Statistical Estimation of Extreme Deviation of Parameters in Railway Interlocking and Communication Systems

Borislav. D. Boiadjiev[1] and Georgi. D. Nenov[2]

Abstract – **The estimation of extreme deviations is offered in this paper. It has used imitation modelling and/or experimental measurements. With the help of rows of parameters are obtained in relatively simple way the statistical extremums.**

Keywords – **Mathematical model, optimal experiment, saturated plans, statistical extremum.**

The Stability of parameters of devices and systems for ensuring the railway traffic is the basis of safety for passengers, personnel, goods and equipment. Found the reflection in the results of the research in this field, have monographic works and in journals including those in Bulgarian [5, 6].

The statistical approaches are often used, but there is essential difficulty for providing a sufficiently representative sample. On the other hand it is obtained by passive observations and searching for statistical extremum is put under question or the information about it is not sufficient [1, 2, 3].

The estimation of extreme deviations is offered in this paper. It has used imitation modelling and/or experimental measurements. With the help of rows of parameters are obtained in relatively simple way the statistical extremums. They are a motivated and adequate estimation of the risk situations, and particularly in the railway traffic.

The offered method includes obtaining a statistical row. For this purpose a matrix is used, which is specified in table 1 [4].

TABLE I

Trial	**Factors**					**Parameters**			
u	x_0	x_1	x_2	…	x_n	y_1	y_2	…	y_m
0	*0*	*0*	*0*	…	*0*	y_{10}	y_{20}	…	y_{m0}
1	*1*	*-1*	*1*	…	*-1*	y_{11}	y_{21}	…	y_{m1}
2	*1*	*1*	*-1*	…	*1*	y_{12}	y_{22}	…	y_{m2}
…	…	…	…	…	…	…	…	…	…
N	*1*	*1*	*-1*	…	*-1*	y_{1N}	y_{2N}	…	y_{mN}

The factors x_i $(i = \overline{1,n})$ are corresponding to the values of the constructive elements. In the most cases they are the resistances of resistors and capacities of capacitors. The active elements (transistors and integral circuits) are represented with their common elementary models or with appropriate summarized parameters [3].

The examined parameters y_j $(j = \overline{1,m})$ of the system or the device are at the right side of the table 1. They are quality factors, with which normal values define the space of operation [7].

The next step in solving the task is to use rows:

$$y_{ju} \ (j = \overline{1,m}); (\mathrm{u} = \overline{0,\mathrm{N}}) . \qquad (1)$$

The appropriate extremum can be determined for each of the examined parameters. When shaping the workspace of the device or system, the minimum and/or maximum are used [1], [2], defined by formulas:

a. When seeking the maximum

$$P(y) = \exp(-\exp(-y));$$

$$y = \frac{y_t - \mu}{\sigma}; \quad \mu = \overline{y} - 0{,}557 . \sigma \ . \qquad (2)$$

b. When seeking the minimum

$$P(y) = 1 - \exp(-\exp(-y));$$

$$y = \frac{y_t - \mu}{\sigma}; \quad \mu = \overline{y} - 0{,}557 . \sigma \ . \qquad (3)$$

With $P(y)$ the probability of occurring the maximum or minimum values of corresponding parameter y_j are defined. Eqs. (2) and (3) incorporate the normalized value of this parameter (y) compared to the real one denoted as y_t .

The rest quantities are:

$$\overline{y} = \frac{\sum_{u=1}^{N} y_u}{N};$$

$$\sigma = 1{,}283 . \sqrt{D};$$

$$D = \frac{\sum_{u=1}^{N} (y_u - \overline{y})^2}{N - 1} . \qquad (4)$$

From table 1 it is seen that N is the number of members of the statistical rows, but y_u are the values of parameter y_j in the corresponding column in the table.

In relation to the extreme parameters deviations of the system (device), two primary tasks can be solved:

1. With selected probability *P(y),* the value y_t of a given parameter, which will not be exceeded is defined. This enables to define the space of operation with given risks in relation to each of parameters.

[1] Georgi Dimitrov Nenov, is with the Department of Communication and Railway Signalling Engineering in "Todor Kableshkov" Higher School of Transport. 158 Geo Milev Street, Sofia 1574, Bulgaria.

[2] Borislav Draganov Boiadjiev, is with the Department of Communication and Railway Signalling Engineering in Todor Kableshkov Higher School of Transport. 158 Geo Milev Street, Sofia 1574, Bulgaria. E-mail: bboiadjiev@vtu.acad.bg.

TABLE 2

u \ n	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	X_9	x_{10}	K_U	δ %	t_r
0	0	0	0	0	0	0	0	0	0	0	**45,1062**	**1,88615**	**8,751.10^{-09}**
1	1	-1	1	-1	-1	-1	1	1	1	-1	**38,6187**	**0,64553**	**8,2253.10^{-09}**
2	1	1	-1	1	-1	-1	-1	1	1	1	**50,1031**	**0,53305**	**9,3472.10^{-09}**
3	-1	1	1	-1	1	-1	-1	-1	1	1	**47,0368**	**2,45086**	**8,3019.10^{-09}**
4	1	-1	1	1	-1	1	-1	-1	-1	1	**44,3438**	**1,89157**	**8,2797.10^{-09}**
5	1	1	-1	1	1	-1	1	-1	-1	-1	**46,8478**	**0,59287**	**9,4433.10^{-09}**
6	1	1	1	-1	1	1	-1	1	-1	-1	**41,656**	**1,6559**	**9,0244.10^{-09}**
7	-1	1	1	1	-1	1	1	-1	1	-1	**40,9833**	**0,55155**	**8,5511.10^{-09}**
8	-1	-1	1	1	1	-1	1	1	-1	1	**47,6903**	**1,84529**	**8,2557.10^{-09}**
9	-1	-1	-1	1	1	1	-1	1	1	-1	**44,6077**	**0,37164**	**9,3218.10^{-09}**
10	1	-1	-1	-1	1	1	1	-1	1	1	**47,9426**	**0,85578**	**7,8837.10^{-09}**
11	-1	1	-1	-1	-1	1	1	1	-1	1	**47,1825**	**2,04663**	**8,6246.10^{-09}**
12	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	**41,0525**	**1,31725**	**9,0921.10^{-09}**

2.If the permissible deviations y_t of each parameter are assigned, the task is to define probabilities about their occurring and the rate of risk.

The offered method can be used for design of systems for transmission and processing information with high protection against risk situations.

The method can be illustrated with a relatively simple example to get more demonstrative notion. The object is pulse amplifier, which parameters are: gain K_{U}, percentage pulse spike $\delta\%$ and time of pulse setting up t_r.

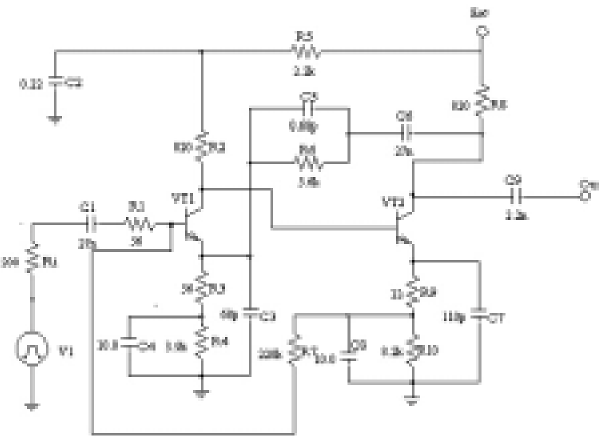

Fig. 1. Pulse Amplifier

The circuit is shown on fig. 1. The variables are normalized to the values at initial state (the zero attempt $u = 0$) and correspond to following:

$x_1 \to R_1$; $x_2 \to R_2$; $x_3 \to R_3$; $x_4 \to R_6$; $x_5 \to R_8$; $x_6 \to R_9$; $x_7 \to C_3$; $x_8 \to C_5$; $x_9 \to C_7$; $x_{10} \to E_{CC}$.

Twelve experiments with the Plaket-Bermans' saturated plans have been realized [4]. They are shown in table 2. The statistical rows, which are necessary for determination of the extremums, are the values K_{U}, δ % and t_r in the corresponding columns. First of all, it is important for the pulse amplifier, not to decrease the gain under the acceptable value, and the pulse spike and time of pulse setting up, must not exceed the definite limits.

The results of the experiment (Table II) are obtained using the software PSpice, but this does not exclude the use of measurements. In both cases very large quantity of working time of skilled specialists is saved. The solution is rationalized and it is possible to reveal unknown characteristics.

Through Eqs. (2) – (4) when $P(y) = 0{,}95$ the following results are got:

$K_{U\,\min} = 34{,}929$; $\delta_{\max} = 3{,}569\%$; $t_{r\,\max} = 10{,}245.10^{-9}\, s$.

CONCLUSION

The mentioned example confirms the advantages of the offered method, which are chiefly in following:

1. The system investigation is rationalized with using a suitable experimental plan, because the amount of calculations and/or measurements is decreased from one to several times.
2. The Statistical extremum is a very suitable estimation of parameters deviations of railway signalling and interlocking systems, since it is directly connected with the risk of failure. Failure probability can be considered with the parameter importance in relation to normal operation and consequences of failures.
3. The method can also be used in connection with the development of other similar systems that make it even more significant.

REFERENCES

[1] Gumbel, E. Y. Statistics of Extremes. Columbia University Press, New York, 1962.

[2] Hahn, G. J., S. S. Shapiro. Statistical Models in Engineering. John Wiley & Sons, New York, 1967.

[3] Vlach, J., K. Singhal. Computer Methods for Circuit Analysis and Design. VNP Company, New York.

[4] Barabashtuk V. I., B. P. Kredentzer, V. I. Miroshnichenko. Planirovanie experimenta v tehnike. Tehnika, Kiev, 1984 (in Russian).

[5] Hristov, H. A. Elektronizatziya na osiguritelnata tehnika. Tehnika, Sofia, 1984 (in Bulgarian).

[6] Hristov, H. A. Osnovi na osiguritelnata tehnika. Tehnika, Sofia, 1990 (in Bulgarian).

[7] Nenov G. D. Nadezhdnost na radioelektronnite izdeliya. Tehnika, Sofia, 1983 (in Bulgarian).