Models of Fault-Tolerant Systems for Uninterruptible Power Supplies

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Abstract – **in this paper analytical reliability models as discrete-continuous stochastic systems are given, which are intended for a design of fault-tolerant systems for uninterruptible power supplies.**

Keywords – **uninterruptible power supply, combined structure redundancy, design for reliability.**

I. INTRODUCTION

Designers of uninterruptible power supplies for a radioelectronic equipment of critical applications pay great attention to the problem of reliability [1]. Informational sources determine the requirements for the reliability of UPS [2, 3] and ways to ensure it through the use of fault-tolerant systems with the appropriate configuration [1, 4, 5, 7]. There is often used combined structural redundancy in fault-tolerant systems which are widely used in the practice of designing of UPS [4, 7].

Often there is noted UPS's high reliability in the product catalogues though the specific values of reliability indexes are not given [6]. In our opinion, this is due to the lack of reliability models of UPS, and experimentally determined reliability indexes can be obtained only after a continuous operation. The need to calculate reliability indexes using non-experimental ways leads to a reliability analysis using simplified models, which tend to give too low or too high values of reliability indexes.

Thus, the problem of development of reliability models of UPS with combined structural redundancy is actual and requires its solution.

II. CONFIGURATIONS OF FAULT-TOLERANT SYSTEMS FOR UNINTERRUPTIBLE POWER SUPPLIES

A typical configuration of fault-tolerant systems for UPS is given in [7]. The report presents the reliability models for the following modifications of the configuration of the fault-tolerant system for UPS:

1) UPS with modular structure, using permanent active redundancy of modules with the load redistribution after the module failure, and the general redundancy of power supply by one accumulator battery.
2) UPS with modular structure, using sliding stand-by redundancy of working configuration's modules, and general redundancy of the power supply by one or two accumulator batteries.
3) UPS with modular structure, using sliding stand-by redundancy of working configuration's modules, the general redundancy of power supply by two accumulator battery groups, and the general redundancy of the monitoring module with the distribution of functions between primary and backup monitoring modules.
4) UPS with modular structure, using sliding stand-by redundancy of working configuration's modules, the general redundancy of power supply by two batteries, a generator, which provides a general reserve of unreliable power network, and automatic switch which performs switching of power supply to generator and to power network.

There is used maintenance for UPS, which can be provided by strategies of preventive or corrective maintenance. UPS must provide necessary power taking in account failures in power supply and, if necessary, must provide protection against interruption in power supply from network. When module fails in power supply UPS operates autonomously using accumulator battery. Operation recovery of power supply is provided due to the redundancy and repair service. The effectiveness of the accumulator battery is determined by its parameters: discharge, charge, and self-discharge duration, mean time to critical failure (or the number of cycles of charge/discharge).

In the case of commutation means failure UPS fails when the signal comes from monitoring and diagnosis means. The effectiveness of monitoring and diagnosis means is determined by selected methods and reliability of means (a hardware and a software), which provide their functions. If malfunction of power supply or accumulator battery is not detected (at the moment of the switching accumulator to load) UPS fails. If unsuccessful at localizing the failed module, the serviceable module is removed from the working configuration of the power supply.

III. BRIEF DESCRIPTION OF THE DEVELOPED MODELS OF THE FAULT-TOLERANT SYSTEMS FOR THE UNINTERRUPTIBLE POWER SUPPLY

For creation of analytical models for fault-tolerant systems for UPS there is used modeling technology, which includes the development of an intermediary model as a graph of states and transitions. Development and analysis of the graph for complicated systems is a time-consuming task. Reliability models of UPS have been developed using advanced technology of modeling of fault-tolerant systems [7], where the formation of the graph of states and transitions is automated, which is important when there is a large number of variants of configurations to be analyzed. This technology is implemented in software module ASNA-1. According to this technology structural-automatic models of fault-tolerant system for UPS have been developed and have been included to the library of reliability models for the UPS design for reliability.

The developed models have a high level of adequacy, which is provided by taking in account that:

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- models include modules of working configuration failures in the power supply, unreliable switching means (load from the power supply to accumulator battery switch and vice versa, the connection of sliding reserve module to a working configuration, connection of the accumulator battery to the charger), unreliable monitoring and diagnostics means, accumulator battery parameters, as well as efficiency of the repair service;
- in case of unreliable monitoring module must be taken into account the intensity of his failures is used;
- in case of unreliability of the power network must be taken into account the intensity of network failures and recoveries are used, and the connection of a load to a generator and vice versa are used.

IV. Design for reliability tasks

Design for reliability of uninterruptible power supply includes the solution of such problems:

- determination of the selected fault-tolerant system's configuration parameters for a given value of reliability index, such as UPS's mean time to critical failure;
- reasoning of the selection of fault-tolerant system for UPS;
- determination of repair service's parameters for a given reliability index, such as UPS's as mean time to critical failure;

To solve these problems one must possess the reliability models of a high level of adequacy.

V. The example of design for reliability problem solution

A necessary value of UPS's reliability index can be provided by several ways: increase in the number of reserve modules, increase in the reliability of modules in working configuration of the power supply, installing batteries with the better parameters, increased requirements to the repair service. However, changing each of these parameters will affect the overall UPS's reliability in different way. It should be noted that some specific set of parameters will determine how the UPS's reliability would be sensitive to change in other parameters. So, actual problem is to determine the dependence of sensitivity of the reliability index on changing the UPS's fault-tolerant system's configuration and maintenance parameters, with different sets of values of other parameters of UPS. The values of other parameters can be also specified for certain situations, which are determined by feasibility (technical, economic, etc.).

As an example, there can be presented the results of determination of the dependence of the UPS's reliability index (mean time to critical failure) on the ratio of the mean repair time to UPS's module mean time to failure (Fig. 1), and on the ratio of the mean battery discharge time to the mean repair time (Fig. 2).

The results presented in Fig. 1 and Fig. 2 illustrates the capabilities of the reliability models in the design of fault-tolerant systems for UPS (in this case, in solution of the problem of providing the requirements for repair service and accumulator batteries).

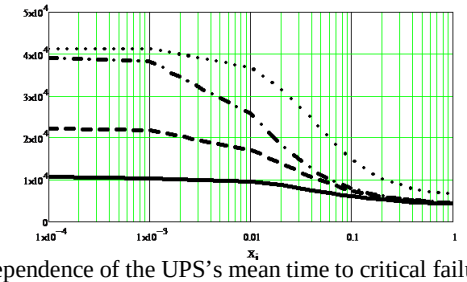

Fig.1. Dependence of the UPS's mean time to critical failure on the ratio of the mean repair time to UPS's module mean time to failure

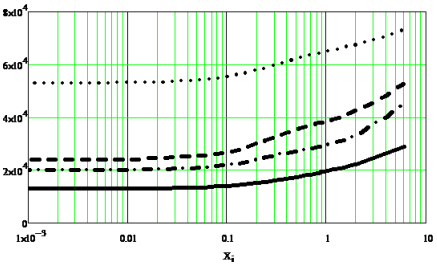

Fig.2. Dependence of the UPS's mean time to critical failure on the ratio of the mean battery discharge time to the mean repair time

VI. Summary

The developed reliability models of fault-tolerant systems for uninterruptible power supply can solve the above list of problems which are urgent for their design.

Models serves as a tool for the designer that helps to answer the question: which change of the parameters will give the biggest increase in reliability, and find values of parameters of selected configuration of a fault-tolerant system of uninterruptible power supply for provision of a given value of the reliability index.

Developed reliability models included to the library of reliability models for the UPS design for reliability.

References

[1] A. Barskov "Fault-tolerant uninterruptible power supplies: modular or monoblock?" - 2009. – Access mode: http://www.iksnavigator.ru/vision/2910564.html

[2] Power supply of Data Center (DC) – Access mode: http://www.policom.ru/solution/engineering/power.php?sphrase_id=2533479

[3] Electrical Installations Code (EIC) - Access mode: http://www.elec.ru/library/direction/pue.html

[4] Solutions for improvement in the reliability of systems of uninterruptible power supply - Abiteh - Access mode: http://www.abitech.ru/solutions/improve_system_reliability_UPS.php

[5] E. Spears "Parallel UPS configurations" – Eaton – 2009 - Access mode: http://www.eaton.com/Electrical/USA/WhitePapers/idcplg?IdcService=GET_FILE&RevisionSelectionMethod=LatestReleased&Rendition=Primary&dDocName=WP09-02

[6] Product Catalogue of Company "Integral" - Access mode: http://integral.pp.ua/downloads1.html

[7] B. Volochiy. "Technology of modeling of the informational system's algorithms of behavior. – Lviv - Lviv Polytechnic National Univ., 2004. - 220 pp.