**Probability-Based Reliability Assessment of Electric Power Transformers**

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**Abstract.** Reliability is the most important indicator of the quality of a traction transformer, which determines its trouble-free operation over a period of time. The concept of reliability of traction transformers is closely related to the concept of their durability and service life. The appearance of the probability of failure of traction transformers at a certain distance l is equal to. Through these formulas, it is possible to calculate the failure indicators of traction transformers at different times and the probabilities of reliable operation

**Keywords:** Traction transformer, failure rate, reliability, uptime, probability, mathematical expectation, variance

# Introduction

Reliability is the ability of traction transformers to keep running within specified limits, with the values of all parameters describing the ability to perform the necessary functions in certain modes and conditions of use, maintenance, repair, storage, and transportation. Reliability is a complex property that consists of a combination of properties depending on the purpose of traction transformers and the conditions of their use: reliability, durability, and stability.

Durability is the ability of traction transformers to maintain a healthy condition until the limit state occurs with a prescribed system of maintenance and repair.

Durability: maintaining the values of reliability, durability, and stability indicators during and after storage and transportation. The reliability index is a quantitative characteristic of one or more properties that make up the reliability of transformers [1, 2, 3, 5].

Probability of faultless operation: the probability that there will be no failure of transformers during a certain period of time.

Average time to first failure is the average value of time to first failure for a batch of traction transformers.

Failure rate is the probability of non-repairable torque transformers breaking down in a unit of time after a certain period of time if there is no breakdown for a certain period of time.

# Materials and Methods

Information was collected on the failures observed in traction transformers. The probability of faultless operation of the transformers is calculated based on the fact that they are in working condition at the beginning of the calculation of their lifetime.

The appearance of the probability of failure of transformers at a certain distance l is:

|  |  |
| --- | --- |
|  | (1) |

here is the probable distance of faultless operation of the transformers (before failure occurs); L is the random breakdown distance of the transformer.

Faultless operation of transformers and its failure are opposite phenomena, which form a complete group of phenomena. Therefore, we can write the probability of failure of transformers at a distance l as follows:

|  |  |
| --- | --- |
|  | (2) |

Formula (2) expresses the probability of failure of transformers.

We can also write the expression (2) in the following form [1, 2, 3, 4, 5]:

|  |  |
| --- | --- |
|  | (3) |

Taking into account the expression (3), the definitions included in the probability theory, we can come to the following conclusion:

q(l)=F(l)

here F(l) is the distance distribution function (integral law).

The following main indicators are used to determine the probability of faultless operation of traction transformers [5, 6, 7, 8]: distance until failure was observed (km); common faults observed in traction transformers; failure observed in torque transformers of suitable interval; number of intervals; limit of intervals*;* Failure rate; Average distance to failure; probability of fault-free operation; average distance of fault-free operation.

Time between intervals:

Average value of the interval:

probability of failure in interval i

Time to breakdown:

Mathematical expectation:

Statistical variance in the i-interval:

Mean square deviation:

Coefficient of variation:

# Results and Discussion

Indicators of observed failures in traction transformers at each interval :

Number of total failure:

Distance between intervals (thousand km):

Breakdown probabilities of traction transformers in each interval:

Average value of the interval:

Mathematical Expectation:

Statistical variance:

Mean square deviation:

Coefficient of variation

In statistical research, the following properties are often used: arithmetic mean squared error in determining mathematical expectation:

The mean squared error in calculating the mean squared deviation:

Rounding the deviation values, we get the following:

Taking the time between failures as a mathematical expectation, we can write its value as   
:

According to the exponential distribution law:

There are some differences between the curve of the theoretical distribution and the statistical distribution. However, it remains to be seen whether these inconsistencies are just due to chance with limited experimental data, or whether they are significant and due to the fact that the fitted curve does not fit the distribution data well. This can be determined using the Pearson correlation test:

here, k- number of statistical distribution intervals, k=6; number of traction transformer failure values in each interval; n- total number of failure values of traction transformers; - probability of failure of torque transformers in the i-th interval.

Breakdown probabilities of torque transformers in the interval :

Pearson's Eligibility Criteria:

The number of degrees of freedom of the distribution depends on R.

The number of degrees of freedom is equal to the number of intervals k divided by the number of independent   
S conditions depending on frequencies : R = k-S.

For the exponential distribution law of random quantity distribution, the number of connections is S = 2. Then we find that R = 6-2 = 4. According to literature data [4, 9], the probability is p=0.99 and the number of degrees of freedom is equal to for for the case where R=4.

The calculated value is equal to , so the hypothesis of exponential distribution and distortion is accepted.

We calculate the reliability of traction transformers at a distance of 1000, 2000, 3000 thosand km for the case where the breakdown speed .

The distribution function is exponential. According to the law of exponential distribution:

In that case:

|  |
| --- |
|  |

**FIGURE 1.** Probabilities of damage and faultless operation of traction transformers

Breakdown probabilities of traction transformers.

# Conclusion

According to the calculations given above, it was calculated that the average operating distance of traction transformers is , and the breakdown speed is equal to, as a result of which the possibilities of calculating the distortion indicators of traction transformers and the probabilities of reliable operation have been created.

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