	0,0422	0,9578
13	0,0056	0,0053	0,0475	0,9525
14	0,0060	0,0057	0,0532	0,9468
15	0,0063	0,0060	0,0592	0,9408
16	0,0068	0,0064	0,0656	0,9344
17	0,0072	0,0067	0,0723	0,9277
18	0,0077	0,0071	0,0794	0,9206
19	0,0080	0,0074	0,0867	0,9133
20	0,0085	0,0078	0,0945	0,9055
21	0,0090	0,0081	0,1027	0,8973
22	0,0096	0,0086	0,1113	0,8887
23	0,0100	0,0089	0,1202	0,8798
24	0,0106	0,0094	0,1295	0,8705
25	0,0112	0,0097	0,1393	0,8607
26	0,0119	0,0103	0,1495	0,8505
27	0,0123	0,0105	0,1600	0,8400
28	0,0131	0,0110	0,1710	0,8290
29	0,0136	0,0113	0,1823	0,8177
30	0,0145	0,0118	0,1942	0,8058
31	0,0150	0,0121	0,2063	0,7937
32	0,0155	0,0123	0,2186	0,7814
33	0,0169	0,0132	0,2318	0,7682
34	0,0102	0,0079	0,2396	0,7604
35	0,0180	0,0137	0,2533	0,7467
36	0,0130	0,0097	0,2630	0,7370
37	0,0195	0,0144	0,2774	0,7226
38	0,0203	0,0147	0,2921	0,7079
39	0,0212	0,0150	0,3070	0,6930
40	0,0220	0,0152	0,3223	0,6777
41	0,0251	0,0170	0,3393	0,6607
42	0,0175	0,0115	0,3508	0,6492
43	0,0246	0,0160	0,3668	0,6332
44	0,0255	0,0161	0,3829	0,6171
45	0,0265	0,0163	0,3993	0,6007
46	0,0273	0,0164	0,4157	0,5843
47	0,0284	0,0166	0,4323	0,5677
48	0,0291	0,0165	0,4488	0,5512
49	0,0303	0,0167	0,4655	0,5345
50	0,0226	0,0121	0,4776	0,5224
51	0,0000	0,0000	0,4776	0,5224
52	0,0000	0,0000	0,4776	0,5224
53	0,0339	0,0177	0,4953	0,5047
54	0,0373	0,0188	0,5141	0,4859
55	0,0225	0,0109	0,5250	0,4750
56	0,0377	0,0179	0,5429	0,4571

After substituting values in equation (14), theoretical function of failure intensity takes the following form:

$$\lambda(t) = 0{,}0159 \cdot \frac{\exp\left[-\frac{(t-50{,}53)^2}{1258{,}01}\right]}{0{,}5 - \Phi(0{,}0399 \cdot t - 2{,}0148)} \tag{15}$$

Figure 3 shows theoretical function of failure intensity of overhead terminals made of bare wires.

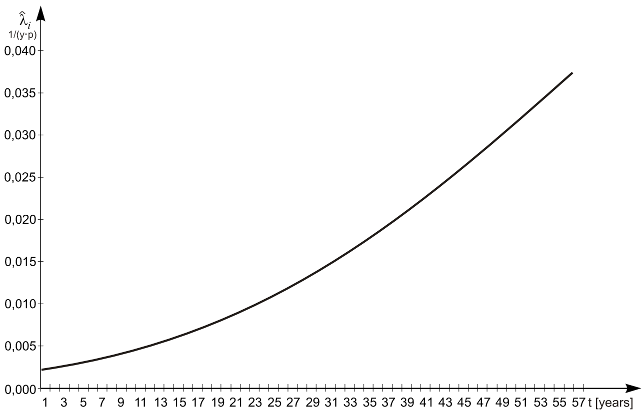

Fig. 3. Theoretical function of failure intensity $\lambda(t)$ of overhead LV terminals made of bare wires

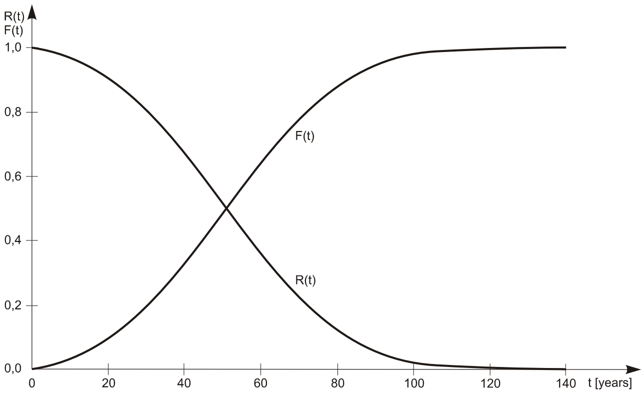

Fig. 4. Theoretical functions of reliability $R(t)$ and unreliability $F(t)$ for overhead terminals made of bare wires

Distribution hypothesis was verified by a test of characters. Results of the performed test were the following: $l_0 = \min(l^+, l^-) = \min(27,29) = 27$; $l_0 = 27 > 20 = l_\alpha$; $l_0 \notin R_\alpha = (-\infty, 20)$. Therefore, on a significance level of α = 0,05, there are no grounds for rejecting a hypothesis of functional form of failure intensity distribution.

By using a dependability between functions $R(t)$, $F(t)$ and $\lambda(t)$, reliability function can be written in the following form:

$$R(t) = 0{,}5083 - 1{,}0166 \cdot \Phi(0{,}0399 \cdot t - 2{,}0148) \tag{16}$$

whereas the unreliability function:

$$F(t) = 0{,}4917 + 1{,}0166 \cdot \Phi(0{,}0399 \cdot t - 2{,}0148) \quad (17)$$

Theoretical functions *R(t)* and *F(t)* for overhead terminals made of bare wires are shown in figure 4.

Expected value of correct operation of overhead LV terminals made of bare wires is 50,53 years.

Assessment of reliability functions of insulated overhead electrical LV terminals

Empirical values of failure intensity $\hat{\lambda}_i$, failure frequency f_i^*, reliability function R_i^* and unreliability (durability) function F_i^* were calculated in accordance with equations (7), (10), (11) and (12). Results of calculations were listed in table 2 and shown graphically in figure 5 and 6.

Table 2. Results of statistical calculations concerning intensity, frequency of failures, distribution of durability and reliability for insulated overhead LV terminals

Year of operation	$\hat{\lambda}_i$	f_i^*	F_i^*	R_i^*
	$\frac{1}{year \cdot piece}$	---	---	---
1	0,0001	0,0001	0,0001	0,9999
2	0,0002	0,0002	0,0003	0,9997
3	0,0001	0,0001	0,0004	0,9996
4	0,0002	0,0002	0,0006	0,9994
5	0,0003	0,0003	0,0009	0,9991
6	0,0002	0,0002	0,0011	0,9989
7	0,0003	0,0003	0,0014	0,9986
8	0,0003	0,0003	0,0017	0,9983
9	0,0004	0,0004	0,0021	0,9979
10	0,0004	0,0004	0,0024	0,9976
11	0,0005	0,0005	0,0029	0,9971
12	0,0005	0,0005	0,0034	0,9966
13	0,0006	0,0006	0,0040	0,9960
14	0,0006	0,0006	0,0046	0,9954
15	0,0007	0,0007	0,0053	0,9947
16	0,0008	0,0008	0,0061	0,9939
17	0,0009	0,0009	0,0070	0,9930
18	0,0009	0,0009	0,0079	0,9921
19	0,0011	0,0011	0,0090	0,9910
20	0,0011	0,0011	0,0101	0,9899
21	0,0013	0,0013	0,0113	0,9887
22	0,0014	0,0014	0,0127	0,9873
23	0,0013	0,0012	0,0140	0,9860
24	0,0017	0,0017	0,0156	0,9844
25	0,0007	0,0007	0,0164	0,9836
26	0,0018	0,0018	0,0182	0,9818
27	0,0023	0,0022	0,0204	0,9796
28	0,0023	0,0022	0,0226	0,9774
29	0,0026	0,0025	0,0252	0,9748
30	0,0028	0,0027	0,0279	0,9721
31	0,0030	0,0029	0,0308	0,9692
32	0,0033	0,0032	0,0340	0,9660
33	0,0035	0,0034	0,0374	0,9626
34	0,0028	0,0027	0,0401	0,9599
35	0,0041	0,0039	0,0440	0,9560
36	0,0047	0,0045	0,0485	0,9515
37	0,0048	0,0046	0,0530	0,9470
38	0,0020	0,0019	0,0550	0,9450
39	0,0054	0,0051	0,0601	0,9399
40	0,0058	0,0055	0,0655	0,9345
41	0,0062	0,0058	0,0714	0,9286
42	0,0066	0,0061	0,0775	0,9225
43	0,0070	0,0065	0,0840	0,9160

Empirical distribution type compliance with a chosen theoretical distribution of failure intensity was analyzed. According to a detailed analysis of the obtained results, it was assumed that a function of failure intensity of insulated overhead LV terminals is subject to normal truncated distribution and is defined with equation (14). Values of distribution (14) determined with the use of Statistica and Excel software equal: m = 76,29 and σ = 24,41.

After substituting values in equation (14), theoretical function of failure intensity takes the following form:

$$\lambda(t) = 0{,}0163 \cdot \frac{\exp\left[-\frac{(t-76{,}29)^2}{1191{,}70}\right]}{0{,}5 - \Phi(0{,}0410 \cdot t - 3{,}1254)} \quad (18)$$

Theoretical function of failure intensity of insulated overhead terminals is shown in figure 7.

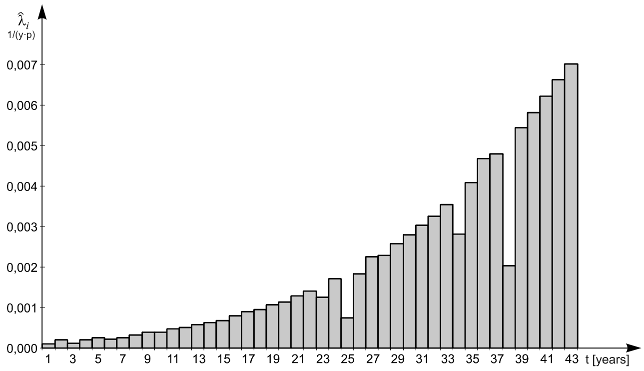

Fig. 5. Empirical intensity of failures of insulated overhead LV terminals

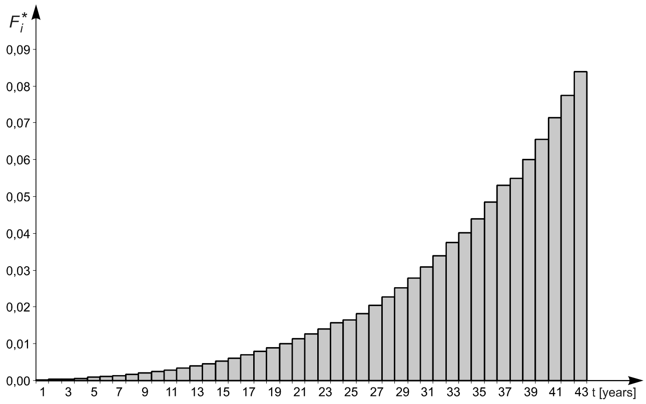

Fig. 6. Empirical reliability function of insulated overhead LV terminals

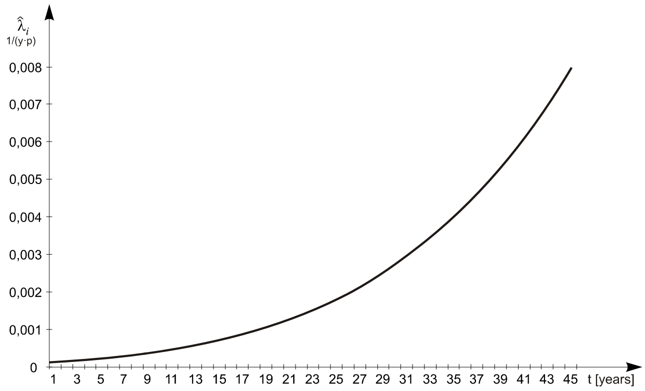

Fig. 7. Theoretical function of reliability *λ(t)* of insulated overhead LV terminals

Distribution hypothesis was verified by a test of characters. Results of the performed test were the following: $l_0 = \min(l^+, l^-) = \min(22{,}21) = 21$; $l_0 = 21 > 14 = l_\alpha$; $l_o \notin R_\alpha = (-\infty, 14)$. Therefore, on a significance level of α = 0,05, there are no grounds for rejecting a hypothesis of functional form of failure intensity distribution.

By using a dependency between functions *R(t), F(t)* and *λ(t)*, reliability function can be written in the following form:

(19) $$R(t) = 0{,}5005 - 1{,}0009 \cdot \Phi(0{,}0410 \cdot t - 3{,}1254)$$

whereas the unreliability function:

(20) $$F(t) = 0{,}4995 + 1{,}0009 \cdot \Phi(0{,}0410 \cdot t - 3{,}1254)$$

Theoretical functions *R(t)* and *F(t)* for insulated overhead terminals are shown in figure 8.

Expected value of correct operation of insulated overhead LV terminals is 76,29 years.

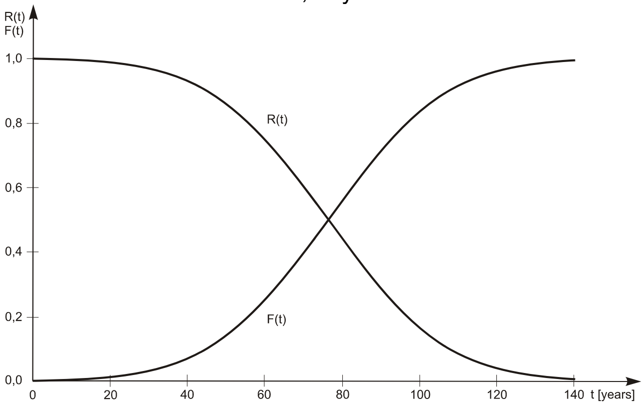

Fig. 8. Theoretical functions of reliability *R(t)* and unreliability *F(t)* for insulated overhead LV terminals

Assessment of reliability functions of cable electrical LV terminals

Empirical values of failure intensity $\hat{\lambda}_i$, failure frequency f_i^*, reliability function R_i^* and unreliability (durability) function F_i^* were calculated in accordance with equations (7), (10), (11) and (12). Results of calculations were listed in table 3 and shown graphically in figure 9 and 10.

Analysis of compliance of the empirical distribution type with selected theoretical distribution of failure intensity was performed. Based on detailed analysis of the obtained results, it was assumed that the function of failure intensity of cable LV terminals is subject to normal truncated distribution and is defined by equation (14). Values of distribution (14) determined with the use of Statistica and Excel software equal: m = 56,42 and σ = 21,64.

After substituting values in equation (14), theoretical function of failure intensity takes the following form:

(21) $$\lambda(t) = 0{,}0184 \cdot \frac{\exp\left[-\dfrac{(t-56{,}42)^2}{936{,}58}\right]}{0{,}5 - \Phi(0{,}0462 \cdot t - 2{,}6072)}$$

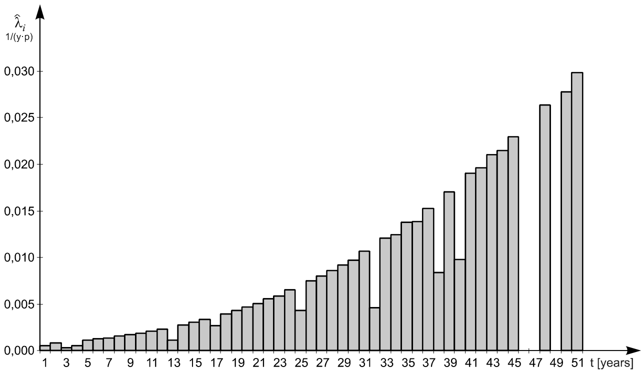

Fig. 9. Empirical intensity of failures of cable LV terminals

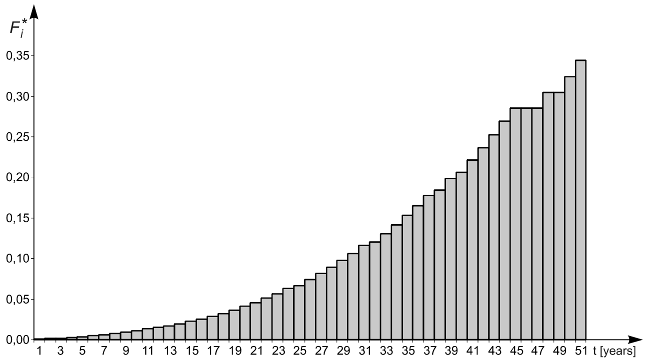

Fig. 10. Empirical reliability function of cable LV terminals

Table 3. Results of statistical calculations concerning intensity, frequency of failures, distribution of durability and reliability for cable LV terminals

Year of operation	$\hat{\lambda}_i$	f_i^*	F_i^*	R_i^*
	$\frac{1}{year \cdot piece}$	---	---	---
1	0,0006	0,0006	0,0006	0,9994
2	0,0008	0,0008	0,0014	0,9986
3	0,0003	0,0003	0,0018	0,9982
4	0,0005	0,0005	0,0023	0,9977
5	0,0011	0,0011	0,0034	0,9966
6	0,0013	0,0012	0,0047	0,9953
7	0,0014	0,0014	0,0060	0,9940
8	0,0016	0,0016	0,0076	0,9924
9	0,0017	0,0017	0,0093	0,9907
10	0,0019	0,0019	0,0111	0,9889
11	0,0021	0,0021	0,0132	0,9868
12	0,0023	0,0023	0,0155	0,9845
13	0,0011	0,0011	0,0166	0,9834
14	0,0028	0,0027	0,0193	0,9807
15	0,0030	0,0030	0,0223	0,9777
16	0,0034	0,0033	0,0256	0,9744
17	0,0027	0,0026	0,0282	0,9718
18	0,0040	0,0039	0,0321	0,9679
19	0,0043	0,0042	0,0362	0,9638
20	0,0047	0,0045	0,0408	0,9592
21	0,0051	0,0049	0,0457	0,9543
22	0,0055	0,0053	0,0509	0,9491
23	0,0059	0,0056	0,0566	0,9434
24	0,0066	0,0062	0,0628	0,9372
25	0,0043	0,0041	0,0668	0,9332
26	0,0075	0,0070	0,0738	0,9262
27	0,0080	0,0074	0,0812	0,9188
28	0,0086	0,0079	0,0891	0,9109
29	0,0092	0,0084	0,0975	0,9025
30	0,0097	0,0088	0,1063	0,8937
31	0,0107	0,0096	0,1158	0,8842
32	0,0046	0,0041	0,1199	0,8801
33	0,0121	0,0107	0,1306	0,8694
34	0,0124	0,0108	0,1414	0,8586
35	0,0138	0,0118	0,1532	0,8468
36	0,0138	0,0117	0,1649	0,8351
37	0,0153	0,0127	0,1777	0,8223
38	0,0084	0,0069	0,1846	0,8154
39	0,0170	0,0139	0,1985	0,8015
40	0,0098	0,0079	0,2063	0,7937
41	0,0190	0,0151	0,2214	0,7786
42	0,0196	0,0153	0,2367	0,7633
43	0,0211	0,0161	0,2528	0,7472
44	0,0215	0,0161	0,2688	0,7312
45	0,0230	0,0168	0,2857	0,7143
46	0,0000	0,0000	0,2857	0,7143
47	0,0000	0,0000	0,2857	0,7143
48	0,0263	0,0188	0,3045	0,6955
49	0,0000	0,0000	0,3045	0,6955
50	0,0278	0,0193	0,3238	0,6762
51	0,0299	0,0202	0,3440	0,6560

Theoretical function of failure intensity of cable terminals is shown in figure 11.

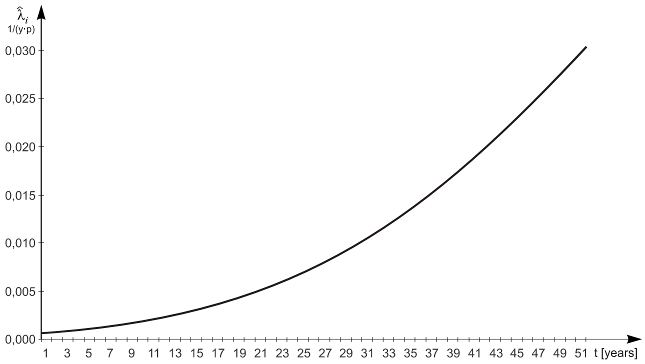

Fig. 11. Theoretical function of reliability $\lambda(t)$ of cable LV terminals

Distribution hypothesis was verified by a test of characters. Results of the performed test were as follows: $l_0 = \min(l^+, l^-) = \min(25,26) = 25$; $l_0 = 25 > 18 = l_\alpha$; $l_o \notin R_\alpha = (-\infty,18)$. Therefore, on a significance level of $\alpha = 0{,}05$, there are no grounds for rejecting the hypothesis of functional form of failure intensity distribution.

Using dependency between functions $R(t)$, $F(t)$ and $\lambda(t)$, reliability function can be written in the following form:

$$R(t) = 0{,}5023 - 1{,}0046 \cdot \Phi(0{,}0462 \cdot t - 2{,}6072) \quad (22)$$

whereas unreliability function can be written as follows:

$$F(t) = 0{,}4977 + 1{,}0046 \cdot \Phi(0{,}0462 \cdot t - 2{,}6072) \quad (23)$$

Theoretical functions $R(t)$ and $F(t)$ for cable terminals are shown in figure 12.

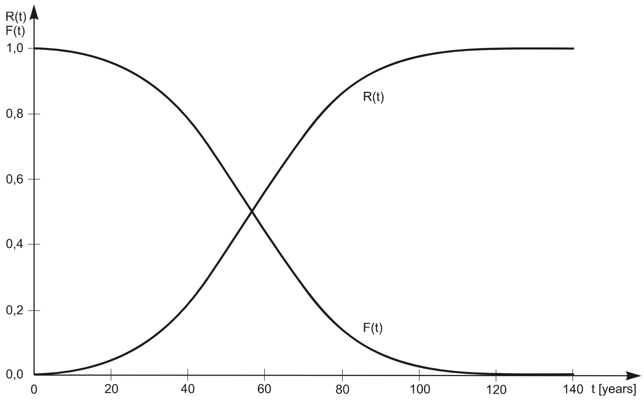

Fig. 12. Theoretical functions of reliability $R(t)$ and unreliability $F(t)$ for cable LV terminals

Expected value of correct operation of cable LV terminals is 56,42 years.

Summary

Electrical LV terminals are terminal elements of distribution networks. Their failure frequency directly influences continuity of power supply to recipients due to the fact that they are not usually subject to redundancy. Only plants with required increased supply reliability are equipped with several independent terminals. Therefore, it is important to constantly monitor their operation. Knowing the basic reliability functions enables to determine the terminal operation period in which, by high probability, it will operate correctly and will not cause power failures.

This article includes results of analysis concerning reliability functions of bare overhead, insulated overhead and cable electrical LV terminals. Overhead terminals are usually used in overhead networks and therefore are mostly typical to local area networks. Cable terminals are usually used in LV cable networks, but also increasingly often as a descent from the overhead network supporting structure.

Empirical intensity, reliability and unreliability functions have been determined for terminals. Intensity functions for all types of LV terminals indicate the increase of intensity in subsequent years of operation.

The article also includes theoretical courses of reliability functions. Theoretical distribution of failure intensity is a normal truncated distribution for all types of LV terminals. Determined functions can be used in many types of technical and economic analyzes, e.g. for the assessment of economically profitable period of terminal operation.

Expected time of proper operation was determined for low voltage terminals as well. It equals 50,53 for bare overhead terminals, 76,29 for insulated overhead terminals and 56,42 for cable terminals.

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