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Optimization of Preventive Maintenance Characteristics of Rural Optical Telecomunication Network

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ABSTRACT: Methods for optimizing the frequency of preventive maintenance and the duration (volume) of maintenance of rural optical telecommunication networks.

KEYWORDS: rural telecommunication network (RTN), passive optical network(PON), preventive maintenance(PM), optimization.

I. INTRODUCTION

Currently in Uzbekistan, a very urgent task is the development of a rural telecommunications network (TCN). To solve this problem, modern and promising technologies should be used. The future rural TCS should provide all user requirements in relation to the services provided with the required quality and reliability.

II. RELATED WORK

In numerous publications (for example, in [1-4]) it was noted that the most suitable technology for the development of access networks in PON (Passive Optical Networks) technology. The implementation of these technology as applied to rural TCS is shown in this figure. Fig.1.

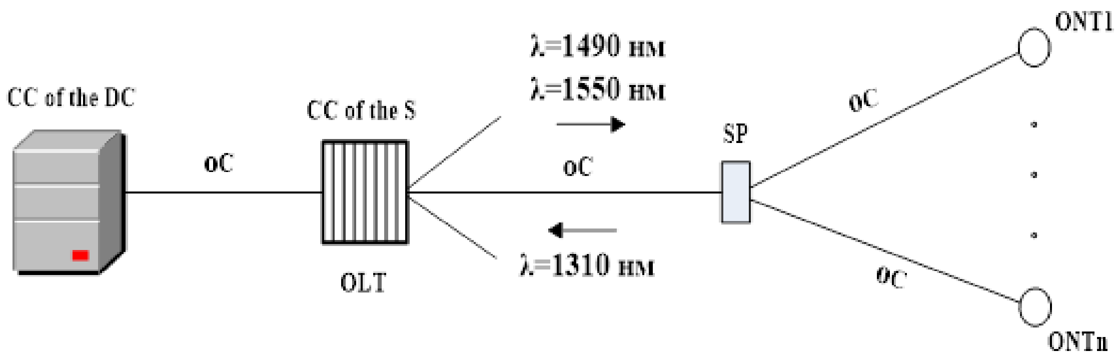

Fig.1. PON schematic fragment model of "tree" type.

In this figure, they mean: CC of the DC– communication center of the District Center, oC-optical cable, CC of the S- communication center of the settlement, OLT-optical Line Terminal (PON equipment in the automatic telephone exchange of the settlement), SP-splitter, ONT-Optical Network Transmination (subscriber unit), n-number of lines.

The PON structure consists of three main elements – OLT station equipment, passive optical splitters (SP) and ONT subscriber terminal. OLT privides interaction of the PON network with external networks, splitters carry out the branching of the optical signal at the subscriber terminals. ONT has the necessary interfaces for interaction from the subscriber side [4, 7-14].

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Distribution units are made in the form of optical cabinents (outdoor or indoor), or couplings, or canisters installed on pedestals outside. In distribution centers, as a rule, there is a cross-field of subscriber ports, where splitters are installed that multiply feeder fibers into a large number of subscriber ports. From the tap-off node to the subscriber, there is a tap-of cable ending in a subscriber optical socket to which the ONT is connected.

Cabinets or couplings installed on support with cross –over sockets inside or couplings with external sealed optical ports are used as distribution units. Feeder and distribution cables with external power cables are completely dielectric (with a glass pond as a power element).

As you know [6], under operating conditions, internal and external destabilizing factors can affect the RTN, which can lead to a deterioration in the RTN performance and a decrease in the quality of its functioning. In this regard to ensure the integrity and stability of the functioning of the RTN, certain requirements are established for it, in relation to reability. For RTN, technical standartshave been established for the value of the availability factor. This complex indicator is the main one for remanufactured technical product of continuous operation. For access networks, the rate of availability is 0,9999 [6]. This means that the duration of communication downtime per year should not exceed 52.6 minutes.

In this regard, the reliability of rural optical RTN should be ensured by comprehensive measures:

-during the development and manufacture of its elements,

-network building.

One of the main ways to ensure the design (required) reliability of the RTN during the operation period is its maintenance, which includes:

-a set of preventive works aimed at preventing failures (replacement of elements, fastening work, etc.);

-work related to the control of technical condition, the purpose of which is to check the compliance of the parameters characterizing the operable state of communication lines to the requirements of regulatory and technical documentation;

-supply with spare elements;

-collection and processing of data on refusals and their reasons;

-timely identification and elimination of failures and malfunctions;

-timely identification and elimination of the causes of malfunctions;

-organization of accounting and analysis of data on the reliability of network elements;

-providing optimal sets of spere parts and accessories (spare tools nad accessories),

Note [6], that when carrying out preventive maintenance, they face to conflicting requirements: on the one hand, for greater confidence is no troube-free peration of the optical transmission line (TL) of signals, it is advisable to carry out prevention more often, and on the other hand, taking into account economic requirements, the frequency and the labor intensity of prevention is advisable to minimize.

III. METHODOLOGY

Therefore, based on these conflicting requirements for the organization of preventive maintenance, it is necessary to look for a compromise solution, i.e. to determine the optical moment of prevention (T_{nopt}), at which, taking into account the specified restrictions on the reliability of the drug (TL), the coefficient of its use would also be within acceptable limits.

Thus, the task is redused to determining the optimal frequency (T_{nopt}) of T_{np} preventive maintenance.

As you know , during the operation of technical products (in our case, TL), there can basically two types of failures: the emergence of others is gradual. Usually, the distribution of the moments of occurrence of sudden failures (for example, in the case of an TL, a break in an optical cable) on the time axis is taken to be the simplest. It is customary to call the simplest such a flow of failures, which simultaneously possesses three properties: stationarity, ordinariness, and absence of aftereffect.

For the simplest flow of failures, the probability of occurrence of failures over a time interval is determined by Poisson formula (the low of rare phenomena)

$$P(n,t) = \frac{(\lambda t)e^{-\lambda t}}{ni} \quad (1)$$

where λ -failure rate.

Then the probability of failure – free operation of a technical product (TL) on a time interval t-will be equal to

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$$P(n=0,t)=e^{-\lambda t}. \quad (2)$$

A gradual failure is a failure characterized by a gradual change in the values of the TL parameters. As the practice of operating fiber-optic communication lines (FOCL) has shown, one of reasons for gradual failures during operation (as a result of the influence of various external factors) is the occurrence of cracks in the core of the optical fiber, which leads to a leakage of part of optical signal power. Therefore by monitoring the change in time in the magnitude of the optical signal power, it is possible to predict the moment of failure. There may be other ways to predict gradual failures, such as monitoring the appearance of cracks in the outer cladding of the fiber. Over time, these cracks extend to the fiber core

Now let us consider the methodology [6-14] for optimizing the frequency of maintenance T_n, i.e. time between two successive maintenance.

Note that with a reduction in the period T_n, the reliability of the RTN increases due to the timely implementation of measures to prevent failures. However, at the same time, the amount of prevention increases. It is necessary to find T_n, a value that provides the best ratio between the reliability of the RTN and the amount of preventive maintenance, that is, at which the utilization rate of the RTN will be the greatest[5-8].

The maximum utilization of transmission lines can be estimated using the utilization factor:

$$K_U=\frac{T_{\varepsilon p}}{T_E}=\frac{T_{\varepsilon p}}{T_{\varepsilon p}+\tau_{\varepsilon np}+\tau_{\varepsilon r}}, \quad (3)$$

Where $T_{\varepsilon p}$ -is the total time of the TL work during the using life.

- $\tau_{\varepsilon np}$ -total time of preventive TL drug control over time T_E.

- $\tau_{\varepsilon nr}$ -total TL recovery time over time T_E.

To determine the optimal value T_n, an expression linking the main maintenance criteria is used, T_n and τ_{np}. this expression is the efficiency of using the RTN.

$$P_{EU}=K_U P(T_n) \quad (4)$$

The efficiency of using the RTN is the probability that at any moment of operation it will be in working order (K_U) and that until the next maintenance, i.e. within a time T_n, she will not refuse to work $[P(T_n)]$.

If in (4) with substitute the expressions for the utilization factor (K_U) and the probability of no-failure operation, then we get

$$P_{EU}=\frac{T_{\varepsilon p}}{T_{\varepsilon p}+\tau_{\varepsilon np}+\tau_{\varepsilon r}}e^{-\lambda T_n}. \quad (5)$$

It is assumed, that the duration of the maintenance is τ_{np} constant and short compared to the frequency of maintenance, i.e. $\tau_{np}=const$, $\tau_{np}\prec\prec T_n$ and that the total recovery time of the RTN $\tau_{\varepsilon nr}$ depends only on the operation time T_E, and

$$T_E=T_{\varepsilon p}+\tau_{\varepsilon np}+\tau_{\varepsilon r}. \quad (6)$$

Therefore, for a given operating time $\tau_{\varepsilon e}=const$. Then taking into account the accepted assumptions.

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$$P_{EU} = \frac{T_Э - \tau_{\varepsilon np} - \tau_{\varepsilon r}}{T_E} e^{-\lambda T_n} = \frac{T_E \frac{T_E}{T_n}\tau_{np} - \tau_{\varepsilon r}}{T_E} e^{-\lambda T_n} = (1 - \frac{\tau_{np}}{T_n} - \frac{\tau_{\varepsilon r}}{TE})e^{-\lambda T_n}, \qquad (7)$$

where is $\frac{T_E}{T_n}$ the number of technical (preventive) services for the time T_E.

Now it is necessary T_n to find such a value at which the efficiency of using the RTN P_{EU}, will have the maximum value. Thus, the problem is reduced to finding the extremum of expression (7). The values T_n at which will P_{EU}, be the maximum, and will be the optimal value T_{n_r}.

Does expression (7) have a maximum?

To make sure of this, let us analyze the change in the factors of this expression with the change T_n. Under the assumptions made, the factor in parentheses is an increasing function T_n (due to the decrease of the first subtracted one).The second factor, i.e. $e^{-\lambda T_n}$ is a monotalically decreasing function T_n from 1 at to 0 at $T_n = \infty$ and final value of the failure rate. but for , i.e. if the RTN is continuously in service the efficiency of the RTN is zero, i.e, and the $P_{EU} = 0$ equality is equal to zero P_{EU} at $T_n = 0$ and $T_n = \infty$ assumes the existence of at least one of its maximum, which must be found by known methods.

We find the value T_n at which the derivative of expression (7) is equal to zero. It will be T_{nopt}. Derivative of expression (5)

$$P^1_{EU} = \frac{\tau_{np}}{T^2_{n\,opt}} e^{-\lambda T_{nopt}} - \lambda(1 - \frac{\tau_{np}}{T_{n\ opt}} - \frac{\tau_{\varepsilon r}}{T_E})e^{-\lambda T_{n\,Oopt}} = 0;$$

$$e^{-\lambda T_{n\,opt}}[\frac{\tau_{np}}{T^2_{n\,OPT}} - \lambda(1 - \frac{\tau_{np}}{T_{n\ OPT}} - \frac{\tau_{\varepsilon r}}{T_E}) = 0; \qquad (8)$$

If the product of to factors is zero, then at least one of them must be thero. But $e^{-\lambda T_n}$ it can be equal only for $T_n = \infty$, which is unacceptable. Therefore, we equate the second factor to zero, i.e

$$\frac{\tau_{np}}{T^2_{n\,OPT}} - \lambda(1 - \frac{\tau_{np}}{T_{n\ OPT}} - \frac{\tau_{\varepsilon r}}{T_E}) = 0; \qquad (9)$$

Further, by algebraic transformation from (7) we obtain a quadratic equation with respect to :

$$\lambda(T_E - \tau_{\varepsilon r})T^2_{n\,OPT} - \lambda\tau_{np}T_E T_{n\ OPT} - T_E\tau_{np} = 0 \qquad (10)$$

After calculation, we have

$$T_{n\ OPT} = \frac{\lambda\tau_{np}T_E \pm \sqrt{\lambda^2\tau^2_{np}T^2_E + 4\lambda(T_E - \tau_{\varepsilon r})T_E T_{np}}}{2\lambda(T_E - \tau_{\varepsilon r})}. \qquad (11)$$

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IV. RESULTS

Determination of the optimal duration (volume) of preventive maintenance: As noted, preventive maintenance (PM) is one type of maintenance. From the point of view PMS, a future of rural PON communication lines is that optical cables are suspended on the poles of the lighting network (if they are preserved) . in this regard, the installer has to climb onto the pole in case of doubt about the strength of the fastening of the optical cable, and this it's already taking a long time.

Our task is to determine PM the minimum duration of the RTN, at which the specified value of the probability of no failure operation would be provided. At the end of prevention. For the convenience of analysis, we will devide the rural RTN inton sections.

For example, using the given picture of the fragment model of the PON scheme of the "tree" type, we assume that the first section will be the OLT transceiver, the second is the line between the OLT and the SP (splitter), the tritium will be the SP, the fourth is the line between the SP and the ONT transceiver, fifth ONT subscriber device . Moreover each section has a known value for the failure rate λ_E. Suppose, that by the time the PM starts, the probability of failure operation of each section decreces to a value.

$$P_i = (T_n) = e^{-\lambda_i T_n} \prec 1, \quad (i = 1,2,3......n) \tag{12}$$

And for whole network

$$P(T_n) = \prod_{i=1}^{n} e^{-\lambda_i T_n} \prec 1, \ (i = 1,2,3......n) \tag{13}$$

Suppose, that as a result of PM, the probability of failure free operation due to PM

$$\Delta P_i = 1 - e^{-\lambda_i T_n}, \qquad (i = 1,2,3......n) \tag{14}$$

To meet the requirements of obtaining the maximum probability of failure free operation of the RTN with minimum time spend on PM, it is obviously advisible to serve only those network sections that give the maximum increase in the probability of failure free operation with minimum service time. To determine such areas of the RTN, the coefficient of expendiency of prevention of areas is introduced:

$$K_{Si} = \frac{\Delta Pi}{t_i}, \tag{15}$$

Where t_j time is the spend on PMS of the i-network section. The coefficient K_{Si} shows what an increase in the probability of no failure operation can be obtained for each section of the per RTN unit of service time. Thus have n, nK_{Si} coefficient P_T, at a given level of probability of failure free operation of which the RTN should have at the time of the end of preventive maintenance, it is possible to select those sections that are expendient P_T, to serve to obtain the given one. For this nK_{Si}, the coefficients $K \prec n$ with the greatest value are selected from. Substituting units in expression (13) instead of multipliers corresponding to the probanilities of failure free operation of the selected sections, the value $P(T_n)$.

If is $P \prec P_t$ calculated several more sections are included in the prevention , choosing them also by the value of coefficient K_{Si}.

Using the method of successive approximations , a list of those network sections is determined that it is advisible to subject to prevention in order to obtain the required value of the probability of failure free operation P_T, . If we assume that all sections of the network are serviced sequentially, then the total duratioin of the PMS can be obtained from the expression.

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$$\tau_{np} = \sum_{i=1}^{\kappa \leq n} t_i \tag{16}$$

This will be the optimal preventive maintenance time under the given conditions.

V. CONCLUSION

As a conclusion on this article, the following can be noted. The above techniques for optimizing the characteristics of maintenance, developed for electronic devices, can be used to optimize the characteristics of maintenance of rural optical telecommunication networks.

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