A New Algorithm of Optimizing Maintenance Cycle by Using RCM Methodology

JAN GALA
Department of Applied Mathematics
VŠB – Technical University of Ostrava
17. listopadu 15, 708 33, Ostrava-Poruba
CZECH REPUBLIC

Abstract: - The paper studies utilize of RCM strategy according an optimal maintenance cycle for a distribution and transformer substation - DTS. The objective of this maintenance is decrease of the costs operation, keep inevitable level of the reliability, safety and discretion on living environment so that standing time of maintenance of the operation facilities have been reduced or stand on. There are new algorithms in the paper for determination of an optimal maintenance cycle of DTS by analyzed from databases delivered from the distribution company, creation of the computational procedures for RCM software and the first pieces of knowledge from the implementation of RCM to the system operation.

Key-Words: - DTS, unplanned outage, importance, credits, optimal maintenance, RCM

1 Introduction

At the Faculty of electrical Engineering and Computer Science at VŠB – Technical University of Ostrava we have already been concerned with the development of a methodology for reliability centred maintenance (RCM) for some years. RCM strategy has two access of calculate: the optimum maintenance cycle for the group of items of equipment, or the order of items of equipment according to importance and condition. This contribution describes the methodology of calculate for optimizing maintenance cycle of DTS (Distribution and Transformer Station) with a new software support [4]. Our main objective is its practical utilizations and inclusion into the system of maintenance of the electrical power company. Because the RCM system utilizes has many information sources and will optimize the maintenance of several thousand components, it is necessary to design a software tool for processing just the same amount of data.

2 Determination of an importance of DTS

For determination of the importance of DTS you need to use equation (1) by which means the number of credits is assigned. This states the importance of the given DTS. With such determined importance by all DTS it is possible to divide individual DTS into groups according to their importance. Optimal maintenance cycle of DTS groups is set for every separate group by applying the cost equation (2) below [1].

The importance of DTS depends on the number and structure of consumers fed from DTS and power consumption. We consider three types of customers based on the power consumption: MOO – small scale customers (residential), MOP – small scale customers (commercial), VO – large scale customers.

$$\begin{aligned} Credits = (N_{MOO} \cdot k_{MOO} + N_{MOP} \cdot k_{MOP} + N_{VO} \cdot k_{VO}) \cdot T + \\ + P \cdot k_P \quad (-) \end{aligned} \tag{1}$$

N_{MOO} number of MOO customers connected to DTS(-),
N_{MOP} number of MOP customers connected to DTS (-),
N_{VO} number of VO customers connected to DTS (-),
k_{MOO} coefficient MOO customers with valuation 1 (-),
k_{MOP} coefficient MOP customers with valuation 5 (-),
k_{VO} coefficient VO customers with valuation 50 (-),
k_P weighted coefficient of load (-),
P proportional load of DTS (-),
T type of DTS; 2 for kiosk and walled, 1 for the others (-).

Since there aren't all consumption data currently available for all DTS, for proper calculation P is considered at zero and thereby the conditions for all DTS remain the same. Later it will be decided whether it will be at the average load of DTS or its maximum value. By the ration k_p the rate of load of DTS in credit mark of DTS importance that can be influenced by the equation. i.e. the increase of k_p lays greater stress on DTS. The DTS facilities were divided into three groups according to number of credits, Table 1. Each of the groups has own unchanging interval of credits.

A	B	C
Credits > 500	500> Credits >= 50	50 > Credits >=0

Table 1. Credits intervals for groups according to the importance

There is the upper limit of 3000 credits that is considered in the Fig.1. There are DTS with much higher number of credits than 3000 in the DTS credit spectrum, however, there aren't more than ten in comparison to other ones, the number of which is approximately 140 times higher. The upper limit of 3000 credits has been chosen for DTS for the appropriate layout of importance in group A. In the overall spectrum of DTS there is a particular number of DTS with a high level of importance and in the "break point" there is an interval limit between group A and group B set. This limit is at the value of 500 credits.
The second limit between group B and group C (see red line in Fig.1) is purposely set at the value of 50 credits in order to prevent the presence of VO consumption automatically, since these consumptions can be perceived as those of greater importance. The equation (1) confirms the meeting of the condition. From this relation it is obvious that it was undesirable that the upper limit of credits in group C would be more than 50 and at the same time it is pointless to set the value under 50, since by doing that there would be facilities with lower importance in a group of DTS facilities with higher importance, which is undesirable as well.

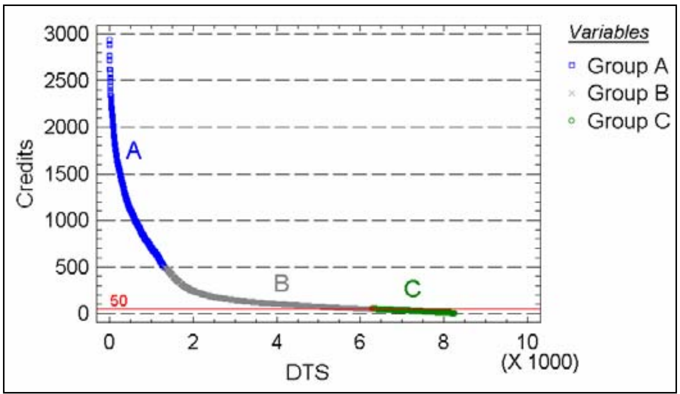

Fig. 1 Layout of credit points of DTS

There are all individual DTS on horizontal axis. Each of all DTS has his number: 1 till 8 288.

3 RCM System

The equation (2) describes the sum of individual costs in a particular period (one year) in dependence on the maintenance rate. The input value is the financial database of maintenance costs and the DTS reparation in the previously observed period. This database is supplied by a power distribution company. The result is a curve, the local minimum of which determines the optimal DTS maintenance cycle. There is the basic RCM equation where "Kc" is Czech shortcut for Czech currency.

$$N_C = N_U + N_O + N_V + S \qquad (Kc \cdot year^{-1}) \qquad (2)$$

N_C the total costs (Kc.year $^{-1}$),
N_U the maintenance costs (Kc.year $^{-1}$),
N_O the repair costs (Kc.year $^{-1}$),
N_V the failure costs (Kc.year $^{-1}$),
S sanctions (Kc.year $^{-1}$).

3.1 The maintenance and repair costs

The costs for periodic maintenance during a season are given by multiplication of maintenance rate and costs of maintenance for one DTS. The maintenance costs for one DTS can be determined as the rate of overall DTS maintenance costs to the number of DTS, which were maintained in the previous period. The costs for the reparation of DTS during a season are set by the multiplication of reparation rate and reparation costs for one DTS.

3.2 The failure costs

The costs for outage of DTS can be divided into two items. Costs for an unplanned outage – these are unexpected DTS outages (atmospheric influence, third party faults, rodents, humidity) and costs of maintenance idle time – due to a planned facility discontinuation (maintenance, check, reparation). The main difference between the calculation of price for power undelivered due to an unplanned outage and power undelivered due to maintenance lies in a financial assessment of such energy. It is expected that the price for undelivered power due to an unplanned outage will be much higher than by a maintenance discontinuation. This idea comes from the presumption of unreadiness of all consumers for a power outage by unplanned outages in comparison to previously announced maintenance outages the consumers can get ready for, e.g. by preparing back-up power resource and thereby minimize the loss caused by unplanned power non-delivery.

Costs for an unplanned outage

$$N_{NV} = V_x \cdot (N_{P1} + \lambda_p \cdot N_{P2} \cdot P \cdot T_V) \qquad (Kc \cdot year^{-1}) \qquad (3)$$

Price for power undelivered due to an unplanned outage

$$N_{P2} = N_{UP2} \cdot k_{ned} \qquad (Kc \cdot MWh^{-1}) \qquad (4)$$

Costs of maintenance idle time

$$N_{PV} = \lambda_U \cdot (N_{PU1} + N_{PU2} \cdot P \cdot T_U) \qquad (Kc \cdot year^{-1}) \qquad (5)$$

V_x importance of the groups (-),
N_{P1} constant costs for unplanned outage (Kc),
N_{PU1} constant costs for maintenance idle time (Kc),
P average load of DTS (MW),
T_V average value of unplanned outage (h),
T_U average value of maintenance idle time (h),
N_{PU2} price for power undelivered due to maintenance idle time ($Kc.MW^{-1}.h^{-1}$),
k_{ned} coefficient for power undelivered due to unplanned outage (-),
λ_P corrected rate of outage ($year^{-1}$),
λ_U maintenance rate ($year^{-1}$).

The ratio of k_{ned} determines the multiplication of price for undelivered electricity as a result of maintenance discontinuation of a facility. It applies the price of undelivered electricity due to the unplanned outage according to equation (4), which has a direct influence on optimal maintenance cycle of the facility. There is such value ration k_{ned} so that the optimal maintenance cycle of the facility in the most important group would be, according to an agreement with the distribution system operator, 4 years. The result of ratio V_X is a decrease of maintenance cycle by increasing price of electricity. The maintenance cycle of DTS group is, therefore, shorter and the maintenance is the more frequent, the greater the importance of DTS group. The value of this ration varies for each individual DTS group, the maximum value is, however, 1. This is possible in case of one DTS group being present only.

3.3 Sanction

There are sanctions into the equation (2) but we do not calculate with them in present time because there aren't one state into the Czech edict No. 306 of Czech power energy institute.

3.4 The parameters need for drawing of results curves of RCM equation

If we want to find an optimal maintenance cycle, we must know next importance values for calculate procedure and drawing of resulting curves. There are: inborn rate of failure, price of energy, average value of energy import, average value of failure time duration, average value of standing time duration.

4 The results of RCM application

There are resulting curves of the equation (2) for group A – Fig.2.

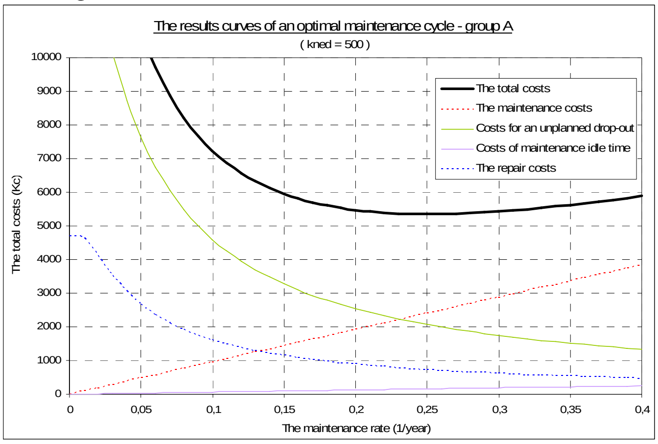

Fig. 2 The curves necessary for the optimizing of maintenance cycle - e.g. for group A, k_{ned} = 500

There are results of RCM application for all groups on Fig.3. There are resulting curves of an optimal maintenance cycle of DTS and each of them has the local minimum. The point of local minimum corresponds to the optimal maintenance cycle [3].

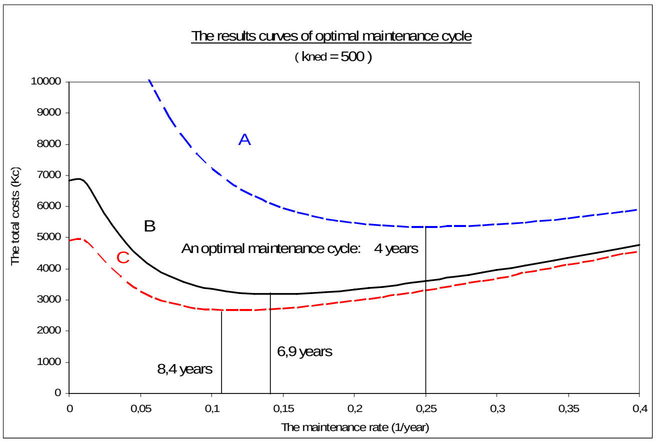

Fig. 3 Confrontation of the resulting optimized maintenance cycles for all groups of DTS, k_{ned} = 500

5 The software for DTS

Software logic is based on the principles of RCM [5]. By means of the software, the maintenance schedule for equipment should be more effective so that the given reliability could be guaranteed. The input is formed by the databases of outages, maintenance, and financial flows; the output is the optimum maintenance cycle for the group of DTS. The program is being developed as a specific application executable in the MS Windows environment [2].

It is an "offline" version now (input data for the program will be read from the exports from databases of the distribution company), on which the functionality of all calculation algorithms will be verified and the program will be completely debugged. The final version will be handed over to the distribution company that will ensure the implementation of this program into the existing information system.

The RCM program was created in the Microsoft Visual Basic 6.0 Professional environment. When translating applications and components into the native code, the first-class technology equal to that in the Microsoft Visual C++ development system is used. Applications may be optimized from the point of view of speed and size, and thus their efficiency may be increased. VB is the basic Windows developer's tool that enables the rapid and cheap creation of applications.

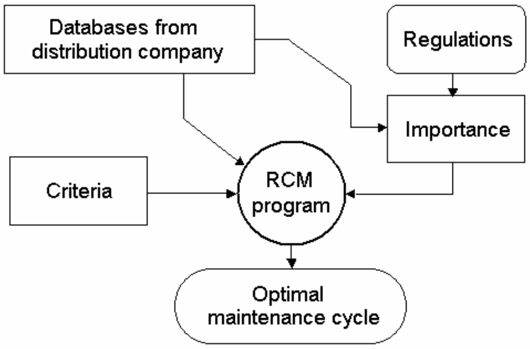

Fig. 4 Block diagram of the program RCM

5.1 Input databases

With reference to the fact that any “importance” cannot be assigned to any specific component, it is necessary to proceed to data division into groups. Then, maintenance intervals of the groups will be different. Input data for the division of components into groups by importance are as follows: for all components of the given type – coefficient for consumer evaluation, the number of groups for division and their limits, and separately for each DTS – identification number, the number of connected consumers by type, possible another division of the component.

The result of the division of components into groups by importance is the determination of the amounts of components in particular groups and the assignation of a group number to each component. Input data for the RCM analysis itself are maintenance costs, repair costs, failure costs, total time of failures, time of scheduled outage, number of all consumers, including their types, number of outages at not obeying the standards, penalties, price of undelivered electrical energy for specific types of consumers, relationship between costs of undelivered energy by particular types of consumers, relationship between costs of outage by specific groups, maintenance rate and the average power passing through the given component. The given data are related to the period under consideration of one year. Sources of these input data are exports from technical records, failure databases and financial databases, or the data are entered directly by the keyboard and are stored in a special file.

5.2 RCM program and outputs

We have to specify input data into the program fields. The screen contains input data serving the division of distribution transformer stations (DTS) into groups by importance – Fig.5. There are different groups indications in the RCM program against indications into the MS Excel environment. The group No.1 corresponds to the group “A”, the group No.2 corresponds to the group “B” and the group No.3 corresponds to the group “C”.

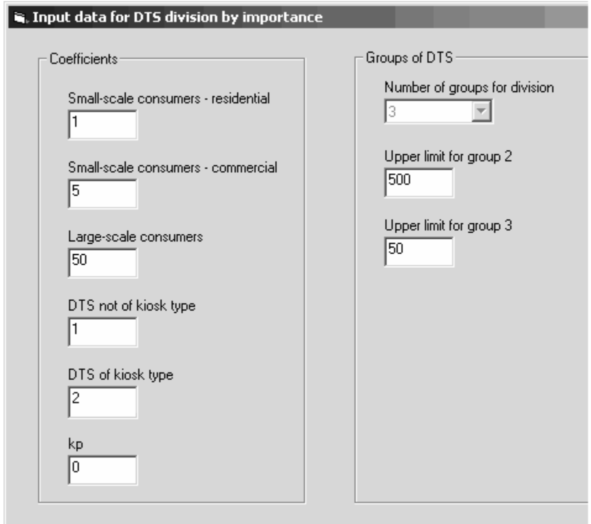

Fig. 5 Data for DTS division by importance

There is an optimal maintenance cycle of the DTS on Fig.6. The local minimum of the total costs curve give the optimum maintenance cycle for DTS into the group 1.

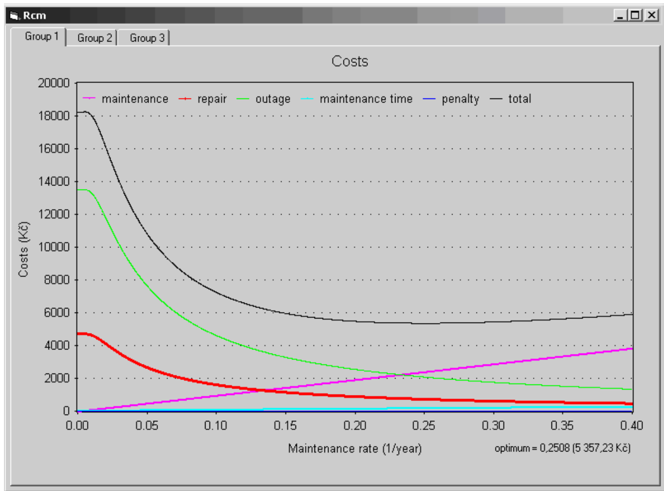

Fig. 6 The resulting curve (black) for group A, k_{ned} = 500

We can see the resulting maintenance period for all groups of DTS. There is the information window of RCM program on next Fig.7.

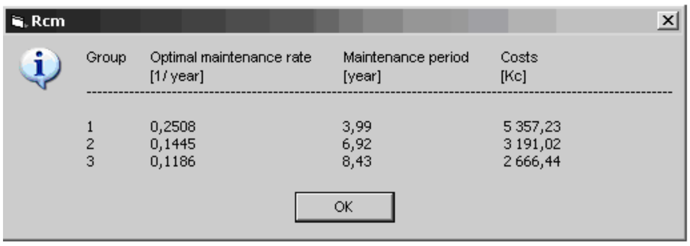

Fig. 7 The results of optimizing cycle for all groups, k_{ned} = 500

6 Conclusion

The contribution describes the first version of the program designed for the optimisation of maintenance of equipment of the distribution system that will provide basic data for responsible and logical decisions about the area of maintenance and basic data for the preparation of an effective maintenance schedule and the creation of a feedback system. On the basis closely worked of the methodology for optimizing maintenance cycle of DTS has been determined an implementation of the RCM strategy by distribution company SME, Inc. group ČEZ to the system operation since January 2005. There are the optimal maintenance cycles into system operation: group A 4 years, B 6 yrs. and C 8 yrs. Next development of the RCM strategy will be aim to the successive implementation for other components into the system operation where the RCM strategy will be use profitable.

Acknowledgement: I am much obliged especially to Vladimír Král, MSc. (VŠB-TU Ostrava, Faculty of Electrical Engineering and Computer Science, Department of Electrical Power Engineering) for his hard work on creation of the new software support – RCM program.

Acknowledgement: This work is supported by The Ministry of Education, Youth and Sports of the Czech Republic. Project CEZ MSM6198910007.

References:

[1] Gala Jan, Rusek Stanislav, RCM System Application and Importance Like an Attribute of Optimal Maintenance of DTS, *6-th European Conference of Young Research and Science Workers in Transport and Telecommunications*, Conference Proceedings Section No.4, 2005, pp. 79-82.

[2]Rusek Stanislav, Goňo Radomír, Král Vladimír, Gala Jan, A Software Tool for the Maintenance Control in Distribution Companies, *The ninth International Conference on Research in Electrotechnology and Applied Informatics*, Conference Proceedings Session VII, 2005, pp. 193-198.

[3]Rusek Stanislav, Goňo Radomír, Reliability Centred Maintenance and its Application to Distribution Networks. *International Scientific Conference EPQU 2003*, Conference Proceedings pp. 529 – 536.

[4] Gala Jan, An Optimalization of Maintenance of Distribution Networks with Respect to Reliability of Energy Supply, *Ph.D. thesis,* Ostrava 2005.

[5] Skog John E., Maintenance task interval determination, *Sixty-sixth Annual International Conference of Doble Clients*, Proceedings Maintenance and Test Engineering, 1999, pp.158-169.