OPTIMAL DURATION EVALUATION OF PREVENTIVE MAINTENANCE AT A POWER EQUIPMENT BASED ON COSTS. APPROACHES IN ERP MAINTENANCE STRATEGY

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Abstract: In this paper we present some details of the economic foundation of technological facilities servicing activities within enterprises, to maintain continuity in their functioning. Periodic repairs can not be removed from the concern of companies, natural wear, aging of materials and qualitative impairment of others make necessary repairs within which to proceed to replace those parts, subassemblies and materials which naturally do not match. Such repairs are planned and known about them, especially there are many controversial opinions. For preventive maintenance approach is more of the decision and is required for everyone who wants a modern and efficient maintenance to keep in mind in comparison and analysis of several of them. For Maintenance work optimize be treated the ERP strategy - Eventual Replacement Policy - This method - consists in periodic time intervals to assess the operational status of a technical facility. If the presence of a degree of wears with strong growth trends, the manager will require a corrective – preventive maintenance works.

If verification confirms preventive equipment in good working condition, this operating system becomes available. The work has compared two modeling techniques: an exponential model, using the d'Asturia – Baldin method and a Weibull model, in this case Kelly chart method.

Keywords: maintenance, failure control

1. INTRODUCTION

Maintenance, defined as a set of activities aimed at maintaining the operational status of fixed assets at the nominal parameters and cost effectively throughout their lifetime, means:

- Planned repairs;
- Action of maintenance;
- Repair accidental;
- Behavior monitoring equipment in service;
- Providing spare parts and materials needed repairs and maintenance;
- Providing technical documentation for repairs and maintenance services (technologies, drawings, diagrams, etc.).
- upgrading equipment.

Periodic repairs can not be removed from the concern of companies, natural wear, aging of materials; others are qualitative impairment necessary repairs within which to proceed to replace those parts, subassemblies and materials which naturally do not match[1].

Such repairs are called planned and there are many opinions about them, especially controversial. Everything starts from the fact that a device that still works is closed for repair. From here, start discussions and controversies at the planned repairs. To eliminate the controversy should be flexible and appropriate criteria for planning[6].

For preventive maintenance approach is more of the decision and is required for everyone who wants a modern and efficient maintenance to keep in mind in comparison and analysis of several of them. One way to increase the efficiency of the operation is planning revisions to ensure renewal of the system before its failure. Moment's renewals prophylactic (preventive) is a strategy for renewal. We believe that preventive renewals system that completely eliminates wear and renewal itself, bringing the system into its initial state. If actual renewals are random events, preventive renewals can be random or deterministic, by the way they are designed strategies for renewal, so over the randomness of the actual overlap renewals renewal preventive strategy. Strategies may be periodic and non-renewal[4]. No periodic strategies are developed taking into account the age and overall system are random, while the magazines are deterministic. Design strategies for renewal shall be based upon criteria, resulting in an average cost of system maintenance per unit time. Most effective strategy for carrying out preventive renewal is renewal of the system when it is worn. This requires constant supervision system for timely detection of wear and strategy in this case strategy is called CRP (continuous replacement policy). If the system status can be known only by checks at discrete moments of time, so the system is regularly inspected TE period, renewal is performed only when there is wear its renewal strategy is called ERP (possibly replacement policy). For these strategies would be necessary knowledge of aging model (which is more difficult). However, reservation systems, the reliability function is a reserve jumps in moments of failure, such as wear increases sharply. This would correspond to the situation in which the renewal is made even if the system is not damaged but destroyed one or more reservations[5].

2. METHOD PRESENTATION

Method d 'Asturias - Baldin consists in solving the equation[1][4]:

$$e^{\lambda T} - \lambda T = 1 + \lambda \frac{c_p}{c_d} \tag{1}$$

Where: λ is the pace of equipment failures - [h-1]
T is the time interval between two consecutive preventive checks in [h]
c_p - cost of a preventive check - [monetary unit]
c_d -unit costs to remedy a fault condition [monetary units / unit time]

Building on Mac - Laurin series the member of equation (1) and retaining the first three terms - the next higher order is insignificant, it holds[4]:

$$1 + \frac{\lambda T}{1!} + \frac{\lambda^2 T^2}{2!} - \lambda T \cong 1 + \lambda \frac{c_p}{c_d} \tag{2}$$

Expression is deduced optimal time interval between two consecutive preventive checks:

$$T_0 = \sqrt{\frac{2}{\lambda} \cdot \frac{c_p}{c_d}} \tag{3}$$

For cost ratio c_p / c_d, French literature recommends a range indicative profile:

$$c_p/c_d \in [0{,}05 \ldots. 0{,}25] \tag{4}$$

3. NUMERICAL APPLICATIONS

In this section the authors resolving two applications types applying numerical methods mentioned[1][4][5].

3.1. Case I

Consider a 110 kV switch with reliability parameter, $\lambda = 0.36 \cdot 10^{-4}\ h^{-1}$, and a report is estimated to cost c_p / c_d = 0.20, c_p = 10 m.u, c_d = 50 m.u.

Obtain:

$$\mathbf{T_o} = \sqrt{\frac{2}{0{,}36 \cdot 10^{-4}} \cdot 0{,}20} \Rightarrow T_0 \cong 105\,\text{ore}$$

Average hourly cost of the practice of this ERP maintenance strategy is:

$$\gamma(T_0) = \frac{c_p - [1 - R(t)]c_d}{\int_0^{T_0} R(t)dt} \tag{5}$$

$$\text{or } \gamma(T_0) = \frac{c_p - [1 - R(T_0)]c_d}{\frac{1}{\lambda}[1 - R(T_0)]} \tag{6}$$

$$\text{and finally: } \gamma(T_0) = \frac{\lambda\{c_p - [1 - R(T_0)]c_d\}}{[1 - R(T_0)]} \tag{7}$$

Substituting the data of calculation results:

$$\gamma(T_0) = \frac{0{,}34 \cdot 10^{-4}[10 - (1 - e^{-0{,}36 \cdot 10^{-4} \cdot 105}) \cdot 50]}{1 - e^{-0{,}36 \cdot 10^{-4} \cdot 105}}$$

$\Rightarrow \gamma(T_0) \cong 0{,}09372$

And the asymptotic level is:

$$\gamma_\infty = \frac{c_p + c_d}{MTBF} \tag{8}$$

So: $\gamma_\infty = 0{,}00216$

Figure 1 represents the evolution of function γ (T).

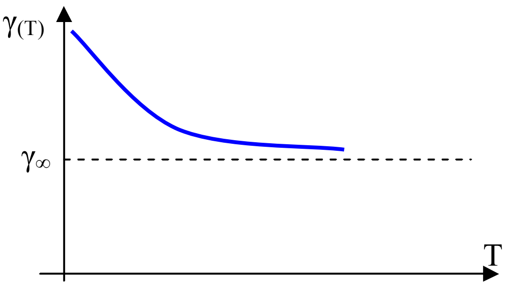

Fig.1 Diagram of function γ (T) - exponential model

Kelly recommended method for Weibull model requires knowledge of the reliability parameters β and η characteristics of the relationship[2][5][8]:

$$R = e^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{9}$$

γ parameter value is considered invalid. Optimal time interval between two preventive checks T_0 is derived from the relation:

$$T_0 = \chi \cdot \eta \tag{10}$$

Where χ is a quantity that is derived based on the parameter β obtained under the Weibull distribution and the ratio $\gamma = c_d / c_p$, based on Kelly diagram represented in Figure 2. In that the parameter η, it is obtained from the relationship:

$$\mathrm{MTBF} = \eta\Gamma\left(\frac{1}{\beta}+1\right) \tag{11}$$

Also, average hourly cost for Wibull model is obtained from the expression in simplified form:

$$\gamma(T) = \frac{c_p - [1-R(T)]c_d}{T} \tag{12}$$

$$\text{and } \gamma_\infty = \frac{c_p + c_d}{T} \tag{13}$$

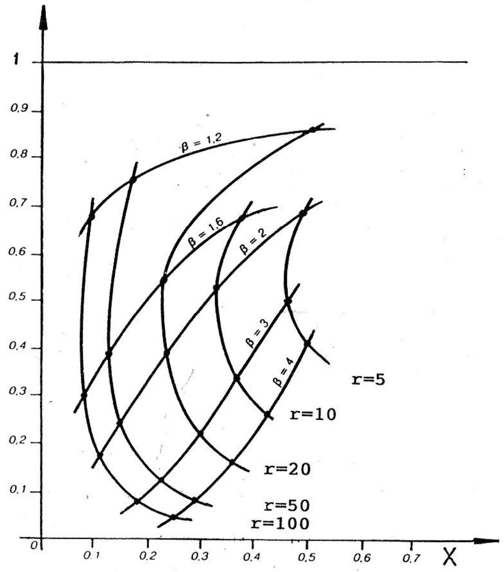

Fig. 2 Kelly diagram

Values of function $\Gamma\left(\frac{1}{\beta}+1\right)$ are given in Table 1

Tab.1 Values of function $\Gamma(1/\beta+1)$

β	$\sigma\left(\frac{1}{\beta}+1\right)$	β	$\sigma\left(\frac{1}{\beta}+1\right)$
0,2	120,0000	2,2	0,8856
0,3	9,2605	2,3	0,8859
0,4	3,3233	2,4	0,8865
0,5	2,0000	2,5	0,8873
0,6	1,5046	2,6	0,8882
0,7	1,2658	2,7	0,8893
0,8	1,1330	2,8	0,8905
0,9	1,0522	2,9	0,8917
1,0	1,0000	3,0	0,8930
1,1	0,9649	3,1	0,8943
1,2	0,9407	3,2	0,8957
1,3	0,9236	3,3	0,8970
1,4	0,9114	3,4	0,8984
1,5	0,9027	3,5	0,8997
1,6	0,8966	3,6	0,9011
1,7	0,8922	3,7	0,9025
1,8	0,8893	3,8	0,9038
1,9	0,8874	3,9	0,9051
2,0	0,8862	4,0	0,9064
2,1	0,8857	*	*

Figure 2 shows the graph of function γ (T) for this model.

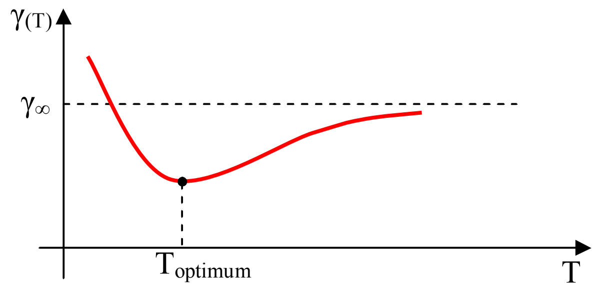

Fig. 3 Graph of function γ (T) - Weibull model

3.2 Case II

Consider a power equipment with the following known parameters:

MTBF = 1500 h

β = 1,6

Follows size χ depending by β and $c_d/c_p = 20$

$\chi \cong 0{,}233$

and the parameter η is obtained from equation (11) and Table 2:

$$\Gamma\left(\frac{1}{1{,}6}+1\right) = 0{,}8966$$

$$\eta = \frac{1500}{0{,}8966} \Rightarrow \eta \cong 1673\ [\mathrm{h}]$$

Optimal value of time T_o is deduced, according to the relation (10)

$$T_o = 0{,}233 \cdot 1673 \Rightarrow 390\ [\mathrm{h}]$$

Let c_p = 200 m.u and c_d = 400 m.u to obtain the report γ = 20, used previously (m.u = monetary units).

Average hourly cost will be (equation 12):

$$\gamma(T_0) = \frac{c_p + \left[1 - e^{-\left(\frac{T_0}{\eta}\right)^\beta}\right]c_d}{T_0}$$

or

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$$\gamma(T_0)=\frac{200+\left[1-e^{-\left(\frac{390}{1673}\right)^{1,6}}\right]4000}{390}$$

$\Rightarrow$ $\gamma(T_0)$ = 1,46307 [m.u./h];

Computing the function γ (T) near the optimum of considered function, the values obtained are:

$\gamma(T = 380h)$ = 1,46442 [m.u./h];

$\gamma(T = 400h)$ = 1,46360 [m.u./h];

Simplified value of this function is derived from equation (13):

$$\gamma_{\infty}=\frac{200+400}{T}\ \text{[m.u./h]}$$

4. CONCLUSIONS

The models presented enable the decision-maker to determine the optimal solution for conducting periodic inspections as exponential or Weibull behavior of the machinery concerned. Minimize costs due to ERP implementation strategy is the key criterion in resolving a wide range of specific issues of preventive maintenance. The time between two checks and preventive checks linked to the costs of repairs worn. The wear rate depends on the durations of interruptions to fix failures.

Average hourly cost of verifying the value of prevention depends on proper functioning of equipment time (MTBF) and the total cost of preventive checks and remedy failures price.

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