ABOUT OPTIMIZING OF LINES AND NETWORKS MAINTENANCE

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Abstract

The result of analysis of the issue having been done, there have been proposed the strategy and mathematical model of optimization of extended object maintenance characterized by the extent of resource recovery depth during the repair of lines and networks. The proposed mathematical model of maintenance optimization would allow to determine the optimal frequency of preventive capital repairs and replacement of lines and networks, as well as the optimal number of overhauls during the service life of extended objects at the given depth of resource recovery.

I. THE ESSENCE OF THE PROBLEM

Lines and networks for various purposes are considered to be extended objects which are the variety of similar type elements connected in series from the point of reliability. For example, these objects include the contact network of electrified sections, overhead and cable power lines, communications lines, data transfer networks in automated control systems and devices of automatics and remote control at railway transport. Identification, localization and recovery of damaged areas of lines and networks are the characteristic feature when there is failure of extended objects. We would imply a set of measures aimed at maintaining and restoring the valid state of objects and at the recovery of their resource by the term "maintenance" according to [1].

We will consider optimization of maintenance at the example of contact networks (CN). During the operation of CN there are done technical service (TS), current repairs (CR) and overhauls (O), as well as reconstruction which is equivalent to the preventive replacement [2,3].There is defined the technical state of CN only while performing the technical service through examinations, inspection, tests and measures [3]. According to [4] when doing CR there is only the performance recovery, but when doing O there is the recovery up to the certain level of object resource as well. Full recovery of object resource takes place while replacing.

At present in the theory of reliability [5,6] there have been developed the methodological issues of optimization of preventive replacements (PR) with emergency replacements (ER) or with minimum emergency repairs (MER) at failures. In the publications mentioned there have been considered only two extreme cases of the resource recovery depth: no update when MER is done and full update when ER or PR is performed. But they are the intermediate values of the resource recovery depth of devices within these two extreme cases which are of practical significance.

The purpose of the article is to propose and to study a mathematical model of maintenance optimization of extended objects characterized by the extent of the resource recovery depth.

II. STRATEGY AND MATHEMATICAL MODEL OF MAINTENANCE OPTIMIZATION

To account for the depth of resource recovery it is proposed to use the parameter a = Tpr - Tir according to [7] which means "age" of an object after performing the preventive overhaul. Tpr and Tir are pre-repair and inter-repair resource correspondently [7]. In the future, when developing mathematical models for maintenance optimizing to assess the resource recovery depth it is advisable to use the dimensionless parameter like α = a/Tpr. If α =0, it means that replacement has been done. If overhaul has been done, for example, in τ time, then "age" decreases from τ to α.τ.

Contact network is considered to be an extended object with many different connected in series elements from the point of reliability. In the process of troubleshooting there is restored only a separate damaged section of CN which, practically, would not modify the current reliability of the contact network as a whole. In this regard, we would consider the strategy of maintenance when failure is eliminated by minimum emergency repair, and after n of preventive overhauls the replacement of the contact networks is done.

The character of changes in the failure intensity (FI) connected with the operation life under this strategy is presented in Fig.1. After minimum emergency repairs the failure intensity is not changed. After overhaul repairs (OR) with x frequency and α as resource recovery depth FI is reduced to $\lambda(\alpha)$,and after PR with xp frequency – to zero level. FI is $\lambda(x+\alpha)$at the time of OR and PR. Here x and xp are measured in units of the resource.

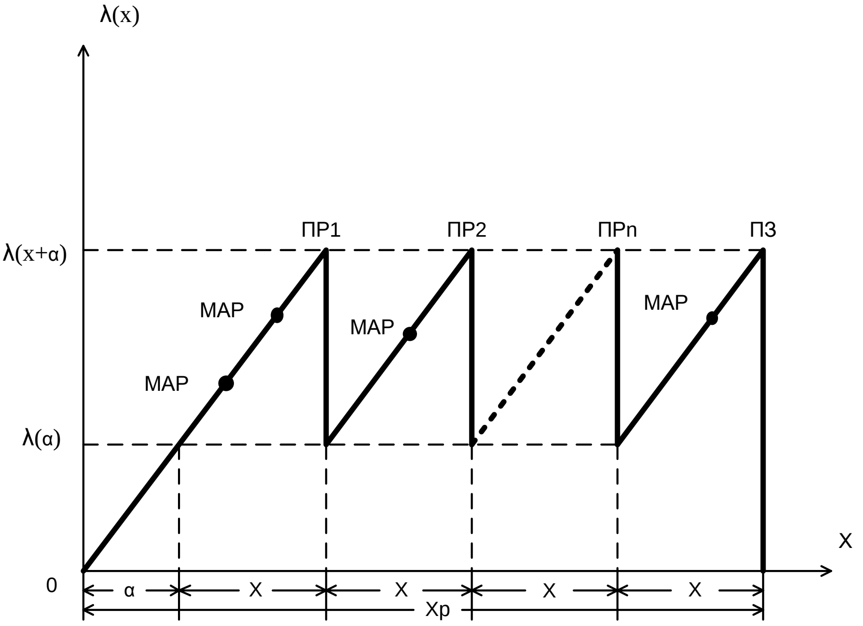

Figure 1. Change of failure intensity in preventive overhaul and replacement with minimum emergency repair

Mathematical model of maintenance optimization for extended objects under this strategy is defined from the expression

$$y = (1 + n\gamma) + \varepsilon \int_0^{x_p} \lambda(x)dx) \Big/ x_p \;, \tag{1}$$

where y is the relative specific operating costs;

γ is parameter of the cost of overhaul repair;

ε is parameter of the cost of minimum emergency repair;

λ is failure intensity;

The number of failures at the $0 - x_p$ interval is defined as

$$\int_0^{x_p} \lambda(x)dx = \int_0^{\alpha} \lambda(x)dx + (n+1)\int_{\alpha}^{x+\alpha} \lambda(x)dx = n\ln P(\alpha) - (n+1)\ln P(x+\alpha). \quad (2)$$

Here P is the probability of non-failure operation.

Substituting the values $\int_0^{x_p} \lambda(x)dx$ from (2) into (1) and given that $x_p = \alpha + (n+1)x$, we obtain the mathematical model as

$$y = \frac{1 + n\gamma + \varepsilon\big(n\ln P(\alpha) - (n+1)\ln P(x+\alpha)\big)}{\alpha + (n+1)x}, \quad (3)$$

Let us consider two particular cases of the model (3):

when $n = 0$ and $\alpha = 0$ (there are done only the replacements fully restoring the initial resource) we obtain the mathematical model as

$$y = {(1 - \varepsilon\ln P(x))}\big/{x},$$

which is known as the model of preventive replacements with minimum emergency repair at failure [5];

when $n \to \infty$ (there are done only overhauls) after the disclosure of the uncertainty in the expression (3), we obtain the mathematical model as

$$y = (\gamma - \varepsilon(\ln P(x+\alpha) - \ln P(\alpha)))\big/x,$$

which corresponds to the strategy of preventive overhauls with minimum emergency repair at failure [7].

Using the expression (3) with given values of n and α the optimal frequency of preventive overhaul x_0 and minimum specific operating costs y_0 could be defined from the condition $\partial y/\partial x = 0$ as

$$\big(\alpha + (n+1)x_0\big)\lambda(x_0+\alpha) + (n+1)\ln P(x_0+\alpha) - n\ln P(\alpha) = (1+n\gamma)\big/\varepsilon;$$

$$y_0 = \varepsilon\lambda(x_0+\alpha).$$

The frequency of overhaul could be defined from the expression

$$x = (x_p - \alpha)/(n+1). \quad (4)$$

Then

$$x + \alpha = (x_p + n\alpha)/(n+1). \quad (5)$$

Substituting the expressions obtained x and x +α from (4) and (5) into the expression (3), we transform it into the form

$$y = \left(1 + n\gamma + \varepsilon \left(n \ln P(\alpha) - (n+1) \ln P\left(\frac{x_p + n\alpha}{n+1} \right) \right) \right) \Big/ x_p \tag{6}$$

Using the expression (6) with given values of n and α the optimal frequency of preventive replacements x_p0 and minimum specific operating costs y_0 could be defined from the condition $\partial y / \partial x_p = 0$ as

$$x_{p0} \lambda \left(\frac{x_{p0} + n\alpha}{n+1} \right) + (n+1) \ln P\left(\frac{x_{p0} + n\alpha}{n+1} \right) - n \ln P(\alpha) = (1 + n\gamma) \big/ \varepsilon;$$

$$y_0 = \varepsilon \lambda \left(\frac{x_{p0} + n\alpha}{n+1} \right).$$

Using the expression (6) with given values of x_p and α the optimal number of overhauls n_0 could be defined from the condition $\partial y / \partial n = 0$ as

$$\frac{x_p - \alpha}{n_0 + 1} \lambda \left(\frac{x_p + n_0 \alpha}{n_0 + 1} \right) + \ln P\left(\frac{x_p + n_0 \alpha}{n_0 + 1} \right) - \ln P(\alpha) = \gamma \big/ \varepsilon \quad .$$

CONCLUSION

To take into account the depth of the resource recovery after overhaul it is advisable to use the parameter which is defined as the difference between pre-repair resource and inter-repair resource related to the pre-repair resource of an extended object.

The proposed mathematical model of maintenance optimization would allow to define the optimal frequency of preventive capital repairs and replacement of lines and networks, as well as the optimal number of overhauls during the service life of extended objects at the given depth of resource recovery.

Reference

[1] Set of federal standards (GOST) 32192-2013. Reliability in railway engineering. Basic concepts. Terms and definitions.

[2] STO RZD 1.12.001-2007. The devices foe electrification and power supply. Maintenance and repair. General requirements.

[3] Rules of construction and technical operation of the contact network of electrified railways. – M.: Transizdat, 2002. – 184p.

[4] Set of federal standards (GOST) 18322. The system of maintenance and repair. Terms and definitions.

[5] Barlow,R., Proshan,F. Mathematical theory of reliability. – M.: Soviet radio, 1961. – 488p.

[6] Beichelt, F., Franken P. Reliability and maintenance. The mathematical approach. – M.: Radio and communication, 1988. – 392p.

[7] Volodarsky V.A., Orlenko A.I. Recovery of the resource and strategies for maintenance of devices // Information management systems at railway transport. – 2015. - № 3. – P/73-77.