III INTERNATIONAL CONFERENCE
TRANSPORT SYSTEMS TELEMATICS TST'03

ZESZYTY NAUKOWE
POLITECHNIKI ŚLĄSKIEJ 2003
TRANSPORT z.51, nr kol. 1608

systems of automatic of the level crossing,
simulation system, system SNOP

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MODELING AND SIMULATION OF SYSTEMS OF AUTOMATIC OF THE LEVEL CROSSING

Regarding a few information concerning the behavior of the automatic of systems of the level crossing, in this paper the manner of modeling of automatic of systems of the level crossing has been presented. Thanks to it, it is possible to analyze mutual relationship between tasks, equipment and organization of operation of these systems.

MODELOWANIE I SYMULACJA SYSTEMÓW AUTOMATYKI PRZEJAZDOWEJ

W artykule przedstawiono sposób modelowania systemów automatyki przejazdowej, dzięki któremu możliwa jest analiza wzajemnych związków między zadaniami, wyposażeniem i organizacją działania tych systemów, a przede wszystkim analiza i ocena ich działania.

1. INTRODUCTION

Permanent development of motor's industry, increasing number of cars and the development of railway traffic have the immense influence on necessity of construction and applying new, safe solutions on railway level crossing. Devices of automatic of the level crossing warn the users of the road about the threat causing by the incoming train and close railway level crossing. Warning can be turned on by staff or automatically by the incoming train.

Analysis of safety of traffic control systems shows, that intersections of railway line with public road are one of the most neuralgic places, subject on rising of conflict, causing significant damages and often causalities among people.

Because of the lack of method and reliability model taking into account sophisticated processes of exploitation with reference to devices of the automatic on railway level crossings, in the paper the manner of modeling of the level crossing systems with the use of simulation technique has been presented.

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2. TECHNICAL STATE OF THE DEVICES OF AUTOMATIC OF THE LEVEL CROSSING ON LINE E-30

Line E-30 on section Opole-Wroclaw-Zgorzelec on length 327,294 km has been chosen as a model of the system of automatic of level crossing. Examined part of line E-30 was divided into five subsystems, which constitute railway lines 132, 275, 282, 278 and 277 (table 1) [1].

At such classification of objects of systems of automatic of the level crossing in the model one type of the device – Level Crossing Railway and 6 types of elements have been distinguished, which include:

- controlling circuits,
- track sensors,
- signal lights,
- toll-bar drives,
- supplying and over voltage protection systems,
- other (eg interface systems, cables sending signals, net driving – etc.).

Table 1

Composition of objects being found on examined fragment of line E-30

No of subsyst.	No of line	Name of subsystem (of railway line)	Number of devices (of railway the level crossings)	Categories of railway the level crossings			Length of railway line [km]
				A	B	C	
1	132	Bytom – Wrocław	25	15	3	7	81,719
2	275	Wrocław Główny – Zagań	25	12	3	10	71,910
3	282	Miłkowice – Zary	12	7	0	5	61,961
4	278	Węgliniec – Zgorzelec	10	8	0	2	26,104
5	277	Opole Groszowice – Wrocław Brochów WBA (Linia E-30C)	18	7	2	9	85,600
Total:			**90**	**49**	**8**	**33**	**327,294**

3. MATHEMATICAL MODEL OF SYSTEM OF AUTOMATIC OF THE LEVEL CROSSING

The model of system of automatic of the level crossing takes into account:

- dynamics of process of exploitation of system of automatic of the level crossing,
- maintenance characteristics of devices and units being elements of these devices,
- maintenance conditions treated as environment parameters (temperature, moisture, pressure, dusts, fog),
- decision process concerning damage and renew of objects,
- influence of disruptions,
- time varying constraints of the system.

Aims of modeling of the automatic of the level crossing are following:

1) expectation of the behavior of system of automatic of the level crossing in the future and at different conditions of interaction of environment
2) the choice of the proper entry interactions satisfying particular conditions and the choice of optimal interaction in particular
3) the choice of the structure or parameters of automatic of the level crossing, satisfying given tasks.

The following assumptions was admitted to build the model of system of automatic of the level crossing: [1, 2, 5]

1. System of automatic of the level crossing is presented with the use of separate subsystems S_i for i = 1, 2, ..., I;
2. In each of the subsystem the number of devices of automatic of the level crossing is determined b_i – (i = 1, 2, ..., I);
3. The set of components of devices of automatic of the level crossing is presented with the help of vectors (in binary natation):

$$\alpha_{i,d} = [\alpha_{i,d,1}, \alpha_{i,d,2}, ..., \alpha_{i,d,kdi}], \text{ where:}$$

k_{di} – the number of elements in d-th device of i-th subsystem.

Above assumptions result that system S, whose elements are devices of system of automatic of the level crossing operating on particular area can be presented through separate subsystems S_i satisfying conditions: [1, 2, 4]

$$\begin{cases} \bigcup_{i=1}^{I} S_i = S \\ \bigcap_{i=1}^{I} S_i = \emptyset \end{cases} \tag{1}$$

where: S – system of automatic of the level crossing,
S_i – subsystem of automatic of the level crossing,
I – the number of distinguished subsystems.

According to assumptions and on the basis of presented relationships the set of random variables characterizing reliability parameters of i-th subsystem of system S should be considered :

$$\begin{cases} \tau_{i,1,1}, ..., \tau_{i,1,k}, ..., \tau_{i,1,k1} \\ \tau_{i,2,1}, ..., \tau_{i,2,k}, ..., \tau_{i,2,k2} \\ ..... \\ \tau_{i,b1,1}, ..., \tau_{i,b1,k}, ..., \tau_{i,b1,kd1} \end{cases} \tag{2}$$

where: $\tau_{i,d,k}$ – time of the proper work of k-th element in d-th device operating in i-th subsystem

The set (2) represents operation of every element of block device occurring in i-th subsystem. The number of sets is equal to the number of subsystems of the system of automatic of the level crossing.

At the assumption that cumulative distribuation of a random variable $F_{i,d,k}(t)$ are known, above set can be replaced by the set of cumulative distribuation of i-th subsystem:

$$\begin{cases} F_{1,1,1}(t), ..., F_{1,1,k}(t), ..., F_{1,1,k1}(t) \\ F_{1,2,1}(t), ..., F_{1,2,k}(t), ..., F_{1,2,k2}(t) \\ ..... \\ F_{1,b1,1}(t), ..., F_{1,b1,k}(t), ..., F_{1,b1,kd1}(t) \end{cases} \quad (3)$$

Each of cumulative distribuations of the set (3) describes the probability of the time of failure-free operation of every element of the device. Model of process of exploitation of system of automatic of the level crossing takes into account both maintenance and renew processes.

4. SIMULATION MODEL OF SYSTEM OF AUTOMATIC OF THE LEVEL CROSSING

Creation of simulation systems mimicking the behavior of the actual systems of automatic of the level crossing is presently the main stimulus of research concerning models of railway traffic control objects. These models allow examining mutual relationships between tasks, equipment and organization of operation with the accuracy comparable with the actual object (with the use of modern computer engineering).

Model of system of automatic of the level crossing should be classified to dynamic models (reflecting operation of system and ambience in time) being characterized by stochastic description of the property of system (description of the system and ambience contains random variables). During modeling of system of automatic of the level crossing the model of Fig.1 has been used [1, 3].

Contemporary models take into account a large number of factors, including sophisticated structural relationships, inner feedback and huge number of elements. Significant feature of simulation method is execution of many experiments in being examined model in order to obtain data allowing reflecting the sequence of the state of being examined models.

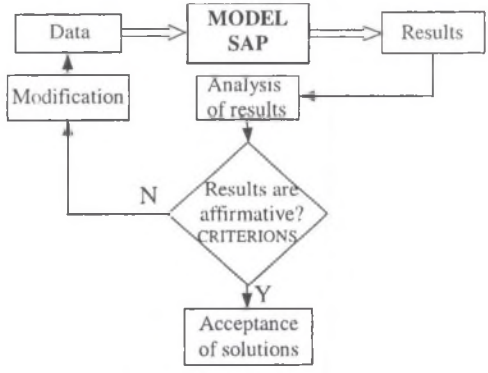

Fig.1. General model of simulation of system (process) of automatic of the level crossing

Taking into consideration model of simulation of system of automatic of the level crossing from fig. 1 it is possible to take the following measures:
- estimate the course of the process of exploitation allowing choosing necessary means for tasks,
- examine reliability of the process of exploitation allowing determination of factor determining operation of automatic of the level crossing at given tasks and equipment,
- make the proper maintenance decisions concerning the choice of means and methods of maintaining devices belonging to system of automatic of the level crossing.

Likelihood of examining results of the modeled object, in this case – system of automatic of the level crossing, depends on the quality of data and the method of analyzing of results.

4.1. STRUCTURE OF THE MODEL

The system of automatic of the level crossing is four level system of scattered structure with hierarchical control. The structure of simulation model of system for analyzing part of line E-30 is presented in Fig.2. The model takes into account relationships between levels: system, subsystems, devices and elements. Because every element is related with several repair technology, therefore the structure of the model can be extended by additional repair technology level, which is simultaneous the basic decision level concerning the choice of repair technology of damaged element [1, 2].

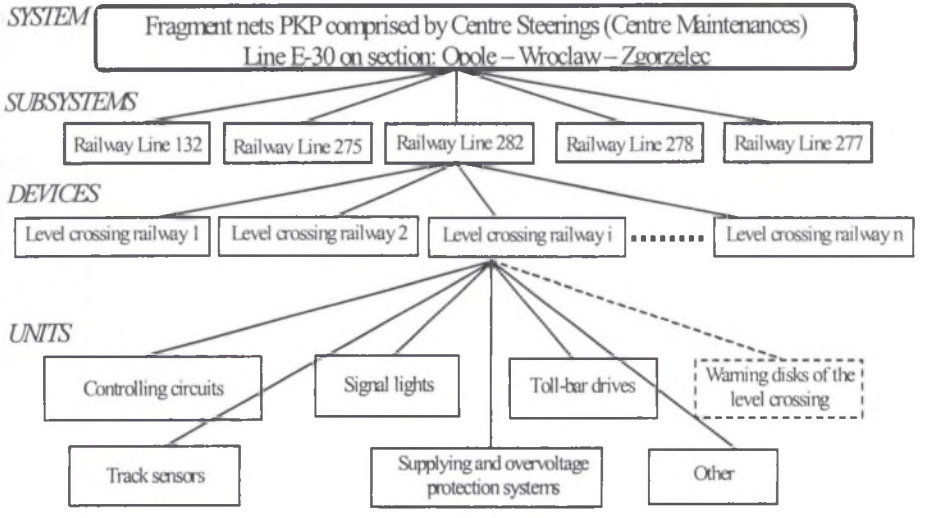

Fig.2. Structure of the simulation model of system of automatic of the level crossing (for line E-30)

4.2. SOFTWARE OF THE SYSTEM *SNOP*

Simulation of the process of exploitation of system of automatic of the level crossing is based on the "successive events" method. The simulation process was defined in the set of procedures corresponding to the single or merged steps of simulation algorithm (Fig.4). In the simulation process the random numbers generator was used and the procedure pooling new values in accordance with early-identified probability distribution. Simulation is controlled by elapsing time synchronized with the real time.

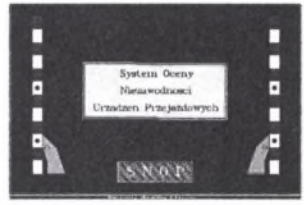

Fig.3. Title page of simulation SNOP program

The set of procedures creating the system SNOP was divided into four functional blocks realized as four separate computer programs (SNOPDANE, SNOPANA, SNOPSYM, SNOPWYN – Fig.5).

Destination of the system of the assessment of reliability of devices of automatic of the level crossing SNOP is:

- setting up data base of structure and exploitation of system of automatic of the level crossing,
- simulation of damage and repair processes,
- analysis, verification and statistical assessment of actual data and simulation's results.

To simulate damage and renew processes cumulative distribution of theoretical distribution of duration of damages and failure-free operation of every element of every device of every subsystem and distribution of number of damages of particular system's objects were assumed. During examining consistency of empirical distributions with hypothetical distributions and consistency of two empirical distributions Chi-quarter and λ-Kolmogorow consistency tests were used.

Results obtained from SNOP program take into account both quantity and frequency analysis in the form:

- the number of damages in the whole system of automatic of the level crossing,
- distribution of the number of damages in particular subsystems,
- distribution of the number of damages of devices in every subsystem,
- distribution of the number of damages with division into type of devices and type of elements,
- distribution of duration of damages of particular type of devices and elements,
- distribution of failure-free time of operation of particular type of devices and elements.

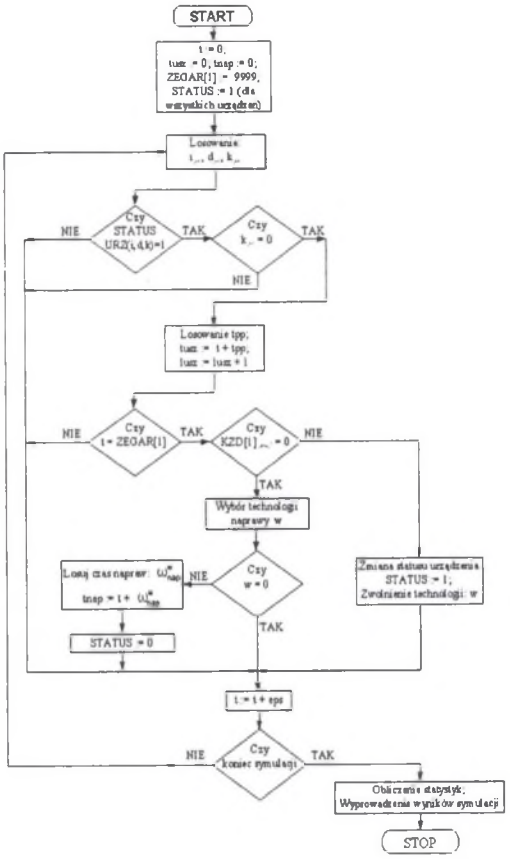

Fig. 4. The algorithm of simulation of system of automatic of the level crossing

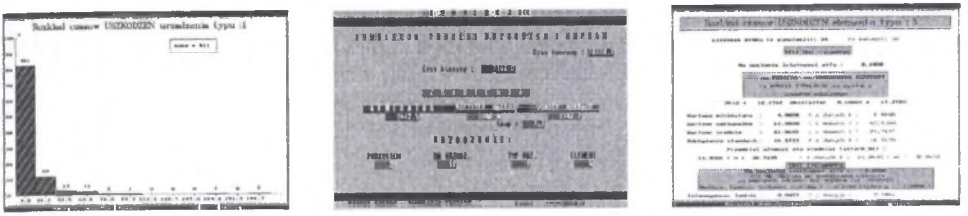

Fig.5. Exemplary screens of simulation SNOP program
a) results of statistical analysis of data of damages from SNOPANA program
b) results of simulation for basic variant in SNOPSYM program
c) verification of simulation results with actual data obtained from SNOPWYN program

5. CONCLUSIONS

The basic purpose of creation of simulation model of system of automatic of the level crossing is the possibility of analysis and the assessment of operation of the system and its renew process at a given description of system's equipment and a given description of schedule of repair technology.

As a results of preformed analysis of data collected on actual object the following information was obtained: description of the structure of system, names of component objects, histograms of number of damages happening in distinguished objects, histograms of duration of damages and failure-free time of operation of devices and elements, index of readiness of devices and elements, information about the number of repair technology, etc.

Changes of exploitation parameters of system of automatic of the level crossing (for example traffic intensity on railway crossing, exploitation's characteristics of particular elements and modules, types of renew methods, repair prophylactics, influence of impacting factors etc) at taking into account the model of system, allow conducting easily the reliability assessment. On the basis of above results it is possible to envisage indispensable correction of methods and maintenance means in such a way that the reliability of devices of automatic of the level crossing is retained at least on unchanging level at the simultaneous increase the load of system.

Another benefit resulting from using the model of system of automatic of the level crossing is the possibility of the comparison of exploitation characteristics of systems of signal lights introduced in PKP, and produced by different domestic and foreign manufactures: ADtranz Zwus (SPA-4), Scheidt & Bachmann (BUES 2000) and Siemens (NE BUE 90E) or systems made in different technologies (relays, hybrid, microprocessors).

For the deep analysis and the assessment of the exploitation process of systems of automatic of the level crossing the verification of exploitation results obtained in different ways (for line E-30 on the section Opole-Wroclaw-Zgorzelec) has been performed. [2]

As a results of performed simulation of system of automatic of the level crossing distribution of the number of damages of particular type of elements distinguished in the system of automatic of the level crossing (Fig.6) was determined. Based on these results it is possible to say that the most of damages occurred for toll-bar drivers (57÷60% of all damages) and the least damages occurred for signal lights (2÷3%).

From the analysis of average values of duration of damages of systems of automatic of the level crossing results that the longest period of failure-free operation occurs in elements of such a type as cables, intermediate objects, disruptions protected devices etc) – average 24 hours per year, the shortest period of failure-free operation – signal lights (5,7 hours per year). Average values of the time of failure-free operation shows that the longest period of failure-free operation occurred in supplying systems – 2353 hours per year that means 98 days continuous operation, and the shortest period occurred in control systems through 95,5 hours per year (about 4 days).

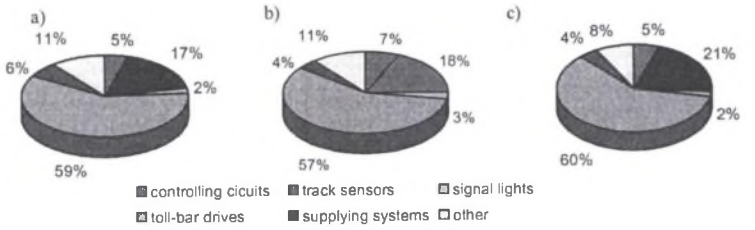

Fig.6. Percentage schedule of damages of units of system of automatic of the level crossing for: a) given statistical data in 1998 year, b) simulation data, c) given statistical data in 1999 year

Values of coefficients of readiness of objects distinguished in system of automatic of the level crossing are comparable and their values are above 0.97 (except for control systems for which $Kg < 0.9$).

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