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Original scientific paper

Security of the control of the transportation systems

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"To get rid of the risk (insecurity) of occurrence of an accident is not possible. The main hazard is not in the lack of security but in that to take risks subconsciously, irrepressibly. The risk – it is both an opportunity and a specific advantage, and a weapon of the knowledgeable.

Ivan Popchev, "Code of the Common Sense", rule 13.

Abstract – **Traffic congestion and resulting pollution affect the quality of life in cities, notably in countries with dominant old diesel engines. One solution is Adaptive Traffic Signal Control using vehicle type and emission measurements. Therefore, a fuzzy controller using magnetic sensor for classifying vehicles and sensor for measuring emissions is proposed.**

Keywords – **security of control, transportation systems, reliability.**

I. Introduction

In the process of design, production, storage and operation of *transportation systems* (TS), the tasks of their technical control occurs. The objective is maintenance of the necessary level of reliability of TC. According to the fundamental work of Prof. Evgeniy Gindev, DscTech. "Foundations of Ap-plied Reliability", Sofia, 2000, **control of the technical condition** should mean a *process of obtaining and processing of information* about the correspondence between the condition of the *object of control* (OC) and its current *primary and secondary parameters* (PSP) set by the manufacturer and deter-mined using the *means of control and measurement* (MCM).

Let us analyze the words "**control**" and "**security**". The verb **control** has been borrowed from the international technical jargon and originates from the French word *controle* with the German component *iran* [2]. The word *controle* is compound and consists of two parts: *contra* (against) and *rola* (roll, shutter). There are convenient Bulgarian replacement words, which are used in co-njunction with it: verification, testing, review, inspection, etc.

Regarding the word 'security', the following definition is available: „**Security** is a degree of resistance or prevention of the objects and the system of objects from harm. It applies to anything which is valuable and at the same time vulnerable" [2]. Regarding the problem of value of the information about the objects and systems, familiarization with the co-author's work "Dialectics of Information" with authors N. Iv. Petrov, Iv. N. Petrov, Sofia, Publishing house "Prof. Marin Drinov", 2020 is necessary.

Exposition: After the brief introduction on the topic of the report, a **definition of security of control in TS** should be given: *"Security of control is a process of receiving and processing of reliable information about the correspondence between the studied subject (TS), its current PSP and the results of the measurements carried out through MCM."*

The so introduced definition of security of control requires the introduction of an analytical expression for determination of the quantity of reliable information I_{RI} regarding TS, determined by using the formula [10]:

$$I_{RI} = -\sum_{i=1}^{n} p_i.\log_2 p_i.\left\{\exp\left[-\int_{t_1}^{t_2}\omega(t)\,dt\right]\right\}. \qquad (1)$$

where TS has n exits and each exit has a probability of occurrence (realization) p_i, in the availability of the condition $0 \le p_i \le 1$. Correspondingly, $\omega(t)$ is the intensiveness of the flow of refusals (failures – hardware and/or software) in TS for the observed time interval $\Delta t = t_2 - t_1$.

While using (1), the information about the current technical condition of TS and their MCM should not be mixed. Therefore we will conditionally talk about transportation systems (TS) and their elements (MCM). The means of control and measurement (MCM) are used for the performance of the following activities:

- measurement of the TS parameters for the purpose of identification of their condition (control of their current reliability);
- determination of the place of refusal or failure in TS;
- prediction of the future condition of the studied object.

For any technical activity (process), 'control' is described with the following main specifications:

- volume or space of the controlled parameters;

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- sequence of the control;
- mode of TS control (operating or non-operating);
- regularity of control (continuous, discrete, single or repeated);
- trueness (reliability) of the control;
- price of the TS control.

The so indicated specifications of TS control determine the descriptive quality of this very responsible process. The process itself is implemented by means of performance of separate checks (measurements) and in each check the current condition of the parameters of the inspected object of control (TS) is determined. The aggregate of all possible checks of the parameters of the *transportation systems* (VS) forms the space of the parameters of those systems.

II. Approaches to the Control of the Transportation Systems

Those approaches are of two types, in the first ne the probable parameters of TS are calculated taking into account the influence of MCM. As an example, the theoretical works [4, 5, 6] are indicated. In the second approach [8] the MCM system is studied and optimized, provided that the structure of the object of control is considered known and permanent. Optimization of the controlled system (MCM) is carried out in the availability of two types of restrictions regarding the object of control: **fundamental and operating**.

The fundamental restrictions refer to the following conditions of the objects of control:

- ❖ The elements of OC fail independently of each other;
- ❖ No new elements fail during the time of control;
- ❖ The accidental modifications of the controlled parameters are not reported;
- ❖ Inn the availability of spare elements of OC, their hazard for failure (probability of failure) is assumed as equal to the hazard of failure of the main part of OC;
- ❖ In the space of checks of OC (its PSP), carried out through MCM, there is no global inspection which leads to instant control.

The specification of the operating restrictions is that they undergo changes which do not influence the reliability of the obtained results, just their volume.

III. Operating Restrictions in the Control of TS

The majority of the contemporary publications related to the theory of optimal control are based on the following operating restrictions:

- ➢ Prior to commencement of the control it is known that the technical object is faulty or has failed;
- ➢ Each separate check from the space of checks has one and only one of the two possible outcomes: positive or negative;
- ➢ The technical object fails when one of its elements fails;
- ➢ The space of checks is sufficient to find the failed element in case of finite number of checks.

It is necessary to note that the operating restrictions are considerable and significantly narrow the class of studied control systems. However, a cmmon solution of the problems related to the TS control, even within the framework of those strong restrictions, cannot be easily found (see the three problems of Bellman) [9, 11, 12]. Fortunately, the study of the operating efficiency is not related to the issues of optimal control.

We will be interested in the controlling elements and systems only to the extent to which we will decide which of the elements of OC has failed and requires repair (restoration). In other words, the process of control will be treated as controlling the operating capacity of the OC elements. Let us contemplate on the problem: "***In what manner and why do the controlling systems (PSP) influence the reliability (probability) specifications of OC"?***

There was a "beneficial" time when the process of control was carried out simply and easily, and the controlling elements (PSP) had reliability indexes multiple times higher than the indexes of the controlled TS. Such a situation allows not to take into account the influence of PSP on the reliablity of OC (TS). This was the time of "**absolute control**". At the end of 20th century and the beginning of 21st century, everything in science related to the control and reliability of TS changes. The methods and systems of control become more complex in an ontological and gnosiological aspect, therefore the quantitative indexes of the reliability of PSP and OC have become comparable. The most important consenquence is that the **results of the measurements with PSP stopped being a trustworthy event and turned to be a probability (stochastic) fact** [13-16]. This is especially topical in the contemporary computer diagnostics of TS and the existing diversity of testing software of the different types of manufacturers of cars, airplanes, helicopters, railway transportation systems, etc. One should bear in mind that the control system (PSP) influences the working capacity of OC(TS) any time when there is no reliable information about the condition of its elements. Therefore it is necessary to carry out a brief reliability analysis of PSP.

IV. Reliability Analysis of the Functioning of MCM

Since the results of the TS control are regarded as a probable event, the MCM is a source of true (reliable) results only when it operates in a reliable manner (under BSS the highest level of reliability of a TS is 0.999, i.e. per 1000 measurements of one and the same TS parameter, one is incorrect and related to a gross relative error). In the dialectics of the complex system the object of control (TS) and the MCM identifying its condition, the concept of reliability is regarded as a previously stipulated mutually unidirectional correspondence between the results of the control and the condition of the object of control. This gives us reasons to draw the following formula [17]:

$$P_{RW,MCM} + Q_{F,MCM} = 1 \quad (1)$$

where: $P_{RW,MCM}$ is the probability of reliability work (PRW) of the measurement and control system (MCM); $Q_{F,MCM}$ – the probability of MCM failure, i.e. the probability for the control and measurement system to provide incorrect results [17, 18].

Where OC (or its elements) are controlled by one (even summarized) parameter on the principle “failed – operating”, the probability for errors in the results of the control constitutes the sum of the probabilities for two possible errors:

- ✓ type I error with a probability of occurrence β_1, where an operating OC is determined as failed;
- ✓ type II error with a probability of occurrence β_2, where a failed OC is determined as operating (flawless).

From the above defined suppositions, the following conclusion is made:

$$Q_{F,MCM} = \beta_1 + \beta_2. \quad (2)$$

It is assumed that the change in the condition of OC does not change the nature of the MCM error but changes the results of the control. For example, if MCM work with a type I error and controls a failed TS, it would display correct results. It should be noted that β_1 and β_2 are unconditional probabilities for errors. There are also conditional probabilities for occurrence of errors in the control of TS using MCM. They are determined under the condition $Q_{F,MCM} = 1$ and are designated by γ_1 and γ_2 and determined according to:

$$\gamma_1 = \beta_1 / Q_{F,MCM} \text{ и } \gamma_2 = \beta_2 / Q_{F,MCM} \quad (3)$$

From formulas (2) and (3) it would mean that:

$$\gamma_1 + \gamma_2 = 1. \quad (4)$$

For a random value of the probability of failure $Q_{F,MCM}$ of MCM the following dependency would follow:

$$P_{RW,MCM} + Q_{F,MCM} . (\gamma_1 + \gamma_2) = 1. \quad (5)$$

Since the present work relates to restorable OC(TS), treated as complex tech-nical systems, it is appropriate to prvide updated summarized block structure of MCM of a TS with a discrete action. This has been displayed on Fig. 1.

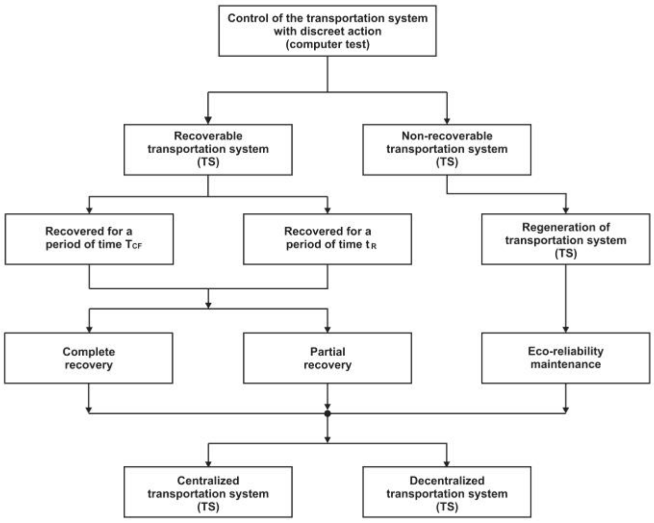

Fig. 1. Summarized block structure of MCM of TS with a discrete action

For all cases of control in the present work, a discrete control is considered, commencing at moment $t = T$, i.e. at the time of ending of the continuous functioning of TS. The permanent control in the interval for **continuous (normal) functioning** T_{CF} is of no importance, as an external interference according to the provisions of technical operation during that period is inadmissible.

Therefore, MCM of TS may be treated as an immediate action system (control carried out for a period of time t_K), notwithstanding that it is possible for it to switch on during the interval T_{CF} (e.g. for current check and preparation for switching on).

The joint functioning of TS (complex system A) and the measurement and control system MCM (system B) is shown on Fig. 2. After the end of the i - th cycle of functioning of a recoverable TO (operating interval T_{CF} of system A) MCM type B starts operating. The following requirement must be observed for this type of control:

$$t_K < 0{,}01 T_{CF} \quad (6)$$

As of the time of its switching on, system B has already failed or operates flawlessly and for the time period t_k ($t_k \neq 0$) it does not change its status. If system B is without recovery and has failed before commencement of the i -th control, it would have failed before $(i+1)$ control cycle. In other words, the control system cannot chan-ge the type of its failure (if any) (Fig. 2).

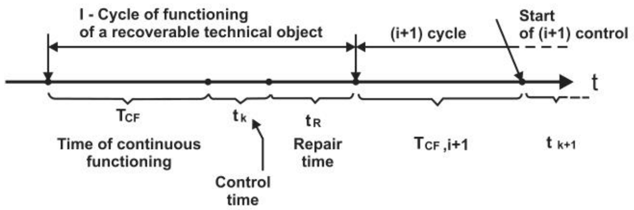

Fig. 2. Cycles of functioning of a recoverable transportation system (TS) controlled by MCM

Let us review a MCM for which the following operating restrictions are valid:

- the probability parameters ($P_{RW,MCM}, \beta_1, \beta_2$) of the control system do not de-pend on the number of operating cycles (Fig. 2);
- MCM gives correct results any time it operates flawlessly (the subjective errors of the human operator are not reported and the adopted method of control is considered to be absolute);
- the existence of errors type I and type II determine the failure of MCM (the flawlessness of MCM as OC is treated).

The functioning of a similar MCM (system B) determines some formal con-dition of system ***A*** in the i - th cycle of functioning, which differs from the factual condition of this system. What could be the results of this inconsistency, is illustrated by the definition of the operating efficiency of a complex transportation system with instant actiion of recovery of its reliability under an additive output effect [10, 11].

For the index of the operating efficiency of the studied transportation system (TS), a multiplication of the **risk** an *incident with transport system* (ITS) $R_{ITS}(\Delta t)$of occurrence of an incident with it (ITS) for a time interval Δt; the mathematical re-liability (expectation) M for the relative number of the operating functional elements of TS is made (it is assumed that system ***A***, consisting of N functional elements works continuously within the interval T_{CF}, but only carries out its task in the time interval $t = T_{CF}$ and the relation of the quantity of reliable information I_{RI} about the condition of TS, determined according to (1), towards the aggregate (total) quantity of infor-mation I_{Σ} determined by [8]:

$$I_{\Sigma} = -\sum_{i=1}^{N} p_i . \log_2 p_i \, , where \sum_{i=1}^{N} p_i = 1 . \qquad (7)$$

The above consideration leads to the following:

$$E_{TS} = R_{ITS}(\Delta t) \cdot M \left\langle \frac{N-k}{N} \right\rangle \cdot \frac{I_{RI}}{I_{\Sigma}} \qquad (8)$$

The following mathematical transformations take place:

$$M\{N-k\}/N = N - M\{k\}/N = N - k/N \, , \quad (9)$$

where $M\{k\} = k$ is the mathematical expectation of the current number of failed ele-ments k of TS for the time of continuous operation at the i - th cycle of functioning.

In formula (8) the risk $R_{ITS}(\Delta t)$ of occurrence of an ***incident with TS*** (ITS) for a time interval Δt is determined by the fundamental work of Acad. Ivan Popchev, "Risk Management Strategies", Sofia, NBU, 2004, p. 68 [9]:

$$R_{ITS}(\Delta t) = \sum_{i=1}^{n} P_i(\Delta t) . V_i(\Delta t) , \qquad (10)$$

where $P_i(\Delta t)$ is the probability of occurrence of a damage with severity $V_i(\Delta t)$ as a result of occurrence of a hazardous event or a series of events within the observation interval of the risk assessor for TS; $V_i(\Delta t)$ is the severity of the damage (damages) occurring as a result of the hazardous event (in this case ITS). The severity of the damage is measured in different units (BGN, number of idle days, number of sick leave days, polluted territories as a result of the incident, etc.); n is the number of types of damages in case of ITS.

After positioning of (10), (9) in (8) the final formula for E_{TS} : follows equation

$$E_{TS} = \sum_{i=1}^{n} P_i(\Delta t) . V_i(\Delta t) \times \{[(N - \bar{k})/N] \cdot \frac{I_{RI}}{I_{\Sigma}}\} . \qquad (11)$$

It is natural to terminate the cyclic functioning of transportation system A, if the number of failed elements $M\{k\} = k$ at the beginning of $(i+1)$ cycle, i.e. after the след i - th cycle of functioning control and the i –th recovery proves to be higher than the previously determined admissible value K_{ADM} for the total number of failures in TS. Because of the occurring discrepancy between the formal and actual condition of MCM of TS, the service staff is not able to determine the exact number of the cycle for which the following condition is met:

$$M\{k\} \leq K_{ADM} \, , \quad (12)$$

The next task is calculation of the average number of cycles for control and repair after which TS should be removed from performance of its task and should be checked using MCM with higher precision (e.g. to undergo a medium repair or overhaul in suitable laboratories and/or plants). The answer of this task is in line with the technological revolution 4.0 related to the global information society [1, 3], and the study is the subject of further scientific work.

V. CONCLUSION

1. In the presented study, a definition of security of the control of the tran-sportation systems has been synthesized.
2. A connection has been established between the process of maintaining security and reliability of the transportation systems and the quantity of information about their condition.

3. The introduced parameter of operating efficiency of the systems (tran-sportation, in particular), is an universal way of studying the dialectics of their aging and recovery.

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