Reliability Analysis of Power Supply Systems for Devices Used in Transport Telematic Systems

Mirosław Siergiejczyk and Adam Rosiński

Faculty of Transport, Warsaw University of Technology
Koszykowa 75, 00-662 Warsaw, Poland
{msi,adro}@it.pw.edu.pl

Abstract. The paper presents questions connected with the transport telematic systems. One of the most important attributes of telematic systems is the data transfer and transmission. The transmitters and receivers applied require reliable power feeding sources. Therefore, buffer power supply units are used that cooperate with backup power sources, such as rechargeable electrical power sources (batteries).

Keywords: reliability, power supply, process of exploitation.

1 Introduction

One of the most important attributes of telematic systems is the data transfer and transmission, namely its flow. The telematic data flow is related directly to telecommunications, or a remote transmission of messages via various types of signals – nowadays mostly electrical or optical signals. Both wired and wireless media (e.g. GSM, radio lines) are used for transmission. The transmitters and receivers applied require reliable power feeding sources. Therefore, buffer power supply units are used that cooperate with backup power sources, such as rechargeable electrical power sources (batteries). The paper presents a reliability analysis of such type of devices.

2 Power Supply Systems for Devices Used in Transport Telematic Systems

Buffer power supply units are the power supply systems that are commonly used in transport telematic systems. They are supplied with a primary voltage (~ 230V AC) and co-operate with lead-acid, dry battery. It provides a backup power supply (-12 V DC). Then, the power supply unit controls the process of battery charging and maintenance automatically. It should also automatically perform a dynamic test of the battery and provide protection against excessive discharge. This has been illustrated on the diagram in Fig. 1. In addition, they are very often equipped with optical and (or) acoustic signalling that informs about its operating status. It may also be provided to technical outputs to remotely control the operation of a power supply system.

J. Mikulski (Ed.): TST 2011, CCIS 239, pp. 314–319, 2011.

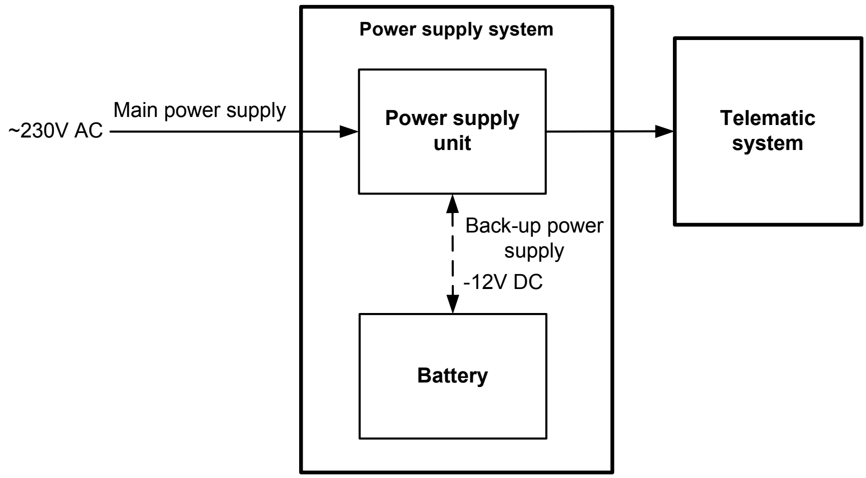

Fig. 1. Power feeding diagram using a buffer power supply unit

The power supply units hereto presented interact with many other systems and external environment, and they may contain a lot of component subsystems [5], [6]. The information about their technical condition is very often transferred to the transportation management centre. For this reason, a significant role in those systems is played by power supply systems. Fig. 2 illustrates an example of a telematic system. Regardless of whether this is the transportation management centre or a supervised by it local telematic system, they have the main power supply of 230 [V] AC and the backup power supply, namely: a rechargeable source of energy in the form of battery (usually 12 [V] DC). The values that characterize the reliability-operational indices should be appropriate [3,4]. Therefore, the issue of reliability analysis of power supply systems for devices that are used in transport telematic systems as well as the determination of selected reliability-operational indices grows so much in its importance [1] ,[2], and [7].

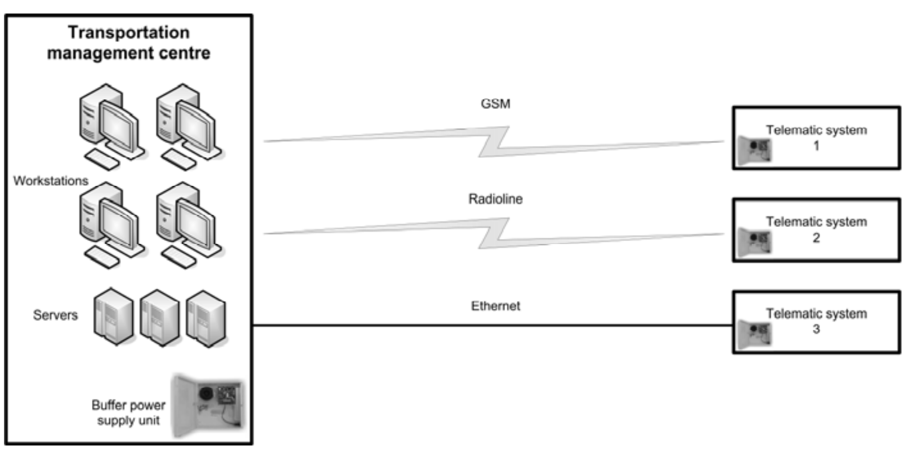

Fig. 2. Example of telematic system diagram

3 Reliability Analysis of Power Supply Systems for Devices Applied in Transport Telematic Systems

By analysing the power supply systems for devices used in transport telematic systems, the relationships that occur in a given system in terms of its safety can be illustrated (Fig. 3).

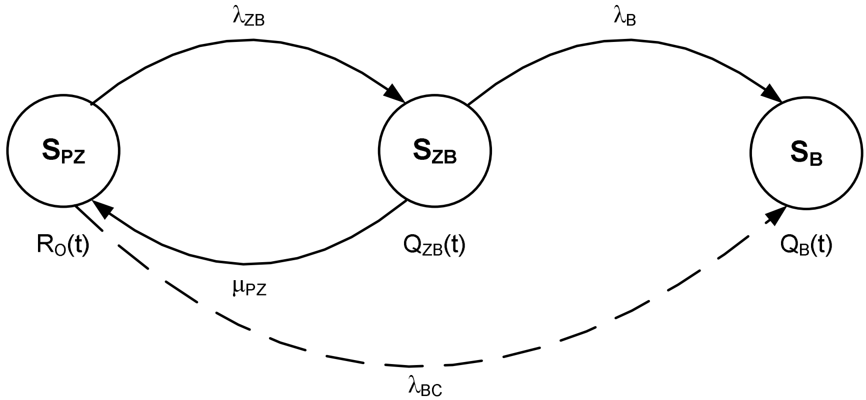

Fig. 3. Relationships in the system

Denotations in the figure:
$R_O(t)$ – the probability function for a device to stay in the state of full fitness,
$Q_{ZB}(t)$ – the probability function for a device to stay in the state of endangered safety,
$Q_B(t)$ – the probability function for a device to stay in the state of safety failure,
λ_{ZB} – the intensity of transitions from the state of full fitness to the state of endangered safety,
μ_{PZ} – the intensity of transitions from the state of endangered safety to the state of full fitness,
λ_B – the intensity of transitions from the state of endangered safety to the state of safety failure,
λ_{BC} – the intensity of transitions from the state of full fitness to the state of safety failure.

The system presented in Fig. 3 can be described by the following Kolmogorov-Chapman's equations (in further considerations, it has been assumed that the intensity of transitions from the state of the full fitness to the state of security failures $\lambda_{BC} = 0$. It is dictated by the fact that during the normal process of those devices operation such transition does not occur. Such situation is currently being only considered and theoretically analysed by the authors of this paper):

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

Assuming the initial conditions:

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

The following linear set of equations is received using the Laplace Transform:

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

Using the inverse transforms, we obtain:

$$R_0(t) = \left[\begin{array}{l} \cos\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2} \right) + \\ + \frac{\mu_{PZ} + \lambda_B - \lambda_{ZB}}{\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2}} \cdot \\ \cdot \sin\left(\sqrt{2 \cdot \lambda_{ZB} \cdot (\mu_{PZ} + \lambda_B) - 4 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2} \right) \end{array} \right] \cdot \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \mu_{PZ} + \lambda_B}{2} \right) \cdot t \right] \tag{4}$$

$$\begin{aligned} Q_{ZB}(t) = {} & \frac{2 \cdot \lambda_{ZB}}{\sqrt{2 \cdot \lambda_{ZB} \cdot \lambda_B - 2 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2}} \cdot \\ & \cdot \sin\left(\sqrt{2 \cdot \lambda_{ZB} \cdot \lambda_B - 2 \cdot \mu_{PZ} \cdot \lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ} + \lambda_B)^2} \cdot \frac{t}{2} \right) \cdot \\ & \cdot \exp\left[-\left(\frac{\lambda_{ZB} + \mu_{PZ} + \lambda_B}{2} \right) \cdot t \right] \end{aligned} \tag{5}$$

$$Q_B(t) = 1 - \left[\begin{array}{l} \cos\left(\sqrt{2\cdot\lambda_{ZB}\cdot(\mu_{PZ}+\lambda_B) - 4\cdot\mu_{PZ}\cdot\lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ}+\lambda_B)^2} \cdot \frac{t}{2} \right) + \\ + \frac{\mu_{PZ}+\lambda_B+\lambda_{ZB}}{\sqrt{2\cdot\lambda_{ZB}\cdot(\mu_{PZ}+\lambda_B) - 4\cdot\mu_{PZ}\cdot\lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ}+\lambda_B)^2}} \cdot \\ \cdot \sin\left(\sqrt{2\cdot\lambda_{ZB}\cdot(\mu_{PZ}+\lambda_B) - 4\cdot\mu_{PZ}\cdot\lambda_{ZB} - \lambda_{ZB}^2 - (\mu_{PZ}+\lambda_B)^2} \cdot \frac{t}{2} \right) \end{array} \right] \cdot \cdot \exp\left[-\left(\frac{\lambda_{ZB}+\mu_{PZ}+\lambda_B}{2} \right) \cdot t \right] \quad (6)$$

The relations obtained allow determining the probabilities for a buffer power supply unit to stay in the states of full fitness R_O, endangered safety Q_{ZB}, and safety failure Q_B.

The relations presented allow developing the reliability of power supply systems for devices already at their designing stage. This is possible inter alia by matching elements with suitable values of their reliability indices. At the same time, they allow to optimise the performance process of those devices through maximising the probability values of staying in the state of full fitness.

4 Conclusion

Telematic systems are nowadays a very large group that affects the safety of travelling. They include the management center that cooperates with local telematic systems. In order to ensure the data flow, it is essential to use different types of transmission media without which the data transmission would be impossible. The transmission media are used both to ensure fast and reliable communication with wide area systems, which require massive amounts of data transmission over long distances, and to transmit simple control messages or a simple measurement data from sensors over short distances. However, it is necessary for all of them to apply power supply systems with respective values of reliability indices. This can be ensured by using power supply systems with rechargeable sources of energy in the form of a battery.

The reliability and operational analysis of buffer power supply units, presented in this paper, has enabled to determine the relations allowing calculating the values of probabilities for the hereto discussed devices to stay in the states of: full fitness, endangered safety and safety failure.

The application of the hereto presented methodology of the reliability and operational analysis allows for increasing the values of reliability indices of the telematic systems being designed. This is possible through analyses and simulations, allowing matching power supply systems, having specific reliability and operational indicators, with the design requirements.

References

1. Będkowski, L., Dąbrowski, T.: The Basis of Exploitation, Part II: The Basis of Exploational Reliability. Military University of Technology, Warsaw (2006)
2. Jaźwiński, J., Ważyńska-Fiok, K.: System Safety. PWN, Warsaw (1993)
3. Rosiński, A.: Design of Electronic Protection Systems with Utilization of the Method of Analysis of Reliability Structures. In: Nineteenth International Conference on Systems Engineering (ICSEng 2008), Las Vegas, USA (2008)
4. Rosiński, A.: Reliability Analysis of the Electronic Protection Systems with Mixed – Three Branches Reliability Structure. In: International Conference European Safety and Reliability (ESREL 2009), Prague, Czech Republic (2009)
5. Siergiejczyk, M.: Maintenance Effectiveness of Transport Telematics Systems, Scientific Works of the Warsaw University of Technology, Transport Series, No. 67, Warsaw (2009)
6. Wawrzyński, W., Siergiejczyk, M., et al.: Final Report on Grant KBN 5T12C 06625. Methods for Using Telematic Measures to Support Realisation of Transport Tasks, Warsaw (2007)
7. Ważyńska-Fiok, K., Jaźwiński, J.: Reliability of Technical Systems. PWN, Warsaw (1990)