OPTIMIZATION OF PLANNING REPAIR SERVICES FOR POWER LINES

Sergey CHEKMARYOV
Russian Federation
econ@peipk.spb.ru

The urgency of the need to optimize the planning process in relation to the repair servicing of electric power networks is due to the high degree of assets wear distribution networks companies have, and it is also due to the limited size of financial resources of these companies. While looking for an optimum solution, it is necessary to consider both the issue of faultless equipment operation, and that of the economic aspects of repair activities. In order to be able execute the modeling of the repair service process, this article contains proposals aimed at using the method of dynamic programming, as the most effective one for the quantitative solution of the current problem.

Let us examine a technological system incorporating a number of component parts, for example, some sections of a power transmission line. In case any isolated failures should take place in its different parts, then the probability that the entire system will run without faults can be defined by the following expression:

$$g = \prod_{i=1}^{m} g_i$$

where g_i is the probability of the faultless operation of its i_{th} part.

In order to contribute to the faultless operation of the said system, repair works of different scope can be carried out on the individual parts of the said system. Let us designate the kind of repairs to be undertaken on the i_{th} part of the system with the symbol x_i.

In such a case, the aggregate cost (i.e., the budget) of repairs in a network company cannot exceed the value S.

In order to be able to solve the said problem, it is necessary to gather information on the faultless operation level $g_i(x_i)$ and on the cost of repairs $c_i(x_i)$ of the i_{th} part of the system.

It is necessary to determine the optimum kinds of repairs for every individual part x_{iopt} that could secure a maximum degree of system faultless operation, with the following limitation being observed:

$$\sum_{i=1}^{3} c_i(x_i^{onm}) \le S$$

The algorithm for solving this problem includes two stages: the first stage represents a stepwise optimization of repair activities for every section of the said technological system. At the second stage, the results of the said step-by-step optimization are to be analyzed.

The first stage incorporates the following:

1. The number of steps has to be determined. The number of steps m is equal to the number of system parts where repair works are to be carried out.

2. The conditions of the system have to be determined. The state of the system at each step is characterized by the amount of funds s_i, that is available before a specific step is taken, $s_i \le S$.

3. Selection of step controlling tools. The controlling element at the i_{th} step is the kind of repairs xi, $i=\overline{1,m}$, that was carried out in the i_{th} part of the system.
4. The function of gain at the i_{th} step $g_i(s_i)$ is the probability of the faultless operation of the i_{th} part, when carrying out the x_i - type repairs:

$$W(S) = \max \prod_{i=1}^{m} g_i(s_i)$$

Consequently, this particular problem can be solved by the method of dynamic programming.

5. The function of transition into a new state has to be determined:
$s_{i+1} = s_i - c_i(x_i)$.
Therefore, if at the moment of the i_{th} step the system was in the s_i state, and when the controlling tool x_i was chosen, then at the $i+1$ step the system will be in the $s_i – c(x_i)$ condition. In other words, if funds in the amount equal to s_i are available, then the amount of $s_i – c(x_i)$ will remain available for a later use.

6. Now, a functional equation for the last step $i=m$ is to be made up:

$$W_m(S) = \max g_m(S), \; x_m(S) = S.$$

At the last step, i. e., before making repairs on the last section, a conditionally optimum control will correspond to the amount of funds that are available; i. e., the amount of funds that still remain can be put into the last part. The conditionally optimum gain will be equal to the probability of the faultless operation of the last part of the system $W_m(S)$.

7. The main functional equation has to be made up now:

$$W_i(s_i) = \max_{x \le s} \{ g_i(x_i) W_{i+1}(s_i - c_i(x_i)) \}$$

This equation signifies the following: let it be so that prior to the i_{th} step the company in question has at its disposal the

remainder of the funds in the amount equal to s_i. Then the amount $c_i(x_i)$ it can use to carry out the x_i kind of repairs, and then it will achieve the faultless operation of the i_{th} part of the system $g_i(s_i)$, the remainder $s_i - c_i(x_i)$ it can use to repair the remaining parts of the system, starting from the $i+1$ to the m_{th} part. The conditionally optimum gain from the repair activities being carried is $W_{i+1}(s_i - c_i(x_i))$. The conditional controlling tool x_i, under which the multiplication products $g_i(x_i)$ and $W_{i+1}(s_i - c_i(x_i))$ are of a maximum value, will become the optimum one.
An absolutely optimum solution at the first stage was achieved for the last step only, this is why the final strategy of making the required repairs at every single part out of three can only be obtained for the **second stage,** i.e., at the stage of analyzing the results of the step-by-step optimization.

A conditionally optimum solution for the last step x_{1opt} is to be determined. The amount of funds that is subject to distribution between all the previous steps will be equal to $s_2 = S - c(x_{1onm})$. Then for s_2 an optimum kind of repairs can be obtained in the second interval x_{2opt}. This means that the condition $s_3 = S - \left\{ c(x_{1onm}) + c(x_{2onm}) \right\}$. Finally, for s_3 we shall get an optimum kind of repairs for the third part x_{3opt}.

In the final analysis, the optimum strategy of making repairs will look as follows: $Xopt=\{x_{1opt};x_{2opt};x_{3opt}\}$. An optimum sort of probability of the faultless system operation, which was found at the last step, then is equal to $W(S)$. The aggregate costs and the costs per interval make up: S; $c_1(x_{1opt})$; $c_2(x_{2opt})$; $c_3(x_{3opt})$, accordingly. The probability of faultless operation of the system parts is $g_1(x_{1opt})$; $g_2(x_{2opt})$; $g_3(x_{3opt})$.