SELECTED ASPECTS OF THE SUPERVISION OF ICT SYSTEMS USED IN THE RAIL TRANSPORT

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Summary

In the article, the DGT-IP R telecommunication system was presented, and then its analysis in terms of the reliability and operation was performed. A particular emphasis was put on the issues related to restoring the state of complete usability. Adopting three states (complete usability R_0, impendency over safety Q_{ZB} and unreliability of safety Q_B) and certain transitions between them, the relationships allowing for determination of probabilities of the system staying in the above mentioned states.

Keywords: ITC system, reliability, operation

WYBRANE ASPEKTY NADZORU SYSTEMÓW TELEINFORMATYCZNYCH STOSOWANYCH W TRANSPORCIE KOLEJOWYM

Streszczenie

W artykule zaprezentowano scharakteryzowano system telekomunikacyjny DGT-IP R, zaś następnie dokonano jego analizy w aspekcie niezawodnościowo-eksploatacyjnym. Zwrócono przy tym szczególną uwagę na kwestie związane z przywróceniem stanu pełnej zdatności. Przyjmując trzy stany (pełnej zdatności R_0, zagrożenia bezpieczeństwa Q_{ZB} i zawodności bezpieczeństwa Q_B) oraz określone przejścia pomiędzy nimi, wyznaczono zależności pozwalające na wyznaczenie prawdopodobieństw przebywania systemu w wymienionych stanach.

Słowa kluczowe: system telekomunikacyjny, niezawodność, eksploatacja

1. INTRODUCTION

The reliability of ICT systems used in the rail transport depends on many factors, such as reliability of individual elements of the ITC network, operation conditions, network topology, etc. There are many methods of increasing the reliability of ITC systems [5]. One of them is increasing the reliability of the network's elements by the choice of a better technology and the use of more reliable devices [1]. It is also possible to increase the reliability by adding additional nodes and parallel channels.

The reliability parameters of the ITC system used in the rail transport are significantly influenced by the way of supervision of the system and its elements in order to determine the condition and detect any occurred damage. In order to meet the requirements of the high operation reliability [4] within ITC systems, programme and device mechanisms for creation during the operation of new functional structures, ways to control the technical equipment of nodes and telecommunications lines, and the detection system of errors and damage are commonly implemented. These actions in the telecommunications are defined with a term of the maintenance of telecommunication devices. The switch diagnostic system is an important element of maintaining digital telecommunication switches. The article presents the architecture of the exemplary telecommunication system (DGT-IP R [2]) applied in the rail transport as well as its reliability and operation model.

The DGT-IP switching system is equipped with the necessary operation and maintenance functions providing the effective and flexible implementation of utility and maintenance processes of switches in the operation and maintenance-free modes, using a centralised system of supervision and management. The operation and maintenance functions implemented in solutions of the DGT-IP R ITC rail system meet the ITU-T relevant recommendations [16] as well as requirements of the rail departmental telecommunication network.

2. THE DGT-IP R SYSTEM ARCHITECTURE

The DGT-IP R system is characterised by a modular design, which allows to configure its equipment according to the user's needs [13]. Most units included in the system are equipped with control processors, which provide distributed control. The architecture of the system can be compared to a microprocessor network. Each microprocessor performs highly specific tasks. The communication between units takes place by the switching field. Each of control microprocessors has its own memory resources independent of the central computer. In this manner, the principle that each microprocessor is closely related (spatially and functionally) to resources and elements which it operates, is observed. The hardware design of the system is based on VLSI large scale integration systems.

Hardware packages are made of multi-layer laminates with the surface-mount technology of elements. The system reliability is increased by doubling essential elements: control unit, switching field, group processor and power supply block operation in the "hot standby" system, making it possible to take over the function of the main component.

The software of the system is continuously performing the diagnosis of all components operation. It immediately signals the malfunction, and automatically reconfigures the system and eliminates the malfunctioning component without disconnection of the combined connections (it automatically switches to the reserve component). The system is equipped with the software that allows also to manually launch internal system testing. As a result of the use of elements with the high reliability ensuring the correct operation of the entire system as well as by reserving essential subsystems, the level of the DGT-IP R system availability, required by recommendations for digital telecommunication systems (99,999% [5]) was provided.

The system software makes it possible to implement all the functions, which are activated by the appropriate database configuration. It takes into account the variation due to the application, the characteristics of the network, services and functions, and it also allows for different types of interfaces.

The general structure of the DGT-IP R ICT rail system was shown in Fig. 1.

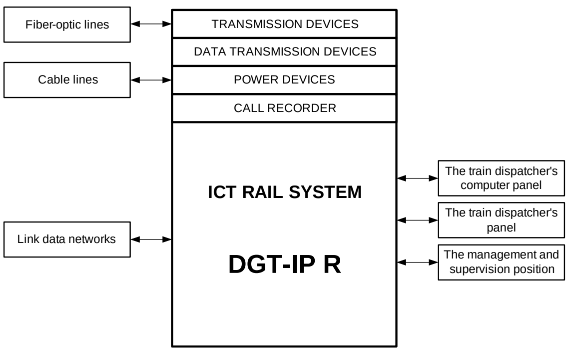

Fig. 1. The general structure of the KST DGT-IP R system

The DGT-IP R ICT rail system creates a communications network providing the communication between a train dispatcher and all stations located within a given railway station, neighbouring railway stations, a line dispatcher and the stations located along the railway route. In addition, the system enables the transmission of data necessary for the proper operation, providing the safety and rail traffic administration.

In the basic version of the equipment, the DGT-R IP system consists of:

- the DGT Millenium telecommunications server,
- the telecom power system operation in a buffer system and providing the system power supply and the accumulator batteries charging [7,11,12],
- accumulator batteries providing the maintenance of the system power supply in case of the disappearance of the tension in the power grid,
- switch,
- the call recorder which makes it possible to record calls from the train dispatcher's panel and other system connects (including warning links),
- the management and supervision positions in the form of a PC with MS Windows with the installed software for:
  - monitoring the system condition,
  - system administration,
  - changing the system configuration,
  - registration and review of events in the system,
  - management and supervision of the call recorder,
- the train dispatcher's panel in a version of the "touch-screen" interface (touch screen) or made with a classical mechanical keyboard.

The DGT Millenium (DGT M) telecommunications server [3] is a fully digital communications system, which constitutes an element of the integrated system of the railway communication providing the ability to complete all operating links with the relevant linear equipment. The server is designed and configured to be able to systemically take into account the characteristics of individual communications networks. The DGT Millenium server may include:

- the central unit with I/O ports,
- the train dispatcher's panel,
- the train dispatcher's computer panel,
- the switch,
- the interface for the remote supervision system,
- the management and supervision position.

Most of the control units of the DGT M server has built-in self-testing basic functions and local databases, which are available both for packages of the operation and maintenance programmes and for the remote control unit. The centralised management of the network offered in the DGT M telecommunication server enables the performance of many specialised operation and maintenance functions for a number of maintenance-free switches of this type. Regardless of the remote supervision systems, the DGT M telecommunication servers have the local operation and maintenance subsystem equipped with a terminal intended for the personnel visiting maintenance-free switches.

3. ANALYSIS OF THE RELIABILITY AND OPERATION OF THE DGT-IP R TELECOMMUNICATION SYSTEM

Conducting the analysis of the operation of the DGT-IP R telecommunication system, it is possible to conclude that the relationships in terms of the reliability [6] and operation [8,9] can be illustrated as shown in Fig. 2.

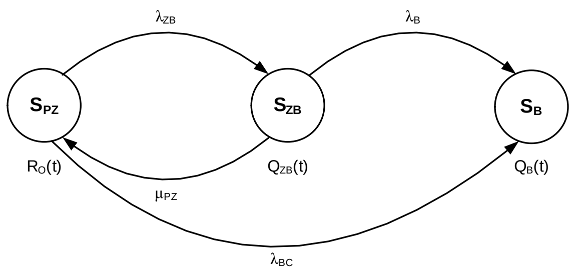

Fig. 2. Relationships in the DGT-IP R telecommunication system

Markings in Fig.:

- $R_O(t)$ – the probability function of the system staying in the state of complete usability,
- $Q_{ZB}(t)$ – the probability function of the system staying in the state of impendency over safety
- $Q_B(t)$ – the probability function of the system staying in the state of safety unreliability,
- λ_{ZB} – intensity of transitions from the state of complete usability to the state of impendency over safety,
- μ_{ZB} – intensity of transitions from the state of impendency over safety to the state of complete usability,
- λ_B – intensity of transitions from the state of impendency over safety to the state of safety unreliability,
- λ_{BC} – intensity of transitions from the state of complete usability to the state of safety unreliability.

The state of complete usability S_{PZ} is a state, in which the DGT-IP R telecommunication system functions correctly. The state of impendency over safety Q_{ZB} is a state, in which all functions are possible to be implemented by the telecommunication system. Therefore, there is a situation in which the subscribers cannot fully use all services. The state of safety unreliability Q_B is a state, in which the telecommunication system is unfit.

The system shown in Fig. 2 can be described by the following Chapman–Kolmogorov equations:

$$\begin{aligned}
R_0^{'}(t) &= -\lambda_{ZB} \cdot R_0(t) + \mu_{PZ} \cdot Q_{ZB}(t) - \lambda_{BC} \cdot R_0(t) \\
Q_{ZB}^{'}(t) &= \lambda_{ZB} \cdot R_0(t) - \mu_{PZ} \cdot Q_{ZB}(t) - \lambda_B \cdot Q_{ZB}(t) \\
Q_B^{'}(t) &= \lambda_B \cdot Q_{ZB}(t) + \lambda_{BC} \cdot R_0(t)
\end{aligned} \tag{1}$$

Assuming baseline conditions:

$$\begin{aligned}
R_0(0) &= 1 \\
Q_{ZB}(0) &= Q_B(0) = 0
\end{aligned} \tag{2}$$

and applying the Laplace transform, we obtain the following system of linear equations:

$$\begin{aligned}
s \cdot R_0^*(s) - 1 &= -\lambda_{ZB} \cdot R_0^*(s) + \mu_{PZ} \cdot Q_{ZB}^*(s) - \lambda_{BC} \cdot R_0^*(s) \\
s \cdot Q_{ZB}^*(s) &= \lambda_{ZB} \cdot R_0^*(s) - \mu_{PZ} \cdot Q_{ZB}^*(s) - \lambda_B \cdot Q_{ZB}^*(s) \\
s \cdot Q_B^*(s) &= \lambda_B \cdot Q_{ZB}^*(s) + \lambda_{BC} \cdot R_0^*(s)
\end{aligned} \tag{3}$$

Using the inverse transform, it is possible to obtain:

$$R_0(t) = \begin{bmatrix} \cosh\left(\sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}} \cdot \frac{t}{2}\right) \cdot \\ \cdot \sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}} + \\ + (\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC}) \cdot \\ \cdot \sinh\left(\sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}} \cdot \frac{t}{2}\right) \end{bmatrix} \cdot \frac{\exp\left[-\left(\frac{\lambda_{ZB} + \lambda_{BC} + \mu_{PZ} + \lambda_B}{2}\right) \cdot t\right]}{\sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}}} \tag{4}$$

$$Q_{ZB}(t) = \frac{2 \cdot \lambda_{ZB}}{\sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}}} \cdot \sinh\left(\sqrt{(\mu_{PZ} + \lambda_B - \lambda_{ZB} - \lambda_{BC})^2 + 4 \cdot \lambda_{ZB} \cdot \mu_{PZ}} \cdot \frac{t}{2}\right) \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \lambda_{BC} + \mu_{PZ} + \lambda_B}{2}\right) \cdot t\right] \tag{5}$$

$$
\begin{aligned}
Q_B(t) = {} & \frac{\lambda_B \cdot \lambda_{ZB}}{\left[\lambda_{ZB}\cdot\mu_{PZ} - (\mu_{PZ}+\lambda_B)\cdot(\lambda_{ZB}+\lambda_{BC})\right]\cdot 2\cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}}\cdot \\
& \cdot\left[\begin{aligned}
& \exp\left(-\left(\frac{\lambda_{ZB}+\lambda_{BC}+\mu_{PZ}+\lambda_B}{2}\right)\cdot t\right)\cdot \\
& \cdot\left(\begin{aligned}
& 2\cdot\cosh\left(\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}\cdot t\right)\cdot \\
& \cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}+ \\
& +(\mu_{PZ}+\lambda_B+\lambda_{ZB}+\lambda_{BC})\cdot \\
& \cdot\sinh\left(\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}\cdot t\right)
\end{aligned}\right) - \\
& -2\cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}
\end{aligned}\right] + \\
& +\frac{\lambda_{BC}}{\left[\lambda_{ZB}\cdot\mu_{PZ} - (\mu_{PZ}+\lambda_B)\cdot(\lambda_{ZB}+\lambda_{BC})\right]\cdot 2\cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}}\cdot \\
& \cdot\left[\begin{aligned}
& \exp\left(-\left(\frac{\lambda_{ZB}+\lambda_{BC}+\mu_{PZ}+\lambda_B}{2}\right)\cdot t\right)\cdot \\
& \cdot\left(\begin{aligned}
& \left((\mu_{PZ}+\lambda_B)^2+2\cdot\lambda_{ZB}\cdot\mu_{PZ}-(\mu_{PZ}+\lambda_B)\cdot(\lambda_{ZB}+\lambda_{BC})\right)\cdot \\
& \cdot\sinh\left(\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}\cdot t\right)+ \\
& +2\cdot(\mu_{PZ}+\lambda_B)\cdot \\
& \cdot\cosh\left(\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}\cdot t\right)\cdot \\
& \cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}
\end{aligned}\right) - \\
& -2\cdot(\mu_{PZ}+\lambda_B)\cdot\sqrt{(\mu_{PZ}+\lambda_B-\lambda_{ZB}-\lambda_{BC})^2+4\cdot\lambda_{ZB}\cdot\mu_{PZ}}
\end{aligned}\right]
\end{aligned} \tag{6}
$$

The obtained relationships allow to determine the probabilities of the DGT-IP R telecommunication system staying in the states of the complete usability R_0 (4), impendency over safety Q_{ZB} (5) and safety unreliability Q_B (6).

In a further analysis, great attention was paid to the state of the complete usability. To that end, the computer software used to analyse the impact of time of restoring the state of complete usability t_{PZ} on the probability value of the system staying in the state of complete usability R_{O}, was applied. Such procedure is shown in the following example.

Example

Assuming the following values describing the analysed system:

- duration of research – 1 year:

$$t = 8760 \ [h]$$

- indestructibility of the telecommunication system resulting in the transition from the state of complete usability to the state of the impendency over safety:

$$R_{ZB}(t) = 0{,}9999$$

- indestructibility of the telecommunication system resulting in the transition from the state of the impendency over safety to the state of safety unreliability:

$$R_B(t) = 0{,}99999$$

- indestructibility of the telecommunication system resulting in the transition from the state of complete usability to the state of safety unreliability:

$$R_{BC}(t) = 0{,}999999$$

The intensity of transitions from the state of the impendency over safety to the state of complete usability μ_{PZ} is – as it is known (in case of the exponential system) – the reciprocal of time t_{PZ}:

$$\mu_{PZ} = \frac{1}{t_{PZ}}$$

If we assume that time of restoration of the complete usability t_{PZ} may be included in the range, $t_{PZ} \in \langle 12;48\rangle \ [h]$ then the probability of the analysed system staying in the state of complete usability is illustrated by the chart presented in Fig. 3.

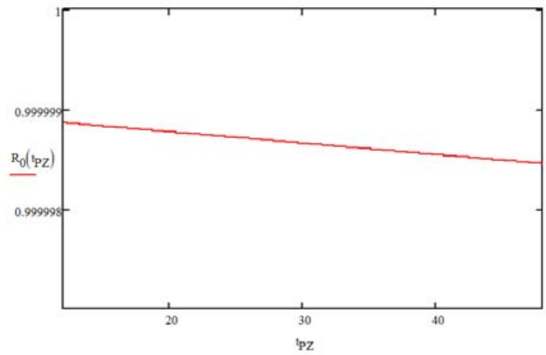

Fig. 3. The dependence of the probability of the system staying in the state of complete usability R_O in the time function of restoration of the state of complete usability t_{PZ}

Using the presented considerations, the impact of restoration time of the state of complete usability on the probability value of the telecommunication system in the state of complete usability can be determined. The value of this probability can be regarded as an indicator of readiness. It allows to compare different kinds of telecommunication system solutions as well as to choose the optimal solution with the assumed criteria (among others, the required level of the system availability). The conducted analysis did not include the impact of electromagnetic interference [10] as well as the information quality [14,15] on the functioning of the system. In further research, the authors plant to take these issues into account.

4. SUMMARY AND CONCLUSIONS

The article presented an analysis of the DGT-IP R telecommunication system in terms of reliability and operation with particular focus on the issues related to restoration to the state of the complete usability. Adopting three states (complete usability R_0, impendency over safety Q_{ZB} and unreliability of safety Q_B) and certain transitions between them, the relationships allowing for determination of probabilities of the system staying in the above mentioned states.

The application of the management system of DGT telecommunication network servers (switches) reduces the response time for damage or failures that occur in the switches, and in particular, it facilitates the location of the damaged element. The application of computer networks in the management system gives the ability to easily distract and increase its reliability.

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Prof. **Miroslaw SIERGIEJCZYK**, PhD. Eng. - scientific fields of interest of the paper co-author concern among other issues of architecture and services provided by telecommunications networks and systems, especially from perspective of their applications in transport, reliability and operation of telecommunications networks and systems, modelling, designing and organising telecommunications systems for transport.

Adam ROSIŃSKI Ph.D. Eng. - scientific interests (reliability, exploitation, diagnostics, projecting) are problems connected with comprehended wide electronic systems of the safety both for stationary as well as for movable objects.