ENHANCING THE RELIABILITY OF RANGE-VERIFIED FERROMAGNETIC CURRENT TRANSFORMERS

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Abstract. *Increasing the reliability of range-adjustable ferromagnetic current transformers. During the test period, the failed FMTO' was not replaced with a new one. Total test period T0=200·103hours During this period, insulation of pipes, failure of their input and output parts, and changes in the working state of FMTO' 1- FMTO' failure intensity, upper limit, bilateral of 90% resource find and calculate reliability limit values.*

Keywords*: ferromagnetic current conductors, Exponential distribution law, values of lower and upper reliability limits, probability of operation without failure.*

We give examples of the calculation and comparative evaluation of the reliability indicators of the ferromagnetic current transformer proposed by us.

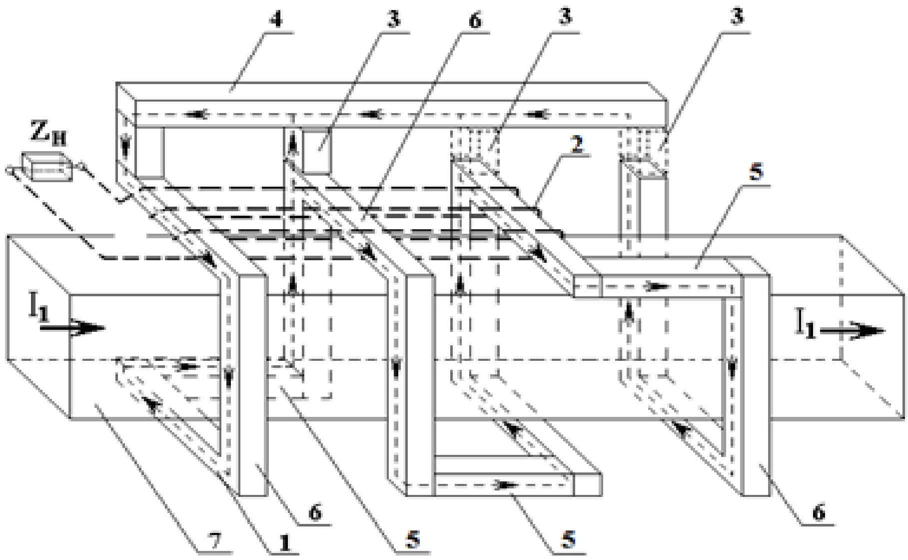

Figure 1. Range adjustable ferromagnetic current transformer..

We calculate the reliability indices for the three new (1st, 2nd, and 3rd) FMTOs presented in Figure 1 below.

The pilot studies conducted in 2020-2021 were carried out on the basis of GOST in agreement with the "Electrical Supply" department of "Uzbekistan Railways" JSC [42].

[N, U, T] tracking plan is selected, and the number of FMTOs is N=50. During the trial period, the failed FMTO was not replaced with a new one.

Total test period T0=200·103 hours. During this period, the insulation of pipes, failure of their input and output parts, and changes in the working condition of FMTOs were observed. Appropriate corrections were made to the output voltages of FMTOs taking into account the mathematical expectation M[u(t)] and dispersion D[u(t)].

FMTO that failed during the trial period was identified. Information on the terms of operation of FMTO according to the collected details is presented in Table 1 [1].

Table 1

1- FMTO's operating periods	80;82;94;98;101;140,3;142;170,4; 181,7;	$\sum t_i = 1472$
2. The terms of operation of the 2nd and 3rd FMTOs	51;78;93;101;103;111;121;127;130; 131;132;148;151;157;163;171;174; 178;180;182;193;195;197	$\sum t_i = 3267$

Based on GOST 17509-72, based on GOST 17509-72, we determine the values of the following parameters for the assembled elements of FMTO' in Fig. 2.7, taking into account the fact that the distribution of the lifetime of the FMTO in question is subject to the exponential law: $T_{o'r}$ - the average value of the lifetime of the FMTO; $P(t)$ - $t = 4 \cdot 10^5$ the possibility of working without a break during the hour; $\lambda(t)$ the intensity of failure; T_γ - $\gamma = 90$ gamma-percentage resources for. Taking into account that the exponential distribution is regular, we calculate the failure intensity of the 1st FMTO for the plan according to table 9 $[N, U, T]$ of GOST 17509-72 as follows:

$$\lambda_1 = \frac{d}{\sum_{i=1}^{d} t_i + (N-d)T_0} = \frac{2}{1472 + (50-2)\times 200\times 10^3} = 0{,}21 \cdot 10^{-6}\, soat^{-1}. \quad (1)$$

λ_1 the two-sided reliability limit values for $\beta = 0{,}9$ the reliability probability. $[N, U, T]$ according to Table 1 in the GOST 17509-72 appendix, we calculate the following for the plan:

lower limit:

$$\lambda_{1q} = \frac{\hat{\lambda} N \chi^2_{\frac{1-\beta}{2},2d}}{d\left(2N - d + \frac{1}{2}\chi^2{}_{\frac{1-\beta}{2},2d}\right)} = \frac{0{,}21\times 10^{-6}\times 50\times 5{,}45}{2\left(2\times 50 - 2 + \frac{1}{2}\times 5{,}45\right)} = 0{,}105 \cdot 10^{-6}\, soat^{-1}; \quad (2)$$

upper limit:

$$\lambda_{1\mathrm{yu}} = \frac{\hat{\lambda} N \chi^2_{\frac{1+\beta}{2},2d}}{d\left(2N - d + \frac{1}{2}\chi^2{}_{\frac{1+\beta}{2},2d}\right)} = \frac{0{,}21\times 10^{-6}\times 50\times 15{,}7}{2\left(2\times 50 - 2 + \frac{1}{2}\times 15{,}7\right)} =$$

$$= 0{,}78 \cdot 10^{-6}\, soat^{-1}, \quad (3)$$

found here $\chi^2{}_{\frac{1-\beta}{2},2d} = 5{,}45$ and $\chi^2{}_{\frac{1+\beta}{2},2d} = 15{,}7$ based on the data presented in [42].

As can be seen from the values λ of expressions λ_q and λ_{yu} the value of and lies between the values of

The average value of the FMTO's service life until it quits is calculated as follows:

$$T_{1o'r} = \frac{1}{\lambda} = \frac{1}{0{,}21\times 10^{-6}} = 4{,}76 \cdot 10^6 \text{ hour}. \quad (4)$$

The values of the lower and upper confidence limits of the average life of the FMTO until failure are, respectively, equal to:

$$T_{1o'r.q} = \frac{1}{\lambda_{yu}} = \frac{1}{0{,}78\times 10^{-6}} = 1{,}28 \cdot 10^6 \text{ hour}, \quad (5)$$

$$T_{1o'r.yu} = \frac{1}{\lambda_q} = \frac{1}{0{,}105\times 10^{-6}} = 9{,}52 \cdot 10^6 \text{ hour}. \quad (6)$$

The probability of operation of the FMTO without failure and its two-way reliability limit values are equal to the following:

$$P_1(t) = e^{-\lambda t} = e^{-0{,}21\cdot 10^{-6}\cdot 400\cdot 10^3} = 0{,}919\,, \quad (7)$$

$$P_1(t)_{yu} = e^{-\lambda_q t} = e^{-0{,}105\cdot 10^{-6}\cdot 400\cdot 10^3} = 0{,}958, \quad (8)$$

$$P_1(t)_q = e^{-\lambda_{yu} t} = e^{-0{,}78\cdot 10^{-6}\cdot 400\cdot 10^3} = 0{,}73. \quad (9)$$

90% resource for FMTO (g=90%) is determined as follows:

$$T_{1\gamma} = \frac{1}{\lambda}\left(-\ln\frac{\gamma}{100}\right) = \frac{1}{1{,}32\cdot10^{-6}}\left(-\ln\frac{90}{100}\right) = 79{,}8\cdot10^{6}\ \text{soat}, \qquad (10)$$

that is, 90% of the resource is less than $0{,}501 \cdot 10^6$ an hour for the 1st FMTO.

Two-sided confidence limits of the 90% resource are found as follows:

$$T_{1\gamma q} = \frac{1}{\lambda_{yu}}(-\ln 0{,}9) = \frac{1}{0{,}78\cdot10^{-6}}(-\ln 0{,}9) = 0{,}135\cdot10^{6}\ \text{hour}, \qquad (11)$$

$$T_{1\gamma yu} = \frac{1}{\lambda_q}(-\ln 0{,}9) = \frac{1}{0{,}642\cdot10^{-6}}(-\ln 0{,}9) = 1{,}03\cdot10^{6}\ \text{hour}. \qquad (12)$$

Now we present the results of calculating the values of reliability indicators for the 2nd and 3rd FMTOs using the above formulas:

$$\lambda_{2,3} = \frac{d}{\sum_{i=1}^{d} t_i + (N-d)L_0} = \frac{2}{3267+(50-2)200\cdot10^3} = 0{,}15\cdot10^{-6}\ soat^{-1}, \quad (13)$$

$$\lambda_{2,3q} = \frac{\lambda_{2,3} N \chi^2_{\frac{1-\beta}{2},2d}}{d(2N-d+\frac{1}{2}\chi^2_{\frac{1-\beta}{2},2d})} = \frac{0{,}15\cdot10^{-6}\cdot50\cdot5{,}45}{2(2\cdot50-2+\frac{1}{2}\cdot5{,}45)} = 0{,}083\cdot10^{-6}\ soat^{-1}, \quad (14)$$

$$\lambda_{2,3yu} = \frac{\lambda_{2,3} N \chi^2_{\frac{1-\beta}{2},2d}}{d(2N-d"+\frac{1}{2}\chi^2_{\frac{1+\beta}{2},2d})} = \frac{0{,}15\cdot10^{-6}\cdot50\cdot15{,}7}{2(2\times50-2+\frac{1}{2}\cdot15{,}7)} = 0{,}556\cdot10^{-6}\ soat^{-1}, \qquad (15)$$

$$T_{2,3o'r} = \frac{1}{0{,}15\cdot10^{-6}} = 6{,}67\cdot10^{6}\ \text{hour}, \qquad (16)$$

$$T_{2,3o'r.q} = \frac{1}{\lambda_{2,3yu}} = \frac{1}{0{,}556\cdot10^{-6}} = 1{,}798\cdot10^{6}\ \text{hour}, \qquad (17)$$

$$T_{2,3o'r.yu} = \frac{1}{\lambda_{2,3q}} = \frac{1}{0{,}083\cdot10^{-6}} = 12{,}048\cdot10^{6}\ \text{soat}, \qquad (18)$$

$$P_{2,3}(t) = e^{-\lambda_{2,3}t} = e^{-0{,}15\cdot10^{-6}\cdot400\cdot10^{3}} = 0{,}941, \qquad (19)$$

$$P_{2,3yu}(t) = e^{-\lambda_{2,3q}t} = e^{-0{,}083\cdot10^{-6}\cdot400\cdot10^{3}} = 0{,}967, \qquad (20)$$

$$P_{2,3q}(t) = e^{-\lambda_{2,3yu}t} = e^{-0{,}556\cdot10^{-6}\cdot400\cdot10^{3}} = 0{,}800, \qquad (21)$$

$$T_{2,3\gamma} = \frac{1}{\lambda_{2,3yu}}\left(-\ln\frac{\gamma}{100}\right) = \frac{1}{-0{,}15\times10^{-6}}\left(-\ln\frac{90}{100}\right) = 0{,}702\times10^{6}\ \text{soat}, \qquad (22)$$

$$T_{2,3\gamma yu} = \frac{1}{\lambda_{2,3yu}}\left(-\ln\frac{\gamma}{100}\right) = \frac{1}{0{,}053\cdot10^{-6}}\left(-\ln\frac{90}{100}\right) = 1{,}269\cdot10^{6}\ \text{soat}, \qquad (23)$$

$$T_{2,3\gamma q} = \frac{1}{\lambda_{2,3q}}\left(-\ln\frac{\gamma}{100}\right) = \frac{1}{0{,}556\cdot10^{-6}}\left(-\ln\frac{90}{100}\right) = 0{,}189\cdot10^{6}\ soat. \qquad (24)$$

The analysis of the reliability indicators of the considered new FMTOs shows that the probability of operation without failure of all three O'O's is higher than the level of demand imposed by the ABTs of TETQs, 1st and 2nd and 3rd It was determined that the difference in the reliability indicators of FMTOs is explained by the resource potential of the materials used in them and the difference in mechanical, thermal, electrical and magnetic properties.

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