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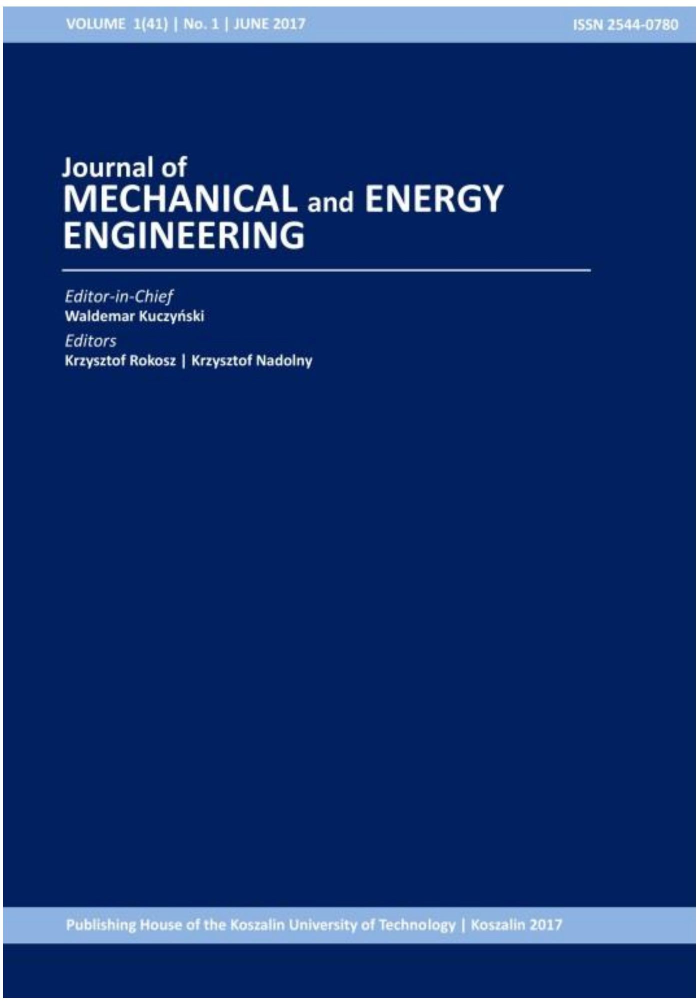

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THE OPERATIONAL-RELIABILITY ASSESSMENT OF A POWER SUPPLY FOR THE ALARM SYSTEM OF A TRANSPORT FACILITY

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Abstract: The following paper presents issues concerning a power supply for the alarm systems used in transport facilities. It describes the guidelines included in the polish standard PN-EN 50131-1:2009 „Systemy alarmowe – Systemy sygnalizacji włamania i napadu – Wymagania systemowe" (Alarm systems – intrusion and hold-up systems – system requirements), a power supply in particular. Then the operational-reliability assessment of a system consisting of a main power supply (230V AC power grid), redundant UPS and diesel generator was made. The aim of that was to obtain formulas for particular state probability values in a symbolic form (Laplace's). The further assessments taking other types of power supply into account will be presented in the forthcoming papers.

Keywords: alarm system, power supply, operation

1. INTRODUCTION

The State Security Center drafted the document entitled „Narodowy Program Ochrony Infrastruktury Krytycznej w Rzeczypospolitej Polskiej" (National Programme for Protection of Critical Infrastructure in Poland), that lists 11 particular subsystems of the critical infrastructure [14]. They are significant for normal operation of the state administration. The tasks carried out by them protect citizens against various threats (i.a. terrorist). The transport system is one of those subsystems. Therefore it is of prime importance to ensure safety of transport facilities, both stationary and mobile. The article puts pressure on operational-reliability issues [4,9,12] of a power supply for the alarm system of a transport facility [10].

The threat signaling system (i.e. electronic protection), depending on particular threats, consist of the following subsystems:

- intrusion and houl-up (SSWiN),
- fire signaling (SSP),
- access control (SKD),
- monitoring (CCTV),
- external area protection.

While facing numerous and various threats, it is important for the alarm system to provide as broad as possible counteractions and at the same time sustain the reasonable operational-reliability indicators.

One of the important aspects of this research is the assessment of a power supply for the alarm systems. Issues concerning reliability [1,3,21] in common power supply systems were outlined during the years in many references. However two of them are more significant than the others [2,20].

The reference [2] presents in details issues concerning the reliability of power systems. It shows a relation between system reliability and financial cost of its improvement. The reference also includes reliability models of power systems taking damage and repair intensities into account. The author also provides probability distributions of reliability indicators. One of the important conclusions are definitely the suggestion of reliability diagram that includes usability/unreliability states and diagram for exclusion of a device from the system during operation. It is particularly important in a view of practical applications of the over-mentioned considerations.

The reference [20] covers the reliability and quality of power supply systems. It provides a classification of different types of power grids as well as operational-reliability calculations. Selected values of the reliability indicators are also included. They can be used in considerations covering the reliability and operation of similar types of power supply systems.

Utilization of different types of redundant power sources is described in details in references [22,23]. They cover the assessments of emergency power supply systems such as: UPS, diesel generators, eco-friendly PV and wind turbines. Analysis conducted on those solutions allows to formulate a conclusion that they increase the operational-reliability indicators.

Some references include the electromagnetic interferences and their influence on the surroundings [8,11,18]. Others presents powers supply systems in a legislative point of view [5,6]. However, there is an evident lack of detailed assessments of solutions to the power supply problem. Therefore this articles is meant to fill this gap.

2. POWER SUPPLY FOR ALARM SYSTEMS

One the most commonly used alarm system is the intrusion and hold-up system. Basic guidelines concerning the design and functionality of this system are included in the european standard EN 50131-1:2006 „Alarm systems – Intrusion and hold-up systems – Part 1: System requirements" (equivalent of polish standard PN-EN 50131-1:2009 „Systemy alarmowe - Systemy sygnalizacji włamania i napadu - Wymagania systemowe"). This elaboration includes i.a. list of basic components of the SSWiN:

- control panel,
- one or more sensors,
- one or more signalers and/or alarms transmission systems,
- main power supply,
- redundant power supply.

The design, installation and operation of the intrusion and hold-up system for facilities of the critical infrastructure requires wide knowledge and experience from the designer, installer and end-user. Therefore it is important to design the system with accordance to the guidelines included in the standards, and to obtain the satisfactory operational-reliability indicators at the same time.

Transport facilities considered as elements of critical infrastructure usually cover vast area and require the intrusion and hold-up system of a mixed structure. An example of such system is shown in Fig. 1. The main component is the control panel connected to various modules via digital transmission buses. Modules perform various functions depending on size and purpose of the protected facility, e.g.:

- increase number of inputs,
- increase number of outputs,
- grant supervision over controlled passages,
- grant wire-less connections.

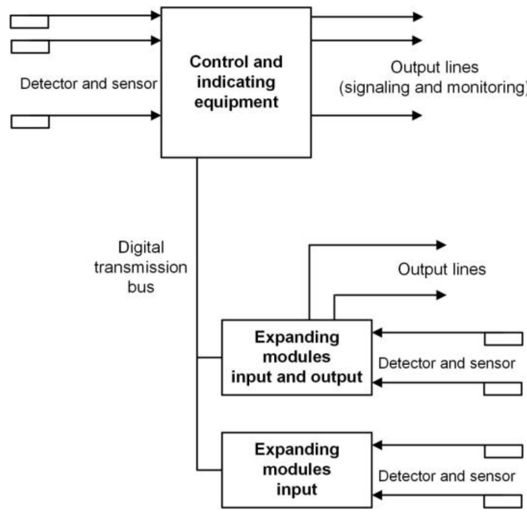

Fig. 1. Intrusion and hold-up systems of mixed structure

One of the most important issues during the design of the hard-wired intrusion and hold-up systems is the proper selection and design of the main and redundant power supply. The standard „Alarm systems – Intrusion and hold-up systems – Part 1: System requirements" [7] distinguish the following types of power supplies used in the intrusion and hold-up systems:

- type A: main and redundant power supply which is controlled and charged by intrusion and hold-up system (e.g. main power supply – power grid 230V AC; redundant power supply – battery charged by SSWiN),
- type B: main and redundant power supply which is not charged by intrusion and hold-up system (e.g. main power supply – power grid 230V AC; redundant power supply – battery, not charged),
- type C: main power supply of finite capacity (e.g. battery).

A type A power supply is shown in Fig. 2. This solution for the intrusion and hold-up system is characterized by the main power supply which is used during the normal operation. In case of impendency of the main power supply, an automatic switch to the redundant power supply occurs (UPS).

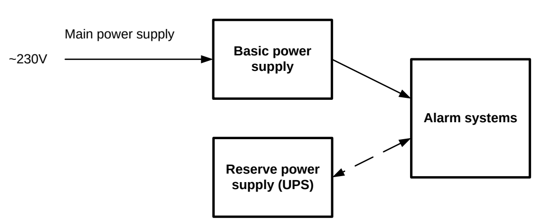

Fig. 2. Example of type A power supply for alarm system

During a long-time operation of a power supply of the alarm systems used in transport facilities [13], various factors can cause transition from complete usability into impendency over safety. In order to increase a probability of complete usability state, various solutions are employed. One of them is the introduction of an additional power source. Therefore, if apart from the main power supply from power grid 230V AC, there are redundant UPS and diesel generator, then a power supply system looks as shown in Fig. 3.

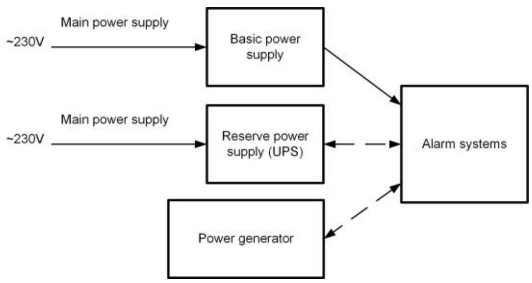

Fig. 3. Example of power supply systems with three power sources

While analyzing the power supply system shown in Fig. 3, one can conclude that its operational-reliability relations look like the diagram in Fig. 4.

The complete usability S_{PZ}, is a state in which all three power sources are available (main and two redundant). The impendency over safety S_{ZB1}, is a state in which the main power source, 230V AC, is impendent. The impendency over safety S_{ZB2}, is a state in which the main power source and the redundant UPS are impendent. The unreliability of safety S_B, is a state in which all three power sources are impendent.

While operating in the complete usability S_{PZ}, in case of a damage of the main power source, 230V AC, the transition into the impendency over safety S_{ZB1} occurs with the intensity λ_{ZB1}. While operating in the impendency over safety S_{ZB1}, the transition into the complete usability S_{PZ} is possible if measures aimed to restore the main power source, 230V AC, are employed.

While operating in the impendency over safety S_{ZB1}, in case of a damage of the redundant UPS, the transition into the impendency over safety S_{ZB2} occurs with the intensity λ_{ZB2}. While operating in the impendency over safety S_{ZB2}, the transition into the impendency over safety S_{ZB1} is possible if measures aimed to restore the redundant UPS are employed.

While operating in impendency over safety S_{ZB2}, in case of damage of the diesel generator, transition into unreliability of safety S_B occurs with intensity λ_{ZB3}. While operating in unreliability of safety S_B, transition into impendency over safety S_{ZB2} is possible if measures aimed to restore the diesel generator are employed.

While operating in the impendency over safety S_{ZB2}, the transition into the complete usability S_{PZ} is possible in case of restoration of two power sources, i.e. main 230V AC and redundant UPS.

The system shown in Fig. 4 can be described using the following Kołmogorow-Chapman equations:

$$R_0'(t) = -\lambda_{ZB1} \cdot R_0(t) + \mu_{PZ1} \cdot Q_{ZB1}(t) + \mu_{B0} \cdot Q_{ZB2}'(t)$$

$$Q_{ZB1}'(t) = \lambda_{ZB1} \cdot R_0(t) - \mu_{PZ1} \cdot Q_{ZB1}(t) - \lambda_{ZB2} \cdot Q_{ZB1}(t) + \\ + \mu_{PZ2} \cdot Q_{ZB2}(t)$$

$$Q_{ZB2}'(t) = \lambda_{ZB2} \cdot Q_{ZB1}(t) - \mu_{PZ2} \cdot Q_{ZB2}(t) - \lambda_{ZB3} \cdot Q_{ZB2}(t) + \\ + \mu_{PZ3} \cdot Q_B'(t) - \mu_{B0} \cdot Q_{ZB2}'(t)$$

$$Q_B'(t) = \lambda_{ZB3} \cdot Q_{ZB2}(t) - \mu_{PZ3} \cdot Q_B'(t)$$

Assuming the following initial conditions:

$$R_0(0) = 1$$

$$Q_{ZB1}(0) = Q_{ZB2}(0) = Q_B(0) = 0$$

and after the Laplace transformation, the following set of equations is obtained:

$$s \cdot R_0^*(s) - 1 = -\lambda_{ZB1} \cdot R_0^*(s) + \mu_{PZ1} \cdot Q_{ZB1}^*(s) + \mu_{B0} \cdot Q_{ZB2}^*(s)$$

$$s \cdot Q_{ZB1}^*(s) = \lambda_{ZB1} \cdot R_0^*(s) - \mu_{PZ1} \cdot Q_{ZB1}^*(s) - \lambda_{ZB2} \cdot Q_{ZB1}^*(s) + \\ + \mu_{PZ2} \cdot Q_{ZB2}^*(s)$$

$$s \cdot Q_{ZB2}^*(s) = \lambda_{ZB2} \cdot Q_{ZB1}^*(s) - \mu_{PZ2} \cdot Q_{ZB2}^*(s) - \lambda_{ZB3} \cdot Q_{ZB2}^*(s) + \\ + \mu_{PZ3} \cdot Q_B^*(s) - \mu_{B0} \cdot Q_{ZB2}^*(s)$$

$$s \cdot Q_B^*(s) = \lambda_{ZB3} \cdot Q_{ZB2}^*(s) - \mu_{PZ3} \cdot Q_B^*(s)$$

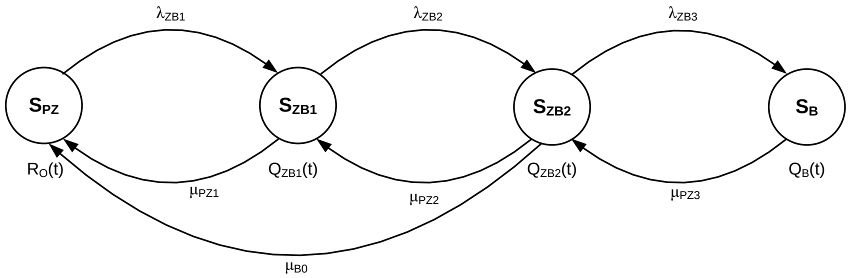

Fig. 4. Relations of power supply for intrusion and hold-up system

State probabilities of the highlighted states in a symbolic form (Laplace) look as follow:

$$R_0^*(s) = \frac{b\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - b\cdot c\cdot d\cdot s + d\cdot s\cdot\lambda_{ZB2}\cdot\mu_{PZ2}}{a\cdot b\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - \lambda_{ZB1}\cdot\mu_{PZ1}\cdot\lambda_{ZB3}\cdot\mu_{PZ3} + a\cdot d\cdot s\cdot\lambda_{ZB2}\cdot\mu_{PZ2} + c\cdot d\cdot s\cdot\lambda_{ZB1}\cdot\mu_{PZ1} + d\cdot s\cdot\mu_{B0}\cdot\lambda_{ZB1}\cdot\lambda_{ZB2} - a\cdot b\cdot c\cdot d\cdot s}$$

$$Q_{ZB1}^*(s) = \frac{\lambda_{ZB1}\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - c\cdot d\cdot s\cdot\lambda_{ZB1}}{a\cdot b\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - \lambda_{ZB1}\cdot\mu_{PZ1}\cdot\lambda_{ZB3}\cdot\mu_{PZ3} + a\cdot d\cdot s\cdot\lambda_{ZB2}\cdot\mu_{PZ2} + c\cdot d\cdot s\cdot\lambda_{ZB1}\cdot\mu_{PZ1} + d\cdot s\cdot\mu_{B0}\cdot\lambda_{ZB1}\cdot\lambda_{ZB2} - a\cdot b\cdot c\cdot d\cdot s}$$

$$Q_{ZB2}^*(s) = -\frac{d\cdot s\cdot\lambda_{ZB1}\cdot\lambda_{ZB2}}{a\cdot b\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - \lambda_{ZB1}\cdot\mu_{PZ1}\cdot\lambda_{ZB3}\cdot\mu_{PZ3} + a\cdot d\cdot s\cdot\lambda_{ZB2}\cdot\mu_{PZ2} + c\cdot d\cdot s\cdot\lambda_{ZB1}\cdot\mu_{PZ1} + d\cdot s\cdot\mu_{B0}\cdot\lambda_{ZB1}\cdot\lambda_{ZB2} - a\cdot b\cdot c\cdot d\cdot s}$$

$$Q_B^*(s) = -\frac{\lambda_{ZB1}\cdot\lambda_{ZB2}\cdot\lambda_{ZB3}}{a\cdot b\cdot\lambda_{ZB3}\cdot\mu_{PZ3} - \lambda_{ZB1}\cdot\mu_{PZ1}\cdot\lambda_{ZB3}\cdot\mu_{PZ3} + a\cdot d\cdot s\cdot\lambda_{ZB2}\cdot\mu_{PZ2} + c\cdot d\cdot s\cdot\lambda_{ZB1}\cdot\mu_{PZ1} + d\cdot s\cdot\mu_{B0}\cdot\lambda_{ZB1}\cdot\lambda_{ZB2} - a\cdot b\cdot c\cdot d\cdot s}$$

where:

$$a = s + \lambda_{ZB1}$$

$$b = s + \mu_{PZ1} + \lambda_{ZB2}$$

$$c = s + \mu_{PZ2} + \lambda_{ZB3} + \mu_{B0}$$

$$d = s + \mu_{PZ3}$$

In further analysis, formulas for state probabilities of: complete usability S_{PZ}, impendences over safety S_{ZB1} and S_{ZB2} as well as unreliability of safety S_B are obtained.

3. CONCLUSIONS

The analysis presented in this paper concerned power supply of the alarm systems that provide an adequate protection to transport facilities. Using the guidelines included in the standard „PN-EN 50131-1:2009: Alarm systems – Intrusion and hold-up systems – Part 1: System requirements", schemes for power supply system consisting of three subsystems: power grid 230V AC, redundant UPS and diesel generator were presented. The operational-reliability assessment of this power supply of the alarm system, made it possible to derive the set of equations. Using those equations, it is now possible to calculate the state probabilities of: complete usability S_{PZ}, impendences over safety S_{ZB1} and S_{ZB2} as well as unreliability of safety S_B. In the forthcoming considerations, an analysis taking other power supplies of the alarm systems into account are planned.

Nomenclature

Symbols

t – time, h
S_{PZ} – complete usability
S_{ZB1} – impendency over safety 1
S_{ZB2} – impendency over safety 2
S_B – unreliability of safety
$R_O(t)$ – complete usability state probability value
$Q_{ZB1}(t)$ – impendency over safety 1 state probability value
$Q_{ZB2}(t)$ – impendency over safety 2 state probability value
$Q_B(t)$ – unreliability of safety state probability value

Greek letters

λ – transition intensity, 1/h
μ – transition intensity, 1/h
λ_{ZB1} – transition intensity from complete usability S_{PZ} into unreliability of safety S_{ZB1}
λ_{ZB2} – transition intensity from unreliability of safety S_{ZB1} into impendency over safety S_{ZB2}
λ_{ZB3} – transition intensity from impendency over safety S_{ZB2} into unreliability of safety S_B
μ_{ZB1} – transition intensity from impendency over safety S_{ZB1} into complete usability S_{PZ}
μ_{ZB2} – transition intensity from impendency over safety S_{ZB2} into impendency over safety S_{ZB1}
μ_{ZB3} – transition intensity from unreliability of safety S_B into impendency over safety S_{ZB2}
μ_{B0} – transition intensity from impendency over safety S_{ZB2} into complete usability S_{PZ}

Subscripts

O – complete usability
$ZB1$ – impendency over safety 1
$ZB2$ – impendency over safety 2

$_B$ – unreliability of safety

Acronyms

AC – alternating current
CCTV – closed circuit television
EN – European standard
PN – Polish standard
SKD – access control system
SSP – fire signaling system
SSWiN – intrusion and hold-up system
UPS – uninterruptible power supply

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