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Analysis Of Factors Decreasing The Reliability Of Designing Rural Communication Networks

AkbarNormurodov[1]

[1]Researcher student Tashkent University of Information Technologies named after Muhammad al-Khwarizmi

Annotation.*The article presents the results of a statistical study to identify the main types of factors that reduce the reliability of the project during the operation of rural fiber-optic networks and the most frequent of them, as well as the likelihood of their recurrence.*

Keywords: *Rural telecommunication networks (RTN), network reliability, viability, availability factor, subscriber line, histogram, mathematical statistics and probability theory.*

Currently, in many countries, special attention is paid to ensuring high reliability of optical communication networks in rural areas, the introduction of new technologies in telecommunication networks.

At the same time, users are required to provide highly reliable broadband services over fiber-optic networks in accordance with established standards, for this, it is important to determine the factors that reduce the reliability of the design of optical networks at the location of the network, and to resolve issues related to the development of telecommunications infrastructure.

It is known that the subscriber units in RTN access networks are an important device, since they act as a transmitter/receiver.

Therefore, the design reliability factor (K_{AF} -availability factor) of the access network is set equal to 0.99999.

For example, in Russia, the criteria for the quality factor of telecommunications networks are ready the following values (Table 1) [1].

This is the basis for the continuous operation of renewable technical products, the decommissioning of the effect that is directly proportional to the total duration of this product in working condition.

Table 1Standards of preparation factor

Types of telecommunication networks	norm, not less
International and long distance telephone network	0,999
Regional telephone network	0,9995
Local telephone network	0,9999
Telegraph and telex network	0,9999
Data transmission networks	0,99

The transmission channel availability factor (K_{AF}) is used as an indicator of the reliability of transmission lines of a telecommunication network and is determined by the following expression:

$$K_{AF} = \frac{T_{PS}}{T_{PS} + \tau_{RT}}, \qquad (1.1)$$

here T_{XK} - RTNaverage operating time without rejection of the transmission channel; τ_{KT} -RTN average return time of the transmission channel to operating mode.

Based on the information provided, the availability factor - K_{AF} of the local telephone network must be at least 0.99999 [1.2], i.e., it is considered normal for any telecommunication network to refuse service within 52.6 minutes per year.

There are internal and external factors that do not allow maintaining network availability over a long period of time, and in rural areas, communication lines are usually hung on the base equipment. There are internal and external factors that negatively affect the stable operation of such communication lines. These factors are:

- swaying of the cable under the influence of the wind;

- interruptions in work due to medical disasters;

- mechanical damage to the communication line as a result of the fracture of tree branches;

- short circuits caused by lightning;

- deliberate harmful actions of people;

- rejection for station devices;

- marriage on connecting lines;

- failures in subscriber access networks;

- failures due to power outages.

The listed factors that reduce the efficiency of communication lines are rare in natural cases and have random features. At the same time, some factors that negatively affect sustainable operation are quickly eliminated by employees of local telecom operators and do not significantly reduce the reliability of the network.

One of the reasons that significantly affect the reliability of the RTN design is the power supply, frequent power outages. This is because in many residential areas, switching devices in call centers and subscriber devices connected via ETTH (Ethernet to the home) or PON (passive optical network) technologies may not have a backup power supply due to cost efficiency.

Therefore, the study used the following statistical distribution series to determine the number and duration of failures that occurred in a telecommunications channel during the year.

Table 2Model for determining the numerical statistical series of distribution

x- values of a random variable	ω -repeat value of a random variable	$\frac{\omega}{n}$
X_1	ω_1	$\frac{\omega_1}{n}$
X_2	ω_2	$\frac{\omega_2}{n}$
X_3	ω_3	$\frac{\omega_3}{n}$
.	.	.
.	.	.
.	.	.
X_m	ω_m	$\frac{\omega_m}{n}$

During the study, four arbitrary types of the factors listed above were selected, and data was generated on how many times they occurred during the year (Table 3), and a histogram based on these data was shown in Figure 1.

Table 3Types and number of failures occurring during the year on rural telecommunication lines

т/р	Type and number of failures	During a year												The number of failures during the year
		1	2	3	4	5	6	7	8	9	10	11	12	
1	In connecting lines	2	4	3	1	3	2	4	2	3	5	2	1	32
2	Maintenance personnel error	1	2	2	3	1	3	2	1	2	2	1	4	24
3	On transmitting or receiving devices	2	1	2	3	1	2	2	4	2	1	2	2	24
4	In the power grid	7	8	4	6	7	8	6	3	2	4	3	5	63
	Total:	13	17	14	17	17	21	21	18	18	22	19	24	143

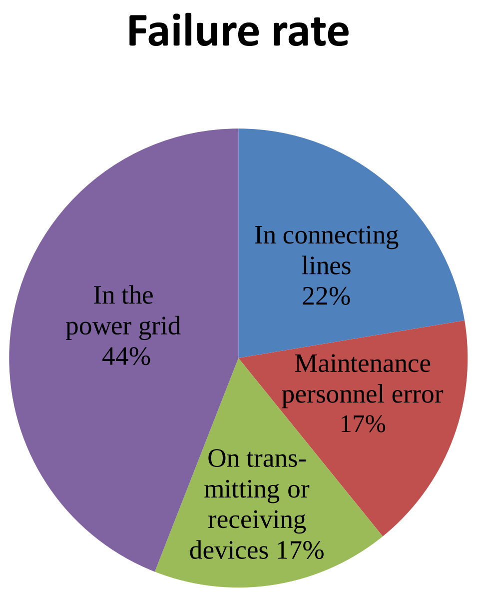

Figure 1. Types of failures occurring during the year and their contribution to the decrease in reliability

The generated statistical distribution series showed that power outages were the most frequent failures, and a study was made on the number and duration of such failures. For this, 3 districts from each region were initially selected and tracked, 3 settlements from each district. To analyze the results obtained, the methods of mathematical statistics and the theory of probability were used (by observing and studying entries in the maintenance logs) [4].

Based on the observations made in the study, it can be assumed that the number of outages (and the duration of each outage) in the supply of electricity to communication lines in residential areas can be determined.

As an example, we assume that a power outage to a communications center in a residential area occurs as shown in Table 4.

Table 4The number of interruptions in the supply of electricity from the power grid to the communication channel

Months	Number of power outages	Duration (hours)	The duration of the common interruptions (hours)
January	3	2,4,4	14
February	5	3,2,2,4,5	16
March	6	2,2,4,2,10,1	21
April	5	8,8,2,2,8	28
May	3	2,2,5	9
June	5	6,4,4,6,2	22

July	7	8,4,4,6,6,4,5	31
August	4	2,4,4,5	15
September	2	4,3	7
October	5	11,6,4,4,2	27
November	4	6,4,4,3	17
December	2	7,2	9
During a year	51		216

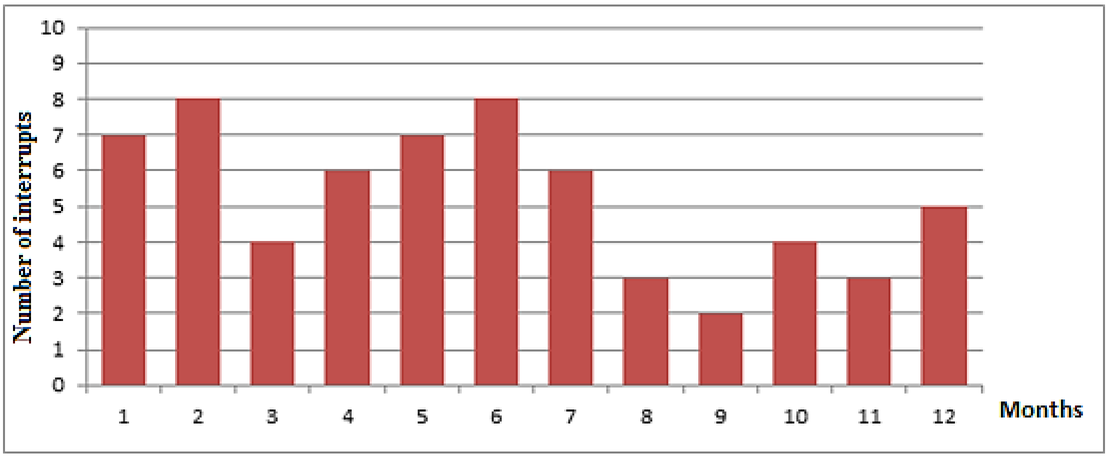

Figure 2. Histogram of power outages throughout the year

The following expression can be used to calculate the average probability of recurring power outages of a specified duration:

$$\bar{x} = \frac{\sum_{i=1}^{12} \omega \times \omega_i}{\sum_{i=1}^{12} \omega_i}$$

The likelihood of recurring power outages for a specified period of time during the year is shown in Table 5.

Table 5The likelihood of recurring power outages over time

Interruptions range	ω_i	ω_i / n
2-4	18	0,35
4-6	20	0,39
6-8	7	0,14
8-10	4	0,08
10 and more	2	0,04
During a year	51	1,00

ω_i -return frequency of values of a random variable;

n -number of interrupts.

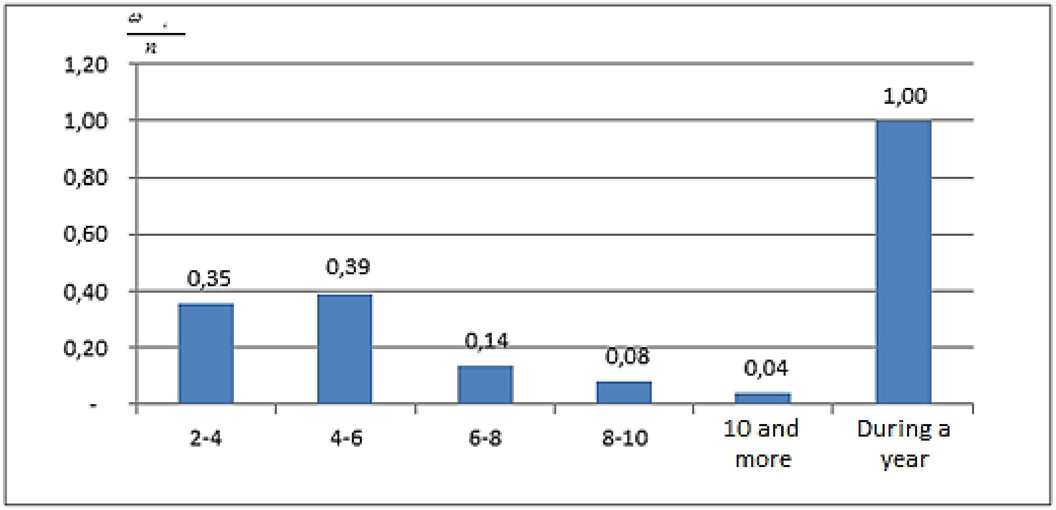

Figure 6. Histogram of power outages of certain duration

Based on the analyzed data, it can be concluded that the supply of electricity from the power grid to communication centers in rural areas may in some cases not meet the RTN reliability requirements.

Conclusion. According to the results of the study and analysis of the data obtained by the method of studying the elapsed time by registration and measurement, instead of the conclusion, the following should be noted:

1. The supply of electricity to communication centers in residential areas is problematic. Although this problem is being studied by scientists, not all of its problems have yet been fully disclosed. Power outages are very frequent and frequent, which in turn contributes to a significant decrease in the reliability of RTN.

2. In the development and radical modernization of the rural telecommunication network (RTN) with the help of new technologies, in any case, you must strictly adhere to the established criteria, and pay particular attention to a comprehensive theoretical and practical study of some of their features.

3. Conducting additional analyzes on the use of energy-saving technologies and cost optimization, training, retraining (andragogy) of specialists capable of managing production processes, servicing new technologies and systems used;

Due to frequent and prolonged power outages, it became necessary to provide ONT (Optical Network Unit) devices with an autonomous power source.

The analysis showed that to maintain the reliability of a rural optical communication network for a long time, timely implementation of comprehensive measures for the maintenance of fiber-optic cables resistant to external factors is required.

To ensure the design (required) reliability of rural fiber-optic networks, the following maintenance methods are recommended:

- preventive maintenance method, carried out at regular intervals or in accordance with specified criteria, aimed at timely prevention of malfunctions or the possibility of failure of a technical object;

- correction method (waiting for the completion of the deviation; in this case, the system partially works, the correction is performed after determining the location of the deviation);

- maintenance management method - carried out through the regular use of methods for monitoring the performance of facilities, quality management of transmission and analysis of the state of maintenance facilities using troubleshooting tools, and preventive work is carried out to minimize preventive maintenance and repair work [5].

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