Methods of information systems synthesis

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METHOD OF SYSTEM DESIGN OF THE NETWORK OF MEANS OF SPECIAL CONTROL

The **subject matter** of the article is the processes of system design of the network of special control means (NSCM). The **aim** is to develop an iterative scheme for the logical design of a network of special controls that will be based on the ideas of the aggregative-decomposition approach, system analysis and system design of complex systems. The **objectives** are: analysis of the features of the network of special control means as an object of design or reengineering; decomposition of the problem of optimization of NSCM to a multitude of tasks related to different hierarchical levels of decomposition, with their interrelationships on the initial data and the results of the solution; formulation of the requirements that the methods and procedures for solving the problems of optimization of the NSCM should satisfy; the development of an iterative logic scheme and the system design method for the NSCM. The **methods** used are: system analysis of design processes, cause-effect analysis, method of system design of complex systems. The following **results** are obtained. The analysis of the peculiarities of the network of special control means as an object of design or reengineering is carried out. Taking into account the characteristics of NSCM, decomposition of the problem of its optimization into a set of interrelated tasks related to different hierarchical levels of decomposition is performed. The scheme of the interrelationships of the selected tasks with the input data and the results of their solution is established. The requirements that must be met by methods and procedures for solving the problems of optimization of NSCM are defined. This allowed the development of an iterative logic scheme and on its basis the method of system design of NSCM. **Conclusions**. On the basis of the analysis of the interrelationships between the optimization problems of NSCM on the input data and the results of their solution, an iterative logic scheme and an interactive method of its system design are developed. It is expedient to use the obtained results for complex determination of the structure, topology, parameters and technology of functioning of NSCM. This will reduce the time to solve problems of designing, planning the development or reengineering of networks of funds, reduce the cost of their creation and operation, through joint solutions to improve the quality of solutions and, on this basis, improve their functional characteristics.

Keywords: large-scale object; special control system; structure, topology; design: optimization; logical scheme of system design.

Introduction

Checking large-scale objects that are designed, created and exploited in our time, characterized by growing complication systems. The increase of scales of the controlled territory or space increases requirements to the operation ability, exactness reliability and vitality of the checking systems, results in the increase of amount and complication of their elements, complication of technologies of their functioning [1-3].

Among the tasks of reengineering planning or planning of development of the checking systems the special place is occupied by the tasks of optimization of their structures. The characteristic feature of the checking of large-scale object systems is that an optimal structure, parameters of their elements, communication means between them and technology of functioning in a great deal are determined by the territorial placing of objects and controls [4-7].

The typical example of the similar systems that is intend for monitoring objects that are disperse on considerable territory is a network of facilities of the Main center of the special control of Ukraine. The basic tasks of this Center are: observance of requirements of international agreements in relations to limitation and prohibition of nuclear tests; the seismic state geophysical phenomena; the radiation state in the points of the distribution of subdivisions of the Center.

Structurally the network of facilities of Center of the special control consists of great number of multilevel centers of control (main center, regional centers, autonomous and movable points), that is disperse on considerable territory. Expansion of great number of control objects, change of requirements of its quality, the improvement of facilities of collection, transmission and treatment of information results in the necessity of optimization of existent network.

Formulation and analysis of the modern state of the problem

To optimize the network of special control tools (NSCT), as in the design or reengineering of other geographically distributed systems (GDS), it is necessary to solve a plurality of combinatorial tasks of structural, topological, parametric and technological optimization. Taking into account that the power of the sets of admissible functioning technologies, the parameters of the elements and connections of such systems is insignificant, the main difficulties are the tasks of optimizing their topological structures [8].

For their solution, exact (combinatorial) and close (heuristic) methods are used. The exact methods allow to find optimum solutions, but, given the NP-complexity of the problem, such methods can be applied only to optimize the simplest systems with a small number of elements that are part of their composition.

In this case, the tasks of placing nodes or elements of the control system are solved according to different criteria, using various target functions, in conditions of different dimensions and degree of certainty of input data, time and resource constraints. This requires the development of a set of problem-solving methods that differ in accuracy and complexity, will have less temporal complexity than combinatorial methods and greater accuracy than existing approximate methods [9]. Modern technologies for designing geographically distributed objects, including NSCT, are based on the ideas of aggregation-decomposition approach, system analysis and system design of complex systems. When implementing a system approach in the design tasks of such GDS one of the main problems is the formal presentation of the process of solving the set of interrelated design problems. Such formalization is presented in more convenient way as a logical scheme for constructing a global design solution [10].

Under this approach, construction of such formalization must precede the correct decomposition of the problem [11]. In the initial stages of the design, the problem is presented as a meta-task MetaTask, consisting of a set of tasks relating to different hierarchical levels of decomposition, with their interconnections by the initial data and the results of the solution [12]:

$$MetaTask = \left\{ Task^{\ell} \right\},$$
$$Task^{\ell} = \left\{ Task_i^{\ell} \right\}, \; i = \overline{1, i_{\ell}}, \; \ell = \overline{1, n_{\ell}}, \qquad (1)$$

where $Task^{\ell\, l}$ – the set of tasks of synthesis, that belong to the level of ℓ;

n_{ℓ} – amount of levels of description of the system;

i – number of task;

i_{ℓ} – amount of tasks that should be solved at level ℓ.

Thus each of tasks is given as some transformer of data:

$$Task_i^{\ell} := In_i^{\ell} \rightarrow Out_i^{\ell}, \; i = \overline{1, i_{\ell}}, \; \ell = \overline{1, n_{\ell}}, \qquad (2)$$

where In_i^{ℓ}, Out_i^{ℓ} – entrance data of i-task and initial data of ℓ-level.

Each of the distinguished tasks of top levels

$$Task_i^{\ell}, \; i = \overline{1, i_{\ell}}, \; \ell = \overline{1, n_{\ell}},$$

can be presented as a set of interconnected subtasks

$$Task_i^{\ell} = \left\{ Task_{ij}^{\ell} \right\}, \; j = \overline{1, j_i},$$

where j_i – amount of subtasks of a task $Task_i^{\ell}$.

The systematic analysis of the problem of the synthesis of GDS and an overview of its current state allows us to conclude that it is expedient to use the three levels of detailed description at the meta-, macro- and micro-levels in the design and technical and economic aspects [12].

MetaTask is considered on a meta-level problem in general. Most macro level tasks are essentially the tasks of system design and differ in the constraints that reflect the specifics of the main stages of the life cycle of the GDS:

$$Task^1 = \left\{ Task_i^1 \right\}, \; \overline{i = 1, 5}, \qquad (3)$$

where $Task_1^1$ – the formation of requirements for geographically distributed systems and the development of a technical design task;

$Task_2^1$ – system design;

$Task_3^1$ – development planning;

$Task_4^1$ – adaptation of GDS;

$Task_5^1$ – reengineering of GDS.

The complex of objectives of the meta-level (3) covers the whole range of issues of structural synthesis of geographically distributed systems that arise at the stages of pre-design studies, design, creation and operation, which are solved in their design and management systems.

The main tasks of the micro level are related to the solution of the issues of system design of the geographically distributed systems [12]

$$Task^2 = \left\{ Task_i^2 \right\}, \; \overline{i = 1, 6}, \qquad (4)$$

where $Task_1^2$ – choice of principles of geographically distributed systems construction ;

$Task_2^2$ – choice of system structure;

$Task_3^2$ – definition of the topology of elements and connections;

$Task_4^2$ – choice of operation technology;

$Task_5^2$ – determination of parameters of elements and connections;

$Task_6^2$ – evaluation of the effectiveness of options and choice of solutions.

For the practical implementation of the system design of the network of special control tools, other geographically distributed systems, it is necessary to develop appropriate mathematical support that takes into account the specifics of the object and the corresponding design technology.

The purpose of the article is to develop an iterative scheme for the logical design of a network of special control tools, based on the ideas of the aggregation-decomposition approach, system analysis and system design of complex systems.

Main results

In the process of developing a decision-making method for the basic task of system designing the GDS, it is necessary to analyze its solvability at three levels: inputs, resources and process [10]. From solving the problem at each level will follow its solvability as a whole.

It should take into account the specific features of the task of system design of geographically distributed systems [7]:

the close relationship of problems structural, topological, parametric, technological synthesis, which requires their joint solution;

the combinatorial nature of most of the tasks (subtasks) that are part of it;

the need for solving problems of great dimension;

the presence in the formulation of problems the factors that are difficult for formalization;

high dynamism or uncertainty of the input data; a wide range of conditions for solving problems.

Analysis of the above features of the tasks of system designing TRS allows us to formulate the requirements that must satisfy the effective methods and procedures for solving design (optimization) of the NSCT [13].

1. Close relationship of tasks and incomplete information certainty of tasks of choosing the principles of network construction, structural, topological, parametric and technological synthesis, as well as analysis and selection of design solutions $Task_i^2$ by input sets $InDat_i^2$ and restrictions Res_i^2, $i=\overline{1,6}$, causes the iterative nature of the methods and procedures for their solution.

This way, it is possible to solve $Task_i^2$, $i=\overline{1,6}$ tasks at the input.

2. High complexity of solution methods $MetDec_i^2$, due to the combinatorial character of most tasks $Task_i^2$, and a wide range of conditions for their solution is required when they solve the use of a plurality of methods $MetDec_{ik}^2$, $i=\overline{1,6}$, which have different complexity and accuracy.

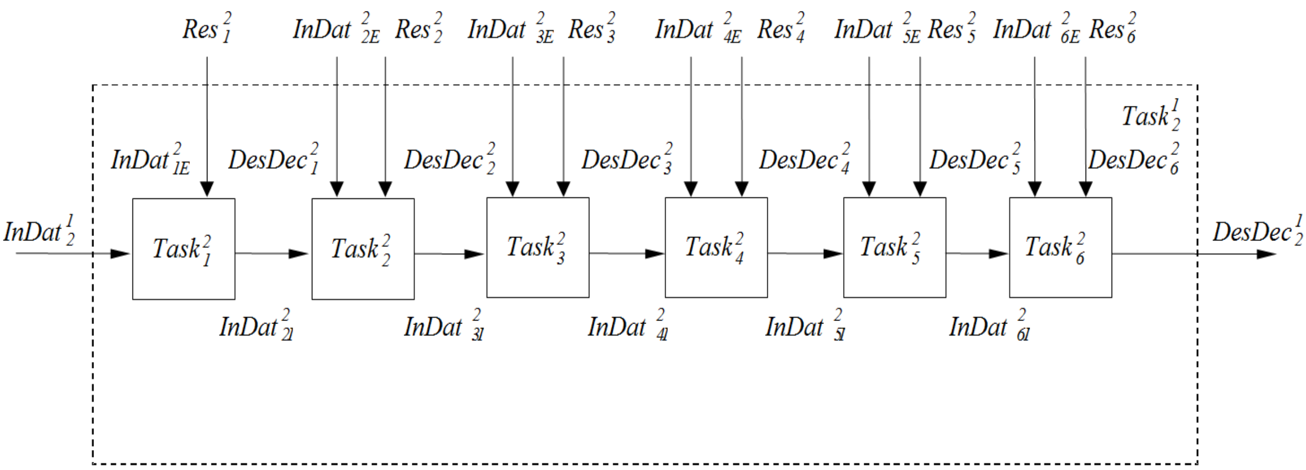
This will enable the solution of the tasks of system design by resources.

3. To make full use of the experience of designers and to take into account factors that are difficult to formalize, it is advisable to build the solution process based on interactive (human-machine) procedures. The process of finding a design solution will consist of complementary procedures for automatic and intelligent synthesis with the participation of the operator.

4. At all stages of designing it is advisable to use techniques that reduce the complexity of solving system design problems $Task_i^2$, $i=\overline{1,6}$.

For this purpose, heuristics that take into account the specifics of tasks, solutions obtained through "fast" procedures, formal or expert assessments can be used.

Taking into account the mentioned features of the tasks of designing (optimization) of the NSCT and the listed requirements for the procedures for their solution, the determined sequence of problem solving of the design of complex geographically distributed systems (fig. 1), as well as the axiom of system design, the method of forming solutions to problems of system design based on the basis of the iterative logic scheme [8] is proposed.



$Task_1^2$ – the task of choosing the principles of building a GDS

$Task_2^2$ – the task of selecting a structure

$Task_3^2$ – the task of determining the topology of elements and relationships

$Task_4^2$ – the task of selecting a functioning; technology

$Task_5^2$ – the task of determining the parameters of elements and connections

$Task_6^2$ – the task of assessing the effectiveness of options and choice of solutions

Fig. 1. The sequence of tasks in the linear scheme of system design of the GDS

Due to the fact that data is not solvable in a linear sequence $Task_i^2$, $i=\overline{2,5}$, the formation of input data $InDat_i^2$ and restrictions Res_i^2 for them in the initial iteration will be carried out on the basis of predictive (in particular, expert) data.

On other iterations as input $InDat_i^2$ and restrictions Res_i^2 the results of solving the following tasks $DesDec_j^2$, $j > \iota$, $i=\overline{1,5}$ *of the* sequential scheme will be used.

The essence of the proposed method for systematic design (optimization) of network of special control tools on the basis of an iterative-sequential logic design scheme may be presented in the following form [13].

1. Beginning of the decision: entering input data $InDat_2^1$ and restrictions Res_2^1 of the task $Task_2^1$.

2. Formation of a solution search strategy.

3. Select a variant of the network structure ($Task_2^2$).

4. Determining the topology of elements and relationships ($Task_3^2$).

5. Choice of operation technology ($Task_4^2$).

6. Determining the parameters of elements and connections ($Task_5^2$).

7. Checking the limitations of the task $Task_2^1$. If the evaluation of the characteristics of the current variant of the construction of the network K (s) does not satisfy the restriction Res_2^1 of the task, go to step 3.

8. Evaluating the effectiveness and choosing the best of the existing variants.

9. If the search solution strategy is not exhausted, go to step 3.

10. Formation of decisions by the operator, estimation of their efficiency and choice of the best variant.

11. The end of the decision: the best variant for the network construction s^o as well as its evaluation $K(s^o)$ by a set of partial criteria *K are determined.*

Initial data $InDat_2^1$ and restriction Res_2^1 of the task:

ObjS – a set of characteristics of objects subject to control;

K – a set of partial criteria used to evaluate the network's performance;

Q, C** – boundary levels of the indicators of the effect (functional characteristics) and costs;

S'={s} – a subset of options that determine the area of the existence of the network;

П – possible principles for building a network.

The search strategy of the solution, which is formed at the step 1, defines the conditions of the iterative implementation of the steps 3-8, as well as the choice of design procedures $ProcDec_i^2$ to get solutions of the task $Task_i^2$, $i=\overline{1,6}$ [8].

The choice of the strategy is based on the solution of the problem, which forms the domain of admissible variants of network construction *S*={s}*, proceeding from the chosen principles of its construction $\pi \in \Pi$.

Specific provisions of the strategy are determined by the necessary precision of the solutions $DesDec_i^2$, $i=\overline{1,6}$, as well as computing resources that can be used to solve the problem.

Steps 3-6 provide for the implementation of design procedures $ProcDec_i^2$, $i=\overline{2,5}$ to solve the tasks of choosing a network structure, determining the topology of elements and relationships, choosing a technology of operation, determining the parameters of elements and relationships in the context of input data $InDat_i^2$ and restrictions Res_i^2.

Each of the procedures $ProcDec_i^2$, $i=\overline{2,5}$ based on one of the task models $ModTask_i^2=\{ModTask_{ik}^2\}$ and uses one of the methods of solving it $MetDec_i^2=$ $=\{MetDec_{il}^2\}$ [8].

Checking restrictions Res_i^2 is carried out in the process of solving each of the tasks $Task_i^2$, $i=\overline{1,5}$. Step 5 provides for verification of restrictions of the general task $Task_i^2$.

Evaluating the effectiveness and choosing the best variant for building a network (step 8) is carried out using formal or expert multi-factor and multi-choice procedures $\{ProcDec_{6k}^2\}$ [8].

Step 9 provides for verification of the completion conditions of the iterative cycle for solving complex tasks $Task_i^2$, $i=\overline{2,5}$ (in particular, the number of cycles of the multistar procedure for searching for the global extremum of the target function).

Step 10 provides for the formation of decisions $s \in S^*$ by the human operator which is responsible for the system designing, as weel as an automated evaluation of their properties by a set of criteria *K(s)*, comparing them with the best of the previously obtained and choosing the best among them s^o.

Depending on the available means of automation of designing and the chosen strategy for the design decisions, various forms of participation of the operator in forming decisions (step 2-10) are possible: operator-programmer, operator-researcher, operator-coordinator [10].

Possibility of solving the tasks of system design (NSCT)=-as a whole follows from the possibility of solving constituent tasks $Task_i^2$, $i=\overline{1,6}$ and the convergence of the entire iterative procedure. In this case, design decisions $DesDec_i^2$ $Task_i^2$, $i = \overline{1,6}$ tasks, on the subsequent iterations of the proposed scheme will become more precise, because they will be formed based on the decisions obtained in the previous iterations. As a result, the accuracy of the solution $DesDec_2^1$ task will be increased.

Conclusions

The analysis of the peculiarities of the problem of system design of the network of the main center of special control, as a kind of territorially distributed objects, made it possible to establish the specific features of the arisen problems.

The close relationships between the tasks of structural, topological, parametric, technological synthesis requires their joint solution. The combinatorial nature of problem problems and their high dimension require the development of effective methods for their solution.

The presence of problem-oriented factors that are difficult to formalize and incomplete certainty of input data makes using of interactive technologies is more effective for the design.

The established features have determined the iterative interactive nature of the proposed logic design scheme and of the proposed method for the design of design solutions.

The practical application of the results obtained will reduce the time for solving the design, planning, or reengineering tasks of the Network of the Main Center for Special Control, reducing the costs of their creation and operation, by jointly solving tasks to improve the quality of solutions and, on this basis, improve the functional characteristics of the network.

Further details of the described logic design scheme and the proposed method for the design of design solutions involves the choice or development of new mathematical models and methods for solving all partial problems:

the choice of principles of network construction;

choice of network structure;

definition of the topology of elements and connections;

choice of operation technology; determination of parameters of elements and connections;

assessing the effectiveness of options and choosing solutions.

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Метод системного проектування мережі засобів спеціального контролю

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Предметом вивчення в статті є процеси системного проектування мережі засобів спеціального контролю (МЗСК). **Мета** – розробка ітераційної схеми логічного проектування мережі засобів спеціального контролю, що ґрунтуватиметься на ідеях агрегативно-декомпозиційного підходу, системного аналізу та системного проектування складних систем. **Завдання:** аналіз особливостей мережі засобів спеціального контролю як об’єкта проектування чи реінжинірингу; декомпозиція проблеми оптимізації МЗСК на множину задач, що відносяться до різних ієрархічних рівнів декомпозиції, з їх взаємозв'язками за вихідними даними та результатами розв’язання; формулювання вимог, яким повинні задовольняти ефективні методи та процедури розв’язання задач оптимізації МЗСК; розробка ітераційної логічної схеми та методу системного проектування МЗСК. Використовуваними **методами** є: системологічний аналіз процесів проектування, причинно-наслідковий аналіз, метод системного проектування складних систем. Отримані такі **результати**. Проведено аналіз особливостей мережі засобів спеціального контролю як об’єкта проектування чи реінжинірингу. З урахуванням особливостей МЗСК виконано декомпозицію проблеми її оптимізації на множину взаємопов’язаних задач, що відносяться до різних ієрархічних рівнів декомпозиції. Встановлено схему взаємозв'язків виділених задач за вхідними даними та результатами їх розв’язання. Визначено вимоги, яким повинні задовольняти ефективні методи та процедури розв’язання задач оптимізації МЗСК. Це дозволило розробити ітераційну логічну схему та на її основі метод системного проектування МЗСК. **Висновки.** На основі аналізу взаємозв'язків задач оптимізації МЗСК за вхідними даними та результатами їх розв’язання розроблено ітераційну логічну схему та інтерактивний метод її системного проектування. Отримані результати доцільно використовувати для комплексного визначення структури, топології, параметрів та технології функціонування МЗСК. Це дозволить скоротити час розв’язання задач проектування, планування розвитку чи реінжинірингу мереж засобів, скоротити витрати на їх створення й експлуатацію, за рахунок спільного розв’язання задач підвищити якість рішень і на цій основі покращувати їх функціональні характеристики.

Ключові слова: великомасштабний об’єкт; система спеціального контролю; структура; топологія; проектування; оптимізація; логічна схема системного проектування.

Метод системного проектирования сети средств специального контроля

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Предметом изучения в статье являются процессы системного проектирования сети средств специального контроля (СССК). **Цель** - разработка итерационной схемы логического проектирования сети средств специального контроля, которая будет основываться на идеях агрегативно-декомпозиционного подхода, системного анализа и системного проектирования сложных систем. **Задачи**: анализ особенностей сети средств специального контроля как объекта проектирования или реинжиниринга; декомпозиция проблемы оптимизации СССК на множество задач, относящихся к разным иерархическим уровням декомпозиции, с их взаимосвязями по исходным данным и результатам решения; формулирование требований, которым должны удовлетворять методы и процедуры решения задач оптимизации СССК; разработка итерационной логической схемы и метода системного проектирования СССК. Используемыми **методами** являются: системологический анализ процессов проектирования, причинно-следственный анализ, метод системного проектирования сложных систем. Получены следующие **результаты**. Проведен анализ особенностей сети средств специального контроля как объекта проектирования или реинжиниринга. С учетом особенностей СССК выполнено декомпозицию проблемы ее оптимизации на множество взаимосвязанных задач, относящихся к разным иерархическим уровням декомпозиции. Установлено схему взаимосвязей выделенных задач с входными данными и результатами их решения. Определены требования, которым должны удовлетворять методы и процедуры решения задач оптимизации СССК. Это позволило разработать итерационную логическую схему и на ее основе метод системного проектирования СССК. **Выводы**. На основе анализа взаимосвязей задач оптимизации СССК по входным данным и результатам их решения разработана итерационная логическая схема и интерактивный метод ее системного проектирования. Полученные результаты целесообразно использовать для комплексного определения структуры, топологии, параметров и технологии функционирования СССК. Это позволит сократить время решения задач проектирования, планирования развития или реинжиниринга сетей средств, сократить расходы на их создание и эксплуатацию, за счет совместного решения задач повысить качество решений и на этой основе улучшать их функциональные характеристики.

Ключевые слова: крупномасштабный объект; система специального контроля; структура; топология; проектирование; оптимизация; логическая схема системного проектирования.