**Estimations of the Residual Life of Electrical Wiring and Algorithm for its Determination**

Olimjon Toirov, Dmitriy Bystrov a), Mavlonkhon Ekhsonov

Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan

*a) Corresponding author:* [*dvbystrov58@gmail.com*](mailto:dvbystrov58@gmail.com)

**Abstract**. The issue of the assessment and forecasting of the electrical wiring residual resource in the operation on the agricultural objects is considered in the article. The authors propose solutions for increasing the electrical wiring sevice life, and also its technical condition preservation meeting the reliability and safety requirements.

**INTRODUCTION**

The development of the industrial sector, the specific conditions of operation and maintenance of electrical energy consumers pose a serious problem of meeting the continuously increasing requirements of production and infrastructure for the reliability and safety of operation of electrification and automation equipment. Violation of the reliability of the functioning of electrical equipment in the industrial sector of the economy leads to significant material losses due to numerous electrical equipment failures, loss of life, fires caused by electrical reasons, as well as deterioration of the environmental situation.

The dominant factor in the threat of man-made danger should be considered the critical wear and tear of electrical wiring and switching equipment. Currently, the technical condition of electrical installations (including electrical wiring) does not meet modern reliability and safety requirements (in more than 50% of all buildings, electrical wiring has reached its standard service life and must be completely replaced).

The presence of such facts requires solving the problem of ensuring the regulatory level of technogenic safety of electrical wiring in rural areas. In this regard, methods for predicting the residual life of electrical installations in buildings and the development of means of monitoring and diagnosing their technical condition become relevant. In accordance with [1-5], the residual resource is understood as the operating time of an object from the moment of monitoring its technical condition until its transition to a limiting or inoperable state .In relation to electrical wiring, the residual resource can be interpreted as a certain technical condition with a given probability for the upcoming time interval (1 year), during which the functionality of the electrical installation remains. As a basic concept, we will consider an approach based on the principle of “safety” [6-8], according to which diagnostics of the technical condition of electrical wiring can be carried out according to indicators (or parameters) that ensure its reliability and safety in accordance with current standards. In this case, the residual life of the electrical wiring can be assessed by a certain set of diagnostic parameters and indicators. We will assume that a diagnostic parameter can be quantified by measuring it, and a diagnostic indicator can only be assessed qualitatively due to the impossibility of measuring it.

The electrical wiring of a building may have a residual life not only before the expiration of its design service life, but also after it. Current standards and methods for calculating the service life of electrical wiring provide for ensuring reliability and reliability, wear resistance under the most unfavorable environmental conditions (high humidity, temperature fluctuations, etc.), electrical and thermal aging of insulation, mechanical stress, i.e. those factors that lead to premature degradation and failure of conductive and insulating parts of the wiring. The values ​​of the listed factors in reality, if the rules of operation of electrical installations are observed, may turn out to be less critical than the calculated values, which reduces the intensity of consumption of the reserves for electrical, thermal and mechanical strength, wear resistance, etc., thereby providing a reserve for the residual life of electrical wiring.

There are two approaches to assessing and predicting the residual life [9-11]. The first approach (deterministic) is used when the service life is less than the standard and the object is insignificantly damaged and allows one to obtain fairly accurate estimates of reliability indicators for a given function *f(t).*

**EXPEREMENTAL RESEARH**

The essence of the forecast in this case comes down to the fact that after certain periods of operation of the electrical wiring *t1, t2,...,* the maximum damage values ​​are measured (in general, represented by a set of diagnostic parameters *φ 1, φ2,..*.), then these dependencies are extrapolated to the maximum permissible damage value φmax. The form of the dependence *f(t)* can be obtained empirically and, under a number of assumptions, can be considered linear in the form *f(t)=φ0+a×t,* where *φ0* and a are constant values ​​under given conditions.

The second approach is used if the service life of the electrical wiring is close to the standard condition or there is significant damage to the insulation or current-carrying elements. In this case, a certain diagnostic of the technical condition is required, which makes it possible to obtain a more accurate forecast aimed at identifying additional reserve service life of the electrical wiring. To predict the resource, a statistical method based on probabilistic estimates can be used [12]. Thus, assessment and prediction of the residual life of electrical wiring can be carried out based on an analysis of its technical condition. One of the sources of obtaining data for predicting residual life is retrospective information. To determine reliability indicators (time between failures), special tests are required - resource or functional. The results of these tests are the main source of information for predicting reliability. Life tests of electrical wires under production conditions, as a rule, are not carried out. Therefore, reliability prediction can be based on the study of the physical processes of destruction of the insulation of product conductors by conducting functional tests of models and samples [13-15]. A less labor-intensive way is a statistical (not physical) approach, which is based on the collection of retrospective information on the reliability of the operating electrical wiring in existing electrical installations. The main indicators of the reliability of electrical products are the time between failures *T0*, the probability of failure-free operation *Q0(t)* and the failure flow parameter *λ(t):*

(1)

Estimates of electrical wiring reliability indicators should be calculated based on sets of random samples obtained experimentally.

We will assume that at some point in time tk there are *n(tk)* objects (electrical wiring) in operation. Then their total operating time will be

(2)

The sum of time between failures for *n(tk)* failures will be equal to

(3)

where *n(tk)* is the total number of failures. Statistically, the MTBF estimate (mathematical expectation) can be calculated as

(4)

**RESEARCH RESULTS**

Let's consider the expert assessment method, which is an integral part of engineering forecasting [16-19]. This method is usually used when there is a lack of retrospective information. In relation to solving the problem of resource assessment, we will consider electrical wiring as a certain set of constituent elements (conducting and insulating). For each element, the expert can determine the probable causes of failures [20-24]. The causes of failures should be divided into sudden (destructive), for example, insulation breakdown, electrical circuit break; gradual (wear) and functional (deviation of diagnostic parameters). For each cause, the expected probability of failure is indicated, based, for example, on four qualitative ratings: no failure (A), low (B), medium (C) and (D) high probability of failure. Processing the survey results involves assessing the numerical equivalents for each element and the electrical wiring as a whole. As a result of processing statistical data on the reliability of electrical wiring elements and numerical equivalents during expert assessment, an empirical relationship can be obtained that allows one to estimate the residual life of the product [25-28].

Let's present retrospective statistical information about electrical wiring failures in the form of time chronological series. Let us adopt the following computational procedure. The entire period of operation of the electrical wiring, starting from inclusion in the existing electrical installation (*t=0)* until the end of observation (*t=t*), is divided into K equal time interval is *Δt=const*. Each time value *tj=jΔt(j=1,2,…,n)* corresponds to random values ​​of the reliability indicator *yj*. In this case, statistical information is converted into a time series *yj(tj),* for which a predictive model is selected [29-32]. With a certain degree of assumption for the time series under study, it is possible to construct a linear model of the form

(5)

where l is the regression order; *ai*—weighting coefficients; *εi*–cumulative approximation coefficient.

By approximating the resulting model, a corresponding trend is constructed, by extrapolating which one can obtain a forecast of reliability indicators and estimate the residual life of the electrical wiring [33-37]. Numerous data indicate an unacceptably low level of technical condition of electrical wiring at industrial facilities.

A problematic situation has arisen when, on the one hand, electrical wiring under operating conditions is exposed to destructive factors and in some cases fails without exhausting its service life, and on the other hand, it is unknown which of the risk factors determines wear and defect, and, consequently, the service life of the electrical wiring of a particular facility. In this regard, it seems important to conduct experimental studies of the wear of the insulating and conductive parts of electrical wiring under the complex influence of the main destructive factors: humidity, temperature, electric field and aggressive environment, and to obtain on this basis mathematical models of aging and damage to electrical wiring of industrial facilities.

**CONCLUSIONS**

1. It has been established that existing methods for monitoring the technical condition of electrical wiring in buildings do not allow an objective assessment of its residual life, thereby making timely decisions to prevent the occurrence of breakdowns, accidents and fires.

2.The concept of residual life prediction proposed in the work allows us to develop and implement principles for diagnosing the technical condition of electrical wiring, which makes it possible to extend the life of its safe operation.

3.The implementation of this goal involves obtaining a multi-parameter model of the service life of electrical wiring depending on the complex of influencing risks, as well as the development of a methodology, algorithm and program for predicting wear and residual life of electrical wiring of objects.

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