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Calculation of an SPTA set using the Dialog computer simulation system (Part 1. General provisions for the calculation of an SPTA set)

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Abstract. *The paper describes the design concept of the DIALOG simulation software suite (SSS) intended for calculating the dependability indicators of electronic systems (ES) of random configuration, as well as solving problems associated with assuring the functional dependability of such systems. The DIALOG SSS employs a specially designed DIALOG-SINTEZ technology that enables automatic synthesis of event simulation models in the form of programs in the selected programming language. In DIALOG SSS, the input data include: system composition in the form of a combination of conventional blocks; criteria of failure event occurrence and repairs; random value parameters (failures of system components in various modes of operation, SPTA requests, etc.); stages of system operation and types of repairs; list of calculated indicators. For the purpose of ensuring the required indicators, the simulation models undergo statistical testing under modified indicators of random values in each new test. Based on the accumulated results of all the performed tests the required indicators are calculated. The DIALOG SSS consists of four components: DIALOG-NRS is intended for the calculation of dependability indicators of non-repairable redundant systems; DIALOG-RRS is intended for the calculation of dependability indicators of repairable redundant systems, as well as the number of and cost of warranty repairs; DIALOG-ZIP-NS is intended for SPTA sets calculation for simple non-redundant systems; DIALOG-ZIP-RS is intended for SPTA sets calculation for any redundant systems. SPTA set calculation is normally done using standard procedures described in regulatory documents. In solving the direct problem of optimal SPTA set calculation, the input data includes the required value of one of the two SPTA sufficiency indicators (SI) and type of costs that are to be optimized (minimized) in order to achieve the target values of SI. In solving the inverse problem of optimal SPTA set calculation, it is required to ensure the specified costs of the initial SPTA supply. As the SPTA supply SI, the mean spare parts (SP) supply delay time out of SPTA* $t_{d.SPTA}$ *and SPTA availability coefficient* $C_{a.SPTA}$ *are used. SPTA optimization using the DIALOG-ZIP SSS allows improving user options through the following additional characteristics: SPTA SP failure logging; optimization of SP count and accounting for the their characteristic features for the purpose of SP emergency delivery (ED); capability to use products with any type of redundancy; when using SPTA-G group set, capability to include differently-structured products into ESs. The paper sets forth the structure diagram of the DIALOG SSS programs interaction, that implies three modes of operation of the simulation model: SI calculation for specific SPTA contents; calculation of preliminary SPTA supply before the beginning of optimization; calculation of optimal SPTA set. The authors examine the matters related to the selection of the required number and duration of simulation model testing.*

Keywords: *simulation, SPTA set, SPTA sufficiency indicators, methods of calculating and estimating SPTA indicators.*

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DIALOG simulation software suite (SSS)

As of late, simulation has become a widely used tool for researching the behaviour and identifying various characteristics of ESs [1], [2].

The DIALOG SSS is intended for calculating the dependability indicators of ESs of any configuration, as well as solving problems associated with assuring their functional dependability. The indicators are calculated using simulation models.

The development of such models has the following distinctive characteristics: the model is to accurately reflect the details of a system's behaviour when affected by failures, in the course of repairs, under control inputs, etc. That can be achieved through universal high-level languages [4] and development of event-oriented models [3]. However, developing such models is associated with significant costs and is time-consuming.

In order to solve this problem, the DIALOG SSS employs a specially designed DIALOG-SINTEZ technology that – based on the description of the simulated system – enables automatic synthesis of event simulation models in the form of program source code in the selected programming language.

The development of simulation models using this process is based on the following properties of the considered systems:

– if a system's behaviour, when affected by failures of its components, is determined only by its composition, connections between components and criteria of failure occurrence, the structure of event models and their fragments for systems with various configurations can be made identical;

– the operating diagram of such a system's dependability can be presented as a combination of conventional blocks, the number of the types of which is limited and sufficient for describing the system.

That will allow creating a common foundation for all models of the selected type, and the input data that defines the configuration and specificity of each system's behaviour can be in the form of modifications or additions to the model foundation.

DIALOG-SINTEZ uses the following tools:

– a template that is a set of model fragments in the selected programming language;

– programs for preparation of input data saved as text files;

– simulation model synthesis program that transforms the text files that describe the system into model fragments and integrates them with the template. The result is an event simulation model in the original programming language. In DIALOG, Fortran and a library of specialized subprograms are used for that purpose.

The event-oriented nature of the synthesized models along with the use of a universal programming language allows reproducing a system's behaviour with any level of accuracy, while automatic synthesis makes model creation several times faster and simpler by doing away with the stage of programming. The time taken to create a model is primarily defined by the time of input data preparation.

Below are the input data used for synthesis in the DIALOG SSS:

– system composition in the form of a combination of conventional blocks;

– criteria of failure and repair occurrence;

– random value parameters, i.e. system component failures in various modes, requests to SPTA, etc.;

– stages of system operation and types of repairs;

– list of calculated indicators.

For the purpose of ensuring the required indicators, the simulation models undergo statistical testing under modified random values in each new test. Based on the accumulated results of all the performed tests, the required indicators are calculated.

The DIALOG SSS consists of four components:

– Part 1. DIALOG-NRS is intended for the calculation of dependability indicators of non-repairable redundant systems;

– Part 2. DIALOG-RRS is intended for the calculation of dependability indicators of repairable redundant systems, as well as the nu mber of and cost of warranty repairs;

– Part 3. DIALOG-ZIP-NS is intended for STPA sets calculation for simple non-redundant systems;

– Part 4. DIALOG-ZIP-RS is intended for STPA sets calculation for any redundant systems.

The DIALOG-NRS SSS allows identifying the following dependability indicators:

a) probability of no-failure (PNF) within the specified time t, $R(t)$;

b) mean time to failure, T_f;

c) gamma-percentile time to failure with specified probability γ, T_γ;

d) ES failure rate at the end of the specified period of time t, $\lambda(t)$;

e) failure rate at the end of the specified period of time t, $a(t)$;

f) data for construction of the graph of PNF as the function of time;

g) data for construction of the graph of failure rate as the function of time;

h) data for construction of the graph of failure rate as the function of time.

The above dependability indicators were defined in [5].

The structure and performance data of the DIALOG-NRS SSS are described in [2].

The DIALOG-RRS SSS allows identifying the following dependability indicators of repairable ES and performs functions associated with ES operational dependability:

a) mean time between failures, T_{mn};

b) mean failure rate at the end of the specified period of time t, $w(t)$;

c) cumulative failure rate at the end of the specified period of time t, $w_c(t)$;

d) data for construction of the graph of mean failure rate as the function of time;

e) data for construction of the graph of cumulative failure rate as the function of time;

f) number of warranty repairs at the specified stages of ES operation within the specified time t;

g) cost of warranty repairs within the specified time t that included one or several stages of ES operation.

The DIALOG-ZIP SSS is intended for calculating the optimal SPTA set and its characteristics that primarily include two sufficiency indicators (SI):

- SPTA availability coefficient $C_{\text{a.SPTA}}$;

- mean spare parts (SP) supply delay time by an SPTA set Δt_{SPTA}.

In solving the direct problem of SPTA set optimization, the input data includes the required SI value ($C^{(\text{rq})}_{\text{aSPTA}}$ or $\Delta t^{\text{rq}}_{\text{SPTA}}$) and type of costs that are to be optimized (minimized) in order to achieve the target values of SI.

In solving the inverse problem, the input data include the cost limitation $C^{\text{lmt}}_{\Sigma\text{SPTA}}$ and specified SI ($C^{(\text{rq})}_{\text{aSPTA}}$ or $\Delta t^{\text{rq}}_{\text{SPTA}}$) that is to be optimized under the given cost limitation.

The DIALOG-ZIP-NS SSS allows calculating an optimal SPTA set and its characteristics for simple non-redundant products. For that purpose, within the SSS, a model of the SPTA structure is created, the input data for the model's operation being the product components' characteristics.

The DIALOG-ZIP-RS SSS allows calculating an optimal SPTA set and its characteristics for any redundant products. For that purpose, two models are used in SSS: the repairable system model created using the programs of the DIALOG-RRS SSS, and the SPTA model created in the DIALOG-ZIP-RS SSS. Both simulation models created through synthesis have event-oriented identical structure elements and single programming language, Fortran, which enables their joint operation with a significant reduction of program execution time as compared to other languages.

A product's failure flow to SPTA is generated by the system model. It can have any form and is defined by the structure of the redundant product and type of repairs at various stages of product operation. The failure flow can also vary in time as the redundant product degrades.

The DIALOG-ZIP-RS SSS can also be used for calculating STPA sets intended for non-redundant systems. However, if the product is a non-redundant system and the request to SPTA occurs immediately after the product's failure, due to the significantly lower labour intensity of input data preparation for SPTA set calculation the DIALOG-ZIP-NS SSS is used. In this case, model generation only requires the preparation of the SPTA structure description, while product failures are generated by a special program that is part of the DIALOG-ZIP-NS SSS.

The DIALOG-ZIP-NS and DIALOG-ZIP-RS are used for calculating SPTA sets of any structure:

– single SPTA sets (SPTF-S);

– group SPTA sets (SPTF-G);

– SPTA systems (SPTAS).

General provisions for SPTA set composition calculation

STPA set calculation is normally done using standard procedures described in regulatory documents [6-8].

In the general case, let us examine a product consisting of N_0 types of components (each i-th type of component can have k_i instances) and operating in cycles, when each repeating cycle with the duration of T_c consists of M stages with each j-th stage ($j = 1, \ldots, M$) having the duration of T_j and failure rate of the component of the i-th type of λ_{ij}.

The product's operating cycle includes stages of operation under various conditions, stages of inactivity, stages of maintenance, etc.

Then, the replacement rate of components of the i-th type is calculated according to formula

$$\Lambda_{si(\text{Cmp})} = k_i \cdot \left[\left(\sum_{j=1}^{M} T_j \cdot \lambda_{ij} \right) / T_c \right], \qquad (1)$$

where $\sum_{j=1}^{M} T_j = T_c$.

The input data per the product's components are entered into columns 1 and 2 of Table 1, the input data that are part of formula (1) are entered into columns 3 to 6 of Table 1 (in

Table 1. Calculation of replacement rate $\Lambda_{Ri(\text{Cmp})}$ for product components

Component number, i	Component name	Stage number, j	Duration of stage, T_j, h	k_i, pcs	$\lambda_{ij} \times 10^6$, 1/h	$\Lambda_{Ri(\text{Cmp})} \times \cdot 10^6$, 1/h
1	2	3	4	5	6	7
1		1 … M	+ … +	+ … +	+ … +	+ …
…	…	…	…	…	…	…
N_o		1 … M	+ … +	+ … +	+ … +	+ …

columns 4 to 6, symbols «+» are given instead of specific numbers). The value $\Lambda_{ri(\text{Cmp})}$ for each i-th type of component calculated according to formula (1) is entered into column 7 of Table 1.

Four primary SPTA set replenishment strategies are normally used:

– scheduled replenishment (conventional index $\alpha_i = 1$);

– scheduled replenishment with emergency deliveries (ED) ($\alpha_i = 2$);

– continuous replenishment ($\alpha_i = 3$);

– replenishment to the level of emergency stock ($\alpha_i = 4$).

Beside the type (index α_i), each replenishment strategy is characterized by one (T_i) or two (T_i and β_i) numerical parameters with values:

– if $\alpha_i = 1$ $T_i = T_{\text{rpl}i}$ is the period of scheduled replenishment of i supply, if $\beta_i = 0$, the parameter is not used;

– if $\alpha_i = 2$ $T_i = T_{\text{r}i}$ is the period of scheduled replenishment of i supply, $\beta_i = \text{T}_{\text{ed}i}$ is the time of ED of i-type SP;

– if $\alpha_i = 3$ $T_i = T_{\text{d}i}$ ($T_{\text{rpr}i}$) is the time of delivery (repair) of i-type SP, if $\beta_i = 0$, the parameter is not used;

– if $\alpha_i = 4$ $T_i = T_{\text{d}i}$ is the time of delivery of i-type SP, $\beta_i = m_i$ is the emergency supply of the i type.

Each individual stock within an SPTA set can, in general, be replenished according to an individual strategy that differs from the others both in type (α_i), and the values of numerical parameters (T_i and β_i).

In case of scheduled replenishment with ED, the following ED data must be additionally specified:

– level of supply replenishment;

– itemized replenishment list;

– ED request time: in case of supply failure or use of the last SP (prefailure).

The SI of an SPTA set $C^{(\text{rq})}_{\text{aSPTA}}$ or $\Delta t^{\text{rq}}_{\text{SPTA}}$ is defined by the corresponding SI of each i-th supply Δt_{si} and C_{ai} ($i = 1\ldots N_{\text{o}}$) using the following formulas [8]:

$$\Delta t_{\text{s.SPTA}} = \frac{\sum_{i=1}^{No} \Lambda_{si(\text{Cmp})} \cdot \Delta t_{si}}{\sum_{i=1}^{No} \Lambda_{si(\text{Cmp})}}; \quad (2)$$

$$C_{\text{s.SPTA}} = \prod_{i=1}^{No} C_{ai}. \quad (3)$$

The theoretical formulas for calculation of the SI of Δt_{si} and C_{ai} derived using mathematical models proposed in [9] are shown in Table 2.

The following designations are used in the table:

A_i, average number of requests for i-th type SP received by the SPTA set over the time T_i

$A_i = k_i \cdot \Lambda_{si(\text{Cmp})} \cdot T_i$; (4)

L_i, initial supply of the i-th type in SPTA;

m_i, minimum level of supply of the i-th type when replenishing to level m_i.

GOST 27.507-2015 [8, annex A] cites the results of SPTA-S set optimization per the required SI $C^{(\text{rq})}_{\text{aSPTA-S}} \geq 0.95$ for the Pamir-1 ES that consists of $N_{\text{o}} = 30$ components. The optimization was performed using standard procedures and ROKZERSIZ and ASONIKA-K-ZIP software suites.

SPTA optimization using the DIALOG-ZIP SSS allows improving user options as compared to the above software suites through the following additional characteristics:

– SPTA SP failure logging;

– optimization of SP count and accounting for their characteristic features for purposed of ED if a replenishment strategy with $\alpha_i = 2$ is used;

– capability to use components with any type of redundancy (e.g. any type of redundancy from [2]);

– capability to include differently-structured products into ESs, when working with a SPTA-G group set.

The list of primary methods used while estimating the indicators and calculating the primary types of SPTA are shown in Table 3.

Structure of the DIALOG-ZIP-RS SSS

The DIALOG SSS includes the following parts intended for SPTA sets calculation:

– part 3. DIALOG-ZIP-NS for STPA sets calculation for simple non-redundant systems;

Table 2. SI calculation formula for i-th type supply in SPTA-S set

Replenishment strategy	Sufficiency indicators
Scheduled replenishment ($\alpha_i = 1$) $T_i = T_{\text{R}i}$	$\Delta t_{si} = T_{\text{n}i}\left[\exp(-A_i)\cdot\sum_{\gamma=L_i+2}^{\infty}\frac{A_i^{\gamma-2}}{\gamma!}(\gamma-L_i-1)\right]$, $C_{ai} = 1-\exp(-A_i)\cdot\sum_{\gamma=L_i+2}^{\infty}\frac{A_i^{\gamma-1}}{\gamma!}(\gamma-L_i-1)$
Scheduled replenishment with ED ($\alpha_i = 2$) $T_i = T_{\text{R}i}$	$\Delta t_{si} = T_{\text{ED}i}\left[\exp(-A_i)\cdot\sum_{\upsilon=1}^{\infty}\sum_{\gamma=\upsilon\cdot(L_i+1)}^{\infty}\frac{A_i^{\gamma-1}}{\gamma!}\right]$, $\Delta t_{si} = 1-\frac{T_{\text{ED}i}}{T_{\text{n}i}}\left[\exp(A_i)\cdot\sum_{\upsilon=1}^{\infty}\sum_{\gamma=\upsilon\cdot(L_i+1)}^{\infty}\frac{A_i^{\gamma}}{\gamma!}\right]$
Continuous replenishment ($\alpha_i = 1$) $T_i = T_{\text{D}i}$	$\Delta t_{si} = T_{\text{D}i}\cdot A_i^{L_i}\left[(L_i+1)!\sum_{\gamma=0}^{L_i+1}\frac{A_i^{\gamma}}{\gamma!}\right]^{-1}$, $C_{si} = 1-A_i^{L_i+1}\left[(L_i+1)!\sum_{\gamma=0}^{L_i+1}\frac{A_i^{\gamma}}{\gamma!}\right]^{-1}$
Replenishment to level m_i ($\alpha_i = 1$) $T_i = T_{\text{D}i}$	$\Delta t_{si} = T_{\text{D}i}\cdot A_i^{m_i+1}\left[A_i^{m_i+1}+(L_i-m_i)(1+A_i)^{m_i+1}\right]^{-1}$, $C_{ai} = 1-A_i^{m_i+2}\left[A_i^{m_i+2}+(L_i-m_i)(1+A_i)^{m_i+1}\right]^{-1}$

Table 3. List of methods of calculating and estimating SPTA indicators

№	Name of method	Designation and assignment of a method for each SPTA type		
		a) SPTA-S	b) SPTA-G	c) SPTAS
1	$A_{F.SPTA}$-based supply estimation	1a. Estimation of $A_{F.SPTA\text{-}S}$ value	—	1b. Estimation of $A_{F.SPTAS}$ value
2	$\Delta t_{S\cdot SPTA}$-based supply estimation	2a. Estimation of $\Delta t_{S\cdot SPTA\text{-}S}$ value	2b. Estimation of $\Delta t_{S\cdot SPTA\text{-}S}$ value	2b. Estimation of $\Delta t_{S\cdot SPTAS}$ value
3	Supply estimation based on the criterion of SPTA costs	3a. Estimation of $C_{SPTA\text{-}O}$ value	3b. Estimation of $C_{SPTA\text{-}G}$ value	3c. Estimation of C_{SPTAS} value
4	$A_{F.SPTA}$-based calculation of optimal supply	4a. Minimization of SPTA-S costs if the $A_{F.SPTA\text{-}S}$ requirements are met	—	4c. Minimization of SPTAS costs if the $A_{F.SPTAS}$ requirements are met
5	$\Delta t_{S\cdot SPTA}$-based calculation of optimal supply	5a. Minimization of SPTA-S costs if the $\Delta t_{S\cdot TPA\text{-}S}$ requirements are met	5b. Minimization of SPTA-G costs if the $\Delta t_{S\cdot TPA\text{-}G}$ requirements are met	5c. Minimization of SPTA-G costs if the $\Delta t_{S\cdot SPTAS}$ requirements are met
6	C_{SPTA}-based calculation of optimal supply	6a. SI optimization under the specified costs of initial SPTA-S supply	6b. SI optimization under the specified costs of initial SPTA-G supply	6c. SI optimization under the specified costs of initial SPTAS supply

– part 4. DIALOG-ZIP-RS for STPA sets calculation for any redundant systems.

This paper dwells on the calculation of the SPTF-S set using the DIALOG SSS.

The calculation method is based on the replacement of live tests of a "product – SPTA set" system with an imitation using event models. The models are submitted to statistical testing. For each test, the number of successful and failed requests to the SPTA set, SP delivery delays and other indicators are calculated. The following actions follow:

– summation of all requests to each supply within the specified number of tests;

– summation of all successful requests to a supply within the specified number of tests;

– summation of SP delivery delays;

– identification of the average numbers of requests to the supply, successful requests, delays of delivery, etc.;

– based on the results, the required indicators are calculated.

DIALOG-ZIP-RS creates a model that simulates the operation of the product, the SPTA and their interaction.

Such model can be used both for non-redundant and redundant products with any type of redundancy, in combination with any type of repairs at various stages of system operation.

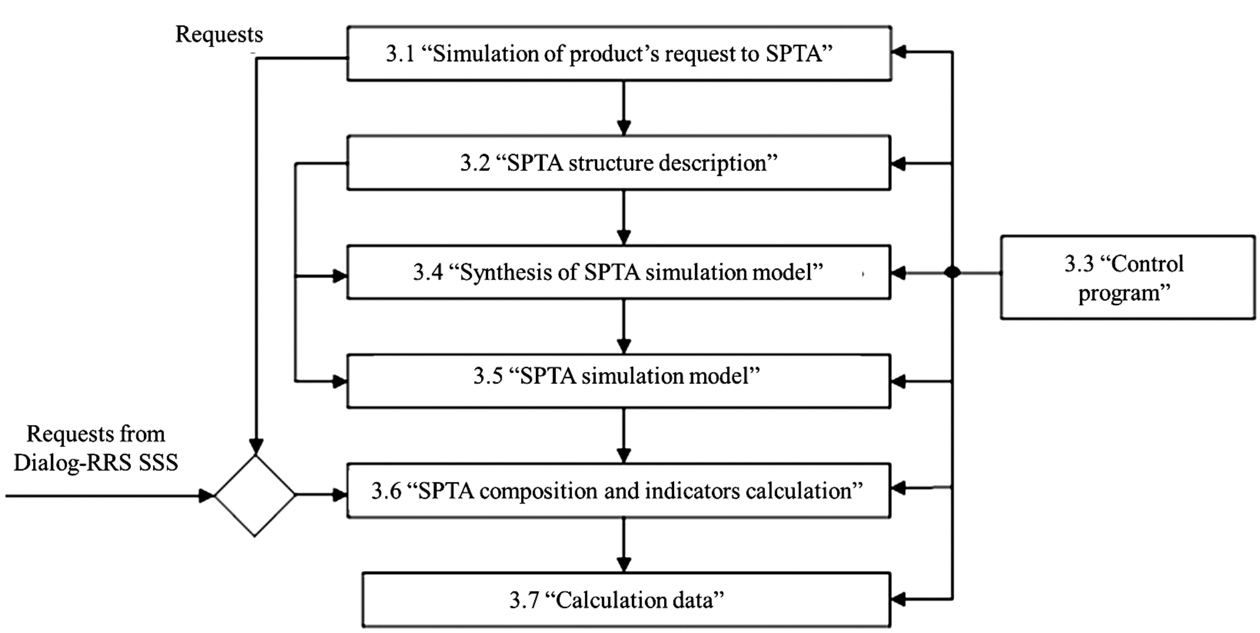

Figure 1 – Structure diagram of the DIALOG-ZIP-RS SSS programs interaction.

The SSS allows defining an optimal SPTA composition and obtaining the following indicators for SPTAs with any structure for redundant and non-redundant products with any types of repairs:

– availability coefficient and other indicators accounting for own failures of the SPs that are part of the SPTA;

– optimal SPTA composition by criterion of minimal cost under the given SI;

– optimal SPTA composition under limited given costs.

If SPTA requests are used that have been obtained through the generation of the simplest failure flow, such indicators can be obtained only for a non-redundant product and emergency full repairs.

The structure diagram of DIALOG-ZIP-RS SSS programs interaction is shown in Fig. 1.

In terms of their functionality, the DIALOG-ZIP-RS SSS programs are divided into three sections.

<u>Section A. Input data.</u>

<u>Program 3.1 “Simulation of product’s request to SPTA”.</u>

This program is intended for generating requests from product to SPTA set in case of non-redundant products. In case redundant products are employed, DIALOG-RRS SSS information is used.

The program creates random sequences of requests to each supply for a period of time equal to the planned simulation time. The time between requests to the supply is a discrete random value with an exponential distribution law and average value equal to the mean time between components failures.

Request times are generated using a subprogram that employs the logarithmic method for obtaining random discrete sequences with an exponential distribution law [10].

An example of a program that uses that method is shown in [3].

<u>Program 3.2 “SPTA structure description”.</u>

The program serves to describe SPTA sets with any structure.

The obtained data are used in the process of automatic synthesis of the SPTA simulation model.

The program is also used for generating input data for the calculation of sufficiency indicators and SPTA set optimization. The data is represented in table form and is saved as a text file.

This data is further used in Program 3.4 “Synthesis of SPTA simulation model” and Program 3.5 “SPTA simulation model” for the purpose of calculations and optimization.

<u>Section B. Indicator calculation and optimization.</u>

<u>Program 3.3 “Control program”.</u>

This program serves to run the DIALOG-ZIP-RS SSS and program execution control. The supervisor program obtains information on the results of other programs’ operation, runs programs, sets operating modes of the simulation model, modes of information output and saving in Program 3.7 “Calculation data”.

The programs can be executed automatically or with an operator’s involvement. Upon his/her command the system’s operation can be interrupted and later resumed. Programs’ operating modes can be changed at launch, individual programs can be run repeatedly.

<u>Program 3.4 “Synthesis of SPTA simulation model”.</u>

Using the data obtained from Program 3.2 “SPTA structure description” and utility files, the SPTA event simulation model is generated in the Fortran language with the parameters specified in the description of the SPTA structure. After translation, the model’s executive file is generated.

<u>Program 3.5 “SPTA simulation model”.</u>

The synthesized model is of the event-oriented type and has the form of source code and executable file. The model can be used on its own out of the DIALOG-ZIP SSS.

The model’s operating principle is based on the simulation of the following sequence of events within the SPTA over the simulation time:

– requests from products for replacement of failed components;

– SPTA replenishment;

– requests for SP delivery;

– failure of SPs in SPTA.

As an event occurs, actions associated with the respective type of event are performed: supply contents are modified and subject to certain conditions SPTA resupply times are planned.

For the purpose of enabling event-specific actions special subprograms are used, where the supply, for which the actions are intended, is specified as a parameter.

Three operating modes are provided for the simulation model that are to be set by the supervisor program:

1. Calculation of indicators. In this mode, SI for the existing SPTA composition are calculated.

2. Calculation of zero supply. The initial supplies before optimization are calculated.

3. Calculation of optimal SPTA composition.

After the mode has been set, the simulation model is subjected to testing.

The parameters obtained from Program 3.2 “SPTA structure description” are used. The input data for the tests consists of the requests received from Program 3.1 “Simulation of product’s request to SPTA”.

<u>Program 3.6 “SPTA composition and indicators calculation”.</u>

By processing the test results the program calculates SI or, in the optimization mode, along with the indicators data on the optimal SPTA composition are processed and displayed.

<u>Section C Calculation data.</u>

<u>Program 3.7 “Calculation data”.</u>

The program serves to save the calculation data for each stage and total system operation time, as well as request flows and SPTA structure descriptions.

Simulation model operation requires the following characteristic to be defined:

- duration of a single test (simulation time);
- number of simulation model tests.

The duration of a single test in simulation time units is equal to the duration of the chosen period of time of "product – SPTA set" system operation, for which SPTA indicators are calculated. The duration of this period is equal to the simulation time that is defined in the SPTA structure description and can be changed when the model is launched.

The recommended minimal number of tests of model $n_{test}^{(min)}$ is calculated when the SPTA set description is developed. The calculation is done based on the assumption that in order to ensure acceptable accuracy of calculation for components with minimal failure rate the number of the occurred failures over the whole time of testing must be at least 1000.

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The authors' contribution

Boris. A. Dolgopolov. Analysis of various aspects of optimal "product – SPTA" system creation, formalization of findings.

Yuri G. Zayko. General description of the DIALOG SSS. Analysis and definition of the requirements for the design of an optimal SPTA system, derivation of primary formulas, description of various options for SPTA design and use recommendations.

Viktor A. Mikhailov. General supervision of problem definition for designing an optimal system for RES maintenance with SPTA and selection of requirements for the design of an optimal SPTA system.

Alexander V. Trakhtomirov. Development of simulation, implementation and processing of results that allow assessing the operation of the "product – SPTA set" system. Description of the DIALOG-ZIP-RS SSS function.