

**МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ**  
**НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ**

Факультет аеронавігації, електроніки та телекомунікацій  
Кафедра авіаційних комп'ютерно-інтегрованих комплексів

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри

В.М. Синєглазов

“” \_\_\_\_\_ 2022 р.

# КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ  
“МАГІСТР”

Тема: “СИСТЕМА АВТОМАТИЗОВАНОГО ПРОЕКТУВАННЯ  
ЕКСТРЕМАЛЬНОГО РЕГУЛЯТОРА ПОТУЖНОСТІ  
СОНЯЧНИХ БАТАРЕЙ”

Виконавець:



Рудь А.А.

Керівник:




к.т.н., професор Аблесімов О.К.

Консультант з екологічної безпеки:



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Нормоконтролер:



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**EDUCATION AND SCIENCE MINISTRY OF UKRAINE**

**NATIONAL AVIATION UNIVERSITY**


Faculty of Aeronautics, Electronics and Telecommunications

Aviation computer-integrated complexes department

ADMIT TO DEFENSE

Head of department

Viktor M. Sineglazov

“” \_\_\_\_\_ 2022

# **QUALIFICATION WORK**

**(EXPLANATORY NOTE)**

GRADUATE OF EDUCATIONAL AND QUALIFICATION LEVEL

“ MASTER ”

**THEME:** “ AUTOMATED DESIGN SYSTEM OF THE EXTREME POWER  
REGULATOR OF SOLAR ”

**Executor:**



**Rud A.A.**

**Supervisor:**



**Ph.D., Professor Ablesimov O. K.**

**Advisor on environmental protection:**  **Ph.D., Associate Professor Iavniuk A.A.**

**Advisor on labor protection:**



**Senior Lecturer Kozlitin O.O.**

**Norms inspector:**



**Ph.D., Professor Filyashkin M.K.**

Kyiv - 2022

# НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій

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Освітньо-кваліфікаційний рівень бакалавр

Спеціальність 151 «Автоматизація та комп'ютерно-інтегровані технології»

**ЗАТВЕРДЖУЮ**

Завідувач кафедри

В.М. Синглазов

“” \_\_\_\_\_ 2022 р.

## ЗАВДАННЯ

на виконання дипломної роботи студенту

Рудь А.А.

- 1. Тема роботи:** «Система автоматизованого проектування екстремального регулятора потужності сонячних батарей»
- 2. Термін виконання проекту (роботи):** з 18.09. 2022р. до 20.11.2022р.
- 3. Вихідні данні до проекту (роботи):** технічні параметри систем стабілізації і керування, сонячних батарей, космічних апаратів відповідно до аналогів промислових зразків.
- 4. Зміст пояснювальної записки (перелік питань, що підлягають розробці):**
  1. Аналіз процедур автоматизованого проектування.
  2. Системи енергозабезпечення космічних апаратів.
  3. Умови експлуатації в космосі сонячних батарей.
  4. Роботизовані системи керування сонячними батареями.
  5. Визначення основних характеристик сонячних батарей.
  6. Обґрунтування і вибір системи автоматичного регулювання потужності сонячних батарей.
  7. Розробка схеми екстремального керування потужністю сонячних батарей.
  8. Вибір конструктивних елементів і розробка екстремального регулятора потужності.
- 5. Перелік обов'язкового графічного матеріалу:**
  1. Функціональні схеми енергозабезпечення космічних апаратів.
  2. Сонячні батареї.
  3. Перетворення світлової енергії в електричну.
  4. Навантажувальні характеристики сонячного фотоперетворювача.
  5. Принцип синхронного детектування.
  6. Аналого-цифровий екстремальний регулятор потужності.
  7. Програмна реалізація моделювання.
  8. Програмне забезпечення автоматизованого синтезу.

## 6. Календарний план-графік

№ п/п	Завдання	Термін виконання	Відмітка про виконання
1	Підбір літератури	22.08.22-26.08.22	<i>ар.р.</i>
2	Технічне завдання	27.08.22-28.08.22	<i>ар.р.</i>
3	Вступ	29.08.22-29.08.22	<i>ар.р.</i>
4	Обґрунтування доцільності автоматизації проектування	30.08.22-10.09.22	<i>ар.р.</i>
5	Формування алгоритму проектування мобільного комплексу	11.09.22-25.09.22	<i>ар.р.</i>
6	Проектування автоматизованої системи керування	26.09.22-15.10.22	<i>ар.р.</i>
7	Програмно-методичне забезпечення експериментальних досліджень під час проектування	16.10.22-30.10.22	<i>ар.р.</i>
8	Охорона навколишнього природного середовища	31.10.22-10.11.22	<i>ар.р.</i>
9	Охорона праці	11.10.22-15.11.22	<i>ар.р.</i>

## 7. Консультація з окремих розділів:

Назва розділу	Консультант (посада, П.І.Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Старший викладач, Козлітін О.О.	20.10.22 <i>ар.р.</i>	18.11.22 <i>ар.р.</i>
Охорона навколишнього природного середовища	к.б.н., доцент, Явнюк А.А.	20.10.22 <i>ар.р.</i>	18.11.22 <i>ар.р.</i>

## 8. Дата видачі завдання: "22" серпня 2022 р.

Керівник: професор \_\_\_\_\_ *ар.р.* \_\_\_\_\_ Аблесімов О.К.

(підпис)

Завдання прийняв до виконання \_\_\_\_\_ *Рудь* \_\_\_\_\_ Рудь А.А.

(підпис)

# NATIONAL AVIATION UNIVERSITY

Faculty of Aeronavigation, Electronics and Telecommunications

Department of Aviation Computer-Integrated Complexes

Education level: master

Specialty 151 "Automation and computer-integrated technologies"

Educational and professional program "Computer-integrated technological processes and production"

**APPROVED BY**

Head of Department

Victor M. Sineglazov.

“” \_\_\_\_\_ 2022.

## TASK

### For the student's qualification work

Rud A.A.

- 1. Theme of the project (work):** "Automated design system of the extreme power regulator of solar batteries".
- 2. The term of the project (work):** from 18.08.2022 to 15.11.2022.
- 3. Output data to the project (work):** technical parameters of stabilization and control systems, solar batteries, spacecraft in accordance with analogues of industrial samples.
- 4. Content of the explanatory note (list of issues to be developed):** 1. Analysis of automated design procedures. 2. Power supply systems of space vehicles. 3. Conditions of operation of solar batteries in space. 4. Robotic solar battery control systems. 5. Determination of the main characteristics of solar batteries. 6. Justification and selection of the system of automatic regulation of the power of solar batteries. 7. Development of a scheme for extreme power management of solar batteries. 8. Selection of structural elements and development of an extreme power regulator .
- 5. List of compulsory graphic material:** 1. Functional schemes of power supply of space vehicles. 2. Solar batteries. 3. Conversion of light energy into electrical energy. 4. Load characteristics of the solar photoconverter. 5. The principle of synchronous detection. 6. Analog-digital extreme power regulator. 7. Software implementation of simulation. 8. Automated synthesis software.

## 6 . Calendar plan-schedule

№	Task	Execution term	Execution mark
1	Selection of literature	22.08.22-26.08.22	<i>apl.</i>
2	Technical task	27.08.22-28.08.22	<i>apl.</i>
3	Introduction	29.08.22-29.08.22	<i>apl.</i>
4	Justification of the feasibility of design automation	30.08.22-10.09.22	<i>apl.</i>
5	Formation of the mobile complex design algorithm	11.09.22-25.09.22	<i>apl.</i>
6	Designing an automated control system	26.09.22-15.10.22	<i>apl.</i>
7	Software and methodological support of experimental research during design	16.10.22-30.10.22	<i>apl.</i>
8	Protection of the natural environment	31.10.22-10.11.22	<i>apl.</i>
9	Occupational Health	11.10.22-15.11.22	<i>apl.</i>

## 7. Special chapters' advisors:

Chapter	Advisor (position, name)	Date, signature	
		Assignment issue date	Assignment accepted
Labor protection	Senior lecturer, Kozlitiu O. O.	20.10.22 <i>apl.</i>	18.11.22 <i>apl.</i>
Environmental protection	Ph.D, Associate Professor, Iavniuk A.A.	20.10.22 <i>apl.</i>	18.11.22 <i>apl.</i>

8 . Date of task receiving: 22.09.22\_\_\_\_\_

Supervisor: \_\_\_\_\_

*apl.*  
(signature)

Oleksandr K. Ablesimov

Issued task accepted \_\_\_\_\_

*Rymf.*  
(signature)

Andrii A. Rud

## РЕФЕРАТ

на кваліфікаційну роботу «Система автоматизованого проектування екстремального регулятора потужності сонячних батарей»

Ключові слова: КОСМІЧНИЙ АПАРАТ, СОНЯЧНА БАТАРЕЯ, СИСТЕМА КЕРУВАННЯ, ПОТУЖНІСТЬ, СИСТЕМА ЕНЕРГОЗАБЕЗПЕЧЕННЯ, АДАПТИВНА СИСТЕМА, СИСТЕМА ЕКСТРЕМАЛЬНОГО КЕРУВАННЯ, ЕКСТРЕМАЛЬНИЙ РЕГУЛЯТОР.

Пояснювальна записка: кількість сторінок – , кількість рисунків – , кількість використаних джерел – .

Об'єктом дослідження є екстремальний регулятор для сонячної батареї при експлуатації в умовах космічного простору.

Мета роботи – розробка структури САПР, математичного та програмного забезпечення автоматизованого проектування регулятора запропонованої системи автоматичного керування потужності сонячних батарей космічного апарату.

Проведено дослідження, за результатами якого було обрано систему екстремального керування потужністю, оскільки САР такого типу мають ряд визначних для поставленої задачі переваг.

Розроблена САПР дозволяє проектувати регулятор пошуку екстремуму методом синхронного детектування, а також систему з керуванням по відхиленню від нуля похідної регульованої координати по керуючому впливу об'єкта керування.



## ABSTRACT

for the diploma thesis "Automated design system of the extreme power regulator of solar batteries"

Keywords: SPACECRAFT, SOLAR BATTERY, CONTROL SYSTEM, POWER, ENERGY SUPPLY SYSTEM, ADAPTIVE SYSTEM, EXTREME CONTROL SYSTEM, EXTREME REGULATOR.

Explanatory note: number of pages - , number of figures - , number of used sources - .

The object of the study is an extreme regulator for a solar battery during operation in outer space.

The purpose of the work is to develop a CAD structure, mathematical and software for the automated design of the regulator of the proposed system of automatic control of the power of solar batteries of the spacecraft.

A study was conducted, based on the results of which a system of extreme power control was chosen, since ACS of this type have a number of significant advantages for the given task.

The developed CAD allows designing an extremum search controller by the method of synchronous detection, as well as a system with control based on the deviation from zero of the derivative of the regulated coordinate based on the control effect of the control object.





## **TECHNICAL TASK**

### **1. Naming and field of application**

The spacecraft's power supply system is a key element of its optimal functioning. In the conditions of outer space, the use of classical sources of electricity is complicated by a number of limitations inherent in the environment, among which is the difficulty of transporting fuel elements and products of system functioning. These limitations determine the use in modern space vehicles of systems whose energy source is solar energy.

The operation of such systems in outer space depends on many factors, including, in particular, the rotation of the spacecraft, the increased level of radiation exposure, mechanical damage caused, for example, by space debris, temperature changes, unevenness of solar radiation, etc.

In order to compensate for these and other factors, a system of automatic power regulation of solar batteries was implemented. The task of such systems is to monitor and maintain the most optimal modes of operation of the battery in view of external disturbances, thereby maintaining the functionality of all systems at a given level.

The constant development and improvement of space vehicles requires the appropriate development of energy supply systems, the introduction of more modern solutions in the matter of maintaining a stable return from electric energy generators, and the development of more advanced control systems of given parameters.

### **2. Goal and purpose of development**

The purpose of the work is to develop the structure of CAD, mathematical and software for the automated design of the regulator of the proposed system of automatic control of the power of the solar batteries of the space vehicle.

### **3. Phase and stages of development**

Classification of spacecraft types.

Analysis of the main features of the operation of power supply systems of space vehicles;

Selection and justification of the selected type of automatic regulation system.

Experimental studies of the automatic control system model.

Development of an extreme solar battery power regulator.

### **4. Control and acceptance procedure**

Control is carried out by the head of diploma design in accordance with the task and calendar plan.

Admission is based on the defense of the qualification work of the Faculty of Aeronautics, Electronics and Telecommunications.

Deadline for submitting the thesis: November 20, 2022.



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5 PROTECTION OF THE NATURAL ENVIRONMENT.....	

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## GLOSSARY

1. CAD is an computer-aided design system.
2. SC is a spacecraft.
3. AAS is an automatic adjustment system.
4. SB is a solar battery.
5. AB is an accumulator battery.
6. ASV is an air-space vehicle.
7. ASS is an aviation and space system.
8. PSS is a power supply system.
9. VS is a voltage stabilizer.
- 10.RCE is a regulation and control equipment.
- 11.CTL is a command transmission lines.
- 12.FEC is a photoelectric converter.
- 13.FC is a photoconverter.
- 14.CVC is a current-voltage characteristic.
- 15.VWC is the volt-watt characteristic.
- 16.OBDC is an on-board digital computer.
- 17.GACC is a ground-based automated control complex.
- 18.RTD is a receiving-transmitting device.
- 19.EMD is an electromechanical drive.
- 20.CD is a control device.
- 21.LS is a light sensor.
- 22.SD is a synchronous detector.
- 23.VR is a voltage regulator.
- 24.LPF is a low-pass filter.
- 25.EPR is an extreme power regulator.
- 26.SG is a synchronizing generator.
- 27.PS is a power sensor.
- 28.SSD is a sampling and storage device.

## INTRODUCTION

The spacecraft's power supply system is a key element of its optimal functioning. The generation of electrical energy in the volumes necessary for the operation of the spacecraft in standard modes can be guaranteed only under the condition of constant and uninterrupted operation of all elements of the power supply system.

In the conditions of outer space, the use of classical sources of electricity (combustion of minerals or gas, chemical reactions, nuclear energy) is complicated by a number of limitations inherent in the environment, among which is the difficulty of transporting fuel elements and products of system functioning. These limitations determine the use in modern space vehicles of systems whose energy source is solar energy, given their resource independence and high stability of operation.

The operation of such systems even within the Earth's atmosphere depends on many factors, including the periods and intensity of illumination, the angle of incidence of the sun's rays, shading of light-sensitive elements, etc. In outer space, these conditions include, in particular, the rotation of the spacecraft, an increased level of radiation exposure, mechanical damage caused, for example, by space debris, temperature changes, etc.

Compensation of these and other factors cannot be perfectly performed exclusively by human forces, so the introduction of a system of automatic regulation of the power of solar batteries became a natural step. The task of such systems is to monitor and maintain the most optimal modes of operation of the battery in view of external factors (disturbances), thereby maintaining the functionality of all systems at a given level. It is easy to understand that automatic regulation systems need energy supply, therefore the main tasks in their design are not only to ensure reliability and accuracy of work, but also to minimize energy consumption for their operation.

Since the composition and technical performance of the basic components of such systems can be very different, it is advisable to use CAD when designing them. This will allow:

- reduce the complexity of design and planning;
- shorten design terms;
- reduce the cost of design and manufacture, reduce operating costs;
- to improve the quality and technical and economic level of design results;
- reduce the costs of full-scale modeling and testing.

Design automation is understood as the optimization of solutions, that is, the achievement of the specified indicators of the designed object with limited expenditure of available resources. The structure of the automated design system is a set of subsystems that should include technical, mathematical and informational means united by a common objective function.

A design procedure in automated design processes is called typical if it is intended for repeated use in the design of a given object. Mathematical support of CAD serves to provide the designer with a wide range of services in design technology. CAD software is made taking into account the concrete computers equipped with the designed system.

In work developed a CAD structure, mathematical and software for automated design of the proposed extreme regulator of the power of the solar batteries of the space vehicle.

## CHAPTER 1

### JUSTIFICATION OF THE FEASIBILITY OF DESIGN AUTOMATION

#### 1.1 Analysis of the problem of using solar batteries on spacecraft and determination of ways to solve it


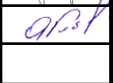


Spacecraft (SC) is the general name of technical devices used to perform various tasks in outer space, as well as conducting experimental and other types of work on the surface of celestial bodies. Carrier rockets or airplanes serve as means of delivering space vehicles into orbit.

A space vehicle, one of the main tasks of which is the transportation of people or equipment in the upper part of the Earth's atmosphere - the so-called near space, is called a spacecraft (SC) or a space flight vehicle (SFV).

Areas of use of space vehicles determine their division by groups:

- suborbital;
- near-Earth orbital, moving along the geocentric orbits of artificial satellites of the Earth;
- interplanetary (expeditionary);
- planetary.

Examples can be space vehicles, which are shown in fig. 1.1.

<b>ACIC DEPARTMENT</b>			<b>NAU 22 0884 000 EN</b>			
Performed	A.A. Rud		Automated Design System of the Extreme Power Regulator of Solar Batteries	N.	Page	Pages
Supervisor	O.K. Ablesimov					
Consultant						
S. controller	M.K. Filyashkin					
Dep. head	V.M. Sineglazov					
				<b>225 151</b>		



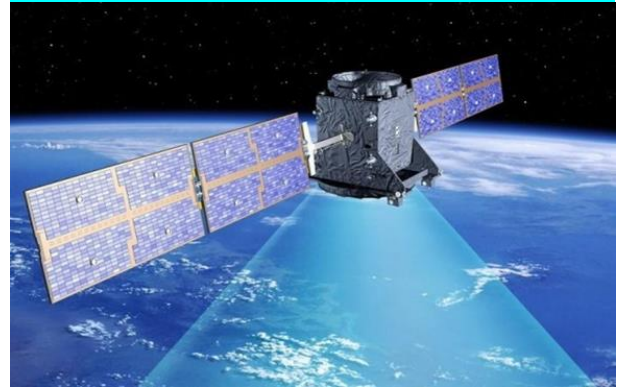


Fig. 1.1 Space aircraft

The spacecraft consists of several components. First of all, it is the target equipment, which ensures the execution of the task facing the spacecraft.

In addition to the target equipment, there is usually a number of service systems that ensure the long-term functioning of the apparatus in the conditions of outer space:

- ✓ energy supply systems,
- ✓ thermoregulation,
- ✓ radiation protection,
- ✓ traffic management,
- ✓ orientation,
- ✓ emergency rescue,
- ✓ landing,
- ✓ management,
- ✓ separation from the carrier,

- ✓ division and docking,
- ✓ on-board radio complex,
- ✓ life support.

The power supply system (PSS) is a space vehicle system that provides generation, storage and distribution of electrical power between other systems. PSS is one of the most important systems, in terms of mass, volume and cost, it occupies about 30% of the total space vehicle, and has a significant impact on the term of its active existence.

The functional composition and performance of energy supply systems are shown in fig. 1.2.

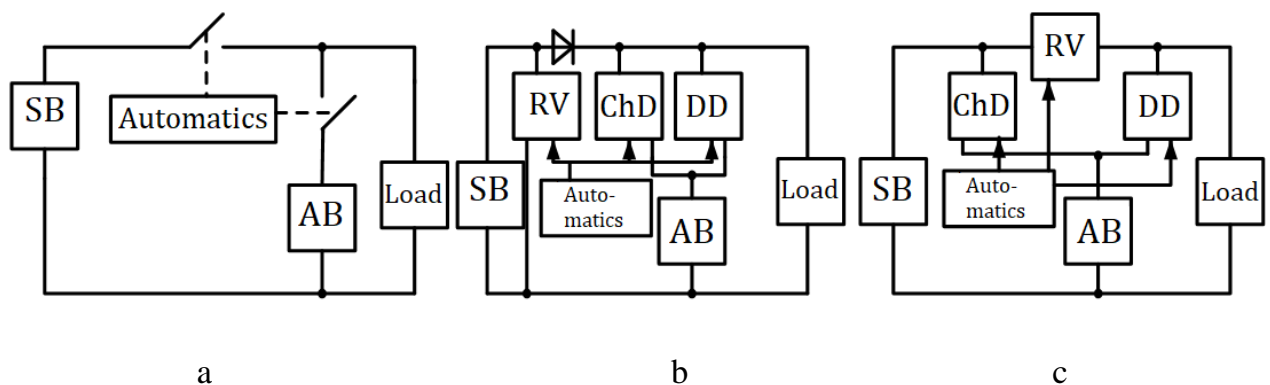


Fig. 1.2 Functional diagrams of energy supply systems:  
 a) with common power buses, b) parallel, c) parallel-serial

To the composition of systems usually includes primary and secondary sources of electricity, chargers and control automation.

The main feature of PSS of spacecraft compared to analogues in ground vehicles, ships and aircraft is, of course, its operation in outer space, as well as the absence of electric machine energy generation.

At the initial stages of development, PSSs were based on the use of chemical current sources, but their small resource naturally necessitated the use of active generators of electrical energy. In turn, among such generators, preference is given to photoelectric converters - solar batteries (SB) on most domestic spacecraft.

The daily change in the intensity of solar radiation necessitates the need for stabilizing factors to compensate for variations in the parameters of the current-current

characteristic. The optimal compensator for such changes is a rechargeable accumulator battery (AB). When the output characteristics reach the upper threshold level, the power supply control unit disconnects the SB from the load and buffer battery.

For accurate regulation and control, the power supply system should include the necessary control devices for PSS parameters, which coordinate the operation of AB, SB and load - the so-called regulation and control equipment (RCE). When changing the illumination of the SB and reducing the characteristics of the AB and SB, it ensures the specified quality of the output voltage in constant and transient modes, implements optimal algorithms for controlling the charge-discharge modes of the AB and optimal use of the SB.

As you can see, at present SB is one of the most reliable and well-tested power plants. Their resource and power indicators believe that in the next decade they will be widely used as power plants on orbital space stations and automatic spacecraft.

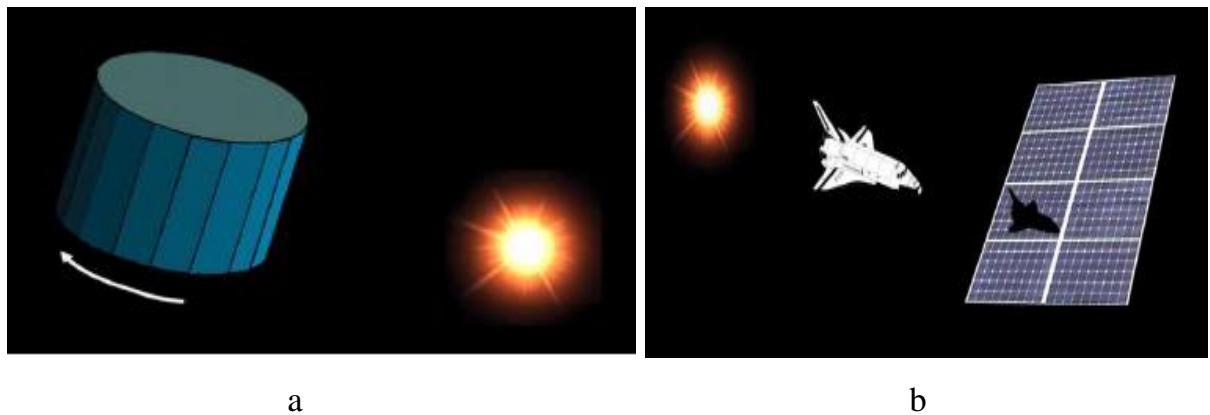


Fig. 1.3 Change of irradiated segments - a, shaded solar battery – b

At the same time, the main characteristics of SB depend on the influence of the environment. In general, the operating conditions of solar batteries (fig. 1.3) on any spacecraft are characterized by five factors:

- level sunny irradiation;
- temperature;
- rotation;
- blackout;
- shielding (shading) of individual solar cells.

Note that the temperature conditions of SB operation on space equipment, on which its efficiency significantly depends, range from  $-30\text{ }^{\circ}\text{C}$  to  $70\text{ }^{\circ}\text{C}$ . In this case, the average efficiency of the SB is only 8...10%.

For more effective work of the SB, it is necessary to orient it to the Sun with an error of up to  $5\text{...}8^{\circ}$ . When using hard panels, this is achieved, as a rule, by reversing the SC itself. SB panels can be movable relative to the spacecraft body. However, in this version, the design of the spacecraft is significantly complicated.

The task of efficient operation of solar batteries on board the spacecraft can be solved by using systems of automatic regulation of their power. To solve this problem, the author recommends adaptive control systems. Any of those presented in fig. 1.4 of the system may be considered.

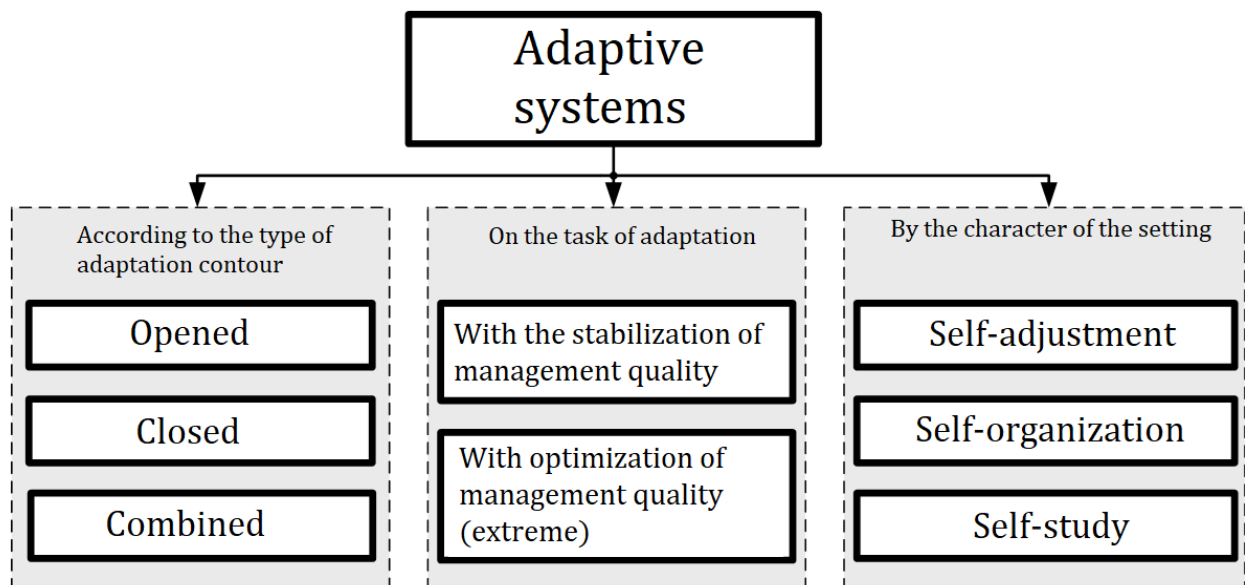


Fig. 1.4 Classification adaptive systems

Since the composition and technical implementation basic components of such complexes can be very different, then with them design expedient apply automated systems. This will allow:

- reduce the complexity of design and planning;
- shorten design terms;
- reduce cost design and manufacture, reduce operating costs;
- raise quality and technical and economic level results design;

- reduce costs for full-scale modeling and testing.

The priority way of solving tasks design is complex automation design, construction experimental, technological and others works at the base modern computational technique that becomes irreplaceable tools increase scientific and technical content of the project, reduction terms and cost him implementation at the expense of processing and conversion of a large volume information, decrease degree technical risk during design, etc.

Ensuring this direction is the main prerequisite for the introduction of the automated design system (CAD).

Based on the above, the purpose of the work is

Development of the structure of CAD, mathematical and software for the automated design of the regulator of the proposed system of automatic control of the power of the solar batteries of the space vehicle.

At the same time were delivered tasks:

- to determine tasks and basic procedures of automated design;
- propose a CAD structure of the power regulator;
- develop methods for designing extreme regulators and power management systems for solar batteries of space vehicles;
- conduct an experimental check efficiency and reliability proposed decisions;
- develop software for the automated synthesis of the system of automatic control of the power of the solar batteries of the spacecraft.

## **1.2 Analysis of problems and methods of designing technical systems**

The design of technical systems (new types and models of machines, equipment, devices, instruments and other products) is a complex and lengthy process, which includes the development of initial data, drawings, technical documentation, necessary for the production of prototypes and the subsequent production and operation of design objects.

Designing is a complex of works aimed at developing a description of a new or modernized technical object, sufficient for the realization or production of the object under the given conditions.

In the design process, there is a need to create a description necessary for the construction of an object that does not yet exist. The task of the designer is to predict the properties of the object in one way or another, to establish the methods of determining the main characteristics of the object under the given conditions, and also to propose methods of technical implementation of these characteristics. At the same time, the procedure of optimal selection of the main characteristics becomes part of the appropriate method of solving the problem, while the meaningful basis of design is the optimization of design solutions.

The design of complex automatic systems begins with the development of a technical task (TT), the design of which includes the following stages:

- preliminary design;
- sketch design;
- technical (working) design.

The stage of preliminary design is the stage of carrying out scientific and research works (SRW). It is directly related to the search for fundamental possibilities of building a system, the study of new principles, structures, technical means, and the justification of the most general solutions. The result of this stage is a technical proposal for development.

In this sense, design can be considered as the final cycle of the process of scientific research, which is related to the field of science. On the other hand, designing with sketch and technical stages opens the cycle of development, familiarization and production of automatic systems related to the field of engineering. The diagram of the main types of scientific research, which characterize the relationship between science and production, is shown in fig. 1.5.

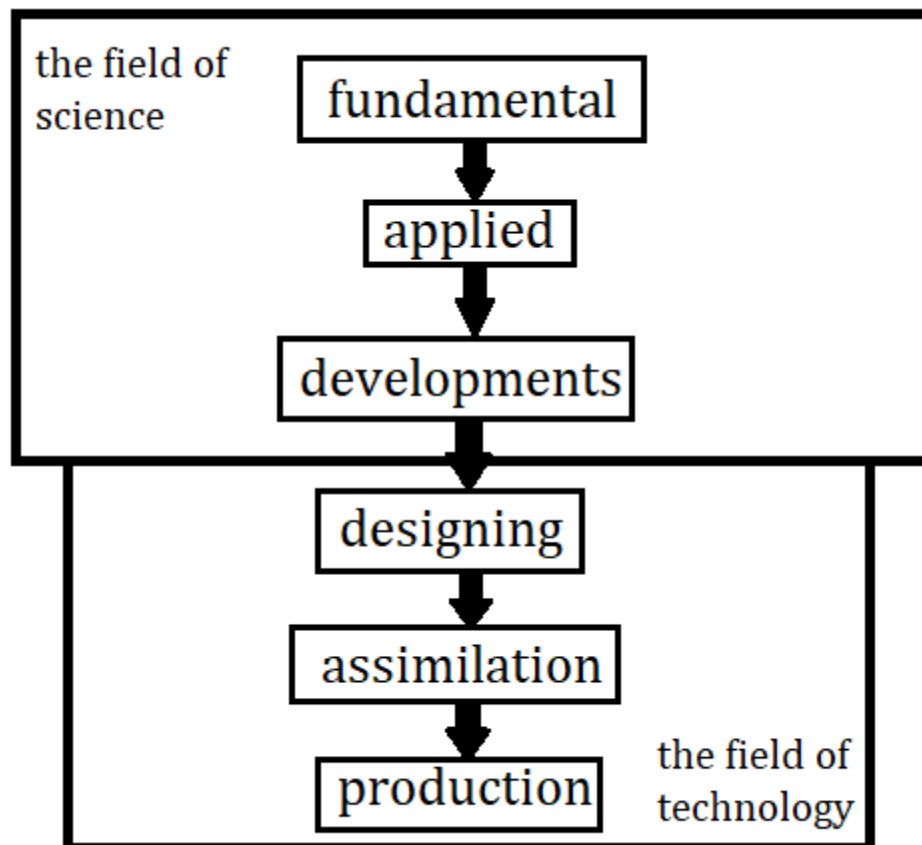


Fig. 1.5 Relationship of research and development

At the stage of sketch design, or the stage of research and development works (RDW), a detailed study of the possibility of building a system is carried out. The result of this stage is a sketch project.

At the stage of technical (working) design, all schematic, design, and technological solutions are thoroughly worked out. In particular, processing of all blocks, nodes and parts of the designed system, as well as technological processes of the production of parts and their assembly into nodes and blocks. The result of this stage is a technical project.

The final stage is the production of a prototype, based on the results of the tests, the necessary changes are made to the project documentation.

With non-automated design, the most time-consuming are the stages of technical and working design. The introduction of automation at these stages leads to the most effective results.

In the process of designing a complex system, certain ideas about the system, essential properties with varying degrees of detail reflecting it are formed. In these

representations, it is possible to distinguish constituent parts - design levels.

The design of technical systems is reduced to the solution of a group of tasks related either to tasks of synthesis or to tasks of analysis.

The concept of "synthesis" of technical object in the broad sense of the word is close in meaning to the concept of "design". The difference arises in the fact that design means the entire process of developing an object, and synthesis characterizes a part of this process, when some option is created, not necessarily final, that is, synthesis as a task can be performed many times during design, interspersed with the solution of the analysis task.

For discrete objects a synthesis task is a task definition structures. For continuous objects, solving the synthesis task means determining the structure and numerical values of the internal parameters of the development devices. If among options structures not just anyone is wanted acceptable option, and the best in some contents (optimal), then this the task of synthesis is called structural optimization. The calculation of internal parameters that are optimal from the positions of some criterion for a given structure of the object is called parametric optimization. The possibilities of setting and solving structural optimization problems are significantly limited, therefore, usually only parametric optimization is understood under optimization.

Analysis of technical objects is the study of their properties; during the analysis, new objects are not created, but given ones are examined.

According to the frequency of application, analysis tasks are divided into typical and atypical ones. The typical solution provides information about the main properties of objects. Atypical analysis tasks serve to obtain some additional information, and the algorithms for solving these tasks can be diverse and not known in advance.

Another classification principle tasks analysis leads to their division into groups tasks univariate and multivariate analysis (fig. 1.6).

Solving problems of univariate analysis allows obtaining information about the initial parameters of the object directly at a given reflecting point, and most often the solution is reduced to a one-time solution of the system of equations or to a one-time test of the object's layout.



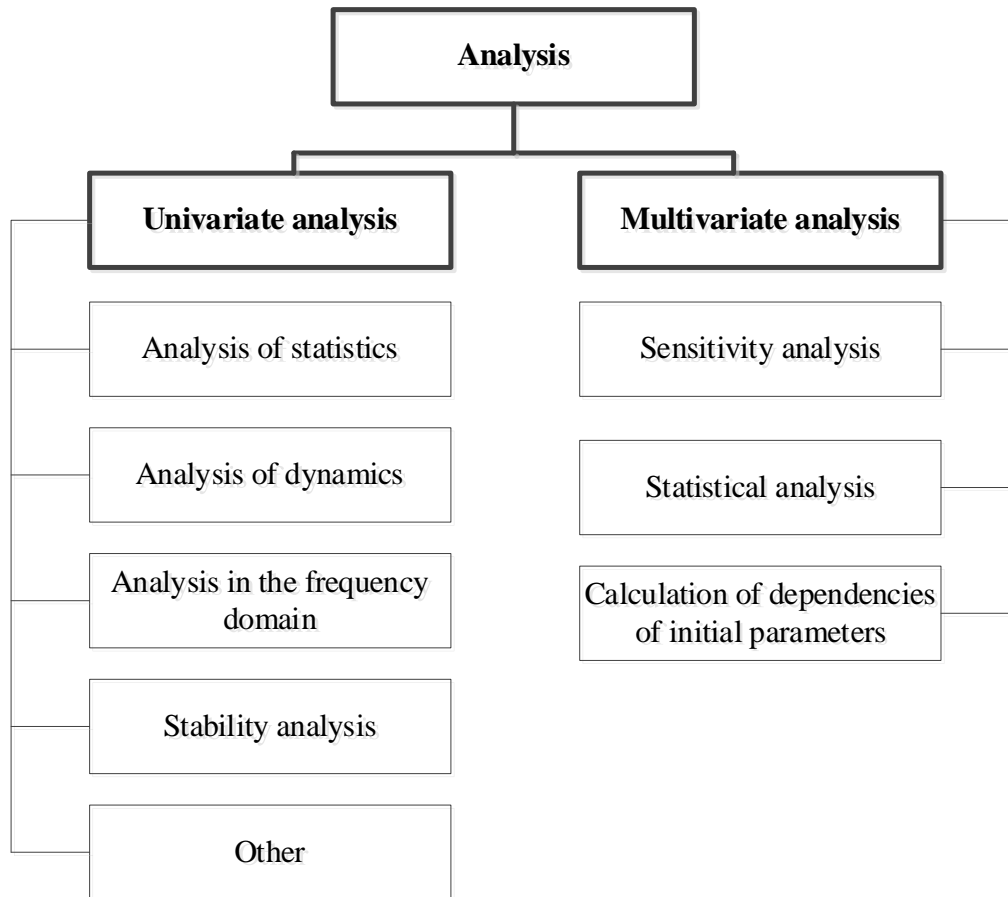


Fig. 1.6 Classification of analysis tasks

Multivariate analysis consists in the study of the object's behavior in some boundary of a given point that is displayed. Usually multivariate analysis requires reusable implementation univariate analysis.

Let's consider features non-machine and machine methods of scientific research and designing.

In their design activities, engineers use experimental, calculation and intuitive-heuristic design methods to varying degrees. The intuition and experience of an engineer are necessary first of all when solving the tasks of synthesis of the structure of most technical objects. Calculation and experimental methods are used to calculate the values of internal parameters.

Calculation manual methods of design can only give purely indicative values of parameters, which should be considered as initial, requiring correction using other methods. The approximate nature of the results of manual calculations is related to the low accuracy of manual calculation methods. Processes in rather complex technical

objects are described by systems of high-order equations. These equations are generally nonlinear. The analytical solution of the system of ordinary differential equations can be obtained only if the order of the system is not higher than the second and the equations are linear. Therefore, manual calculation methods are applicable only when significant simplifications are adopted, which determines the approximate character of the obtained results.

Machine methods are based on use mathematical models designed technical object. Mathematical model is totality mathematical objects and relations between them, which adequately reflects some properties designed technical object. For example, systems of equations are a large and important class of mathematical models. In the design process, those mathematical models are used that reflect the essential properties of the object from the standpoint of the design engineer.

So, the process of designing a technical object can be performed in the following ways:

- non-automated or manual design (if the entire design process is carried out by the designer);
- automated design (design in the mode of human-machine dialogue based on special communication languages);
- automatic design (all transformations of descriptions of objects and the algorithm of its functioning are carried out without human participation).

In the course of research and design, it is necessary to take into account that in recent years the theory of control has reached such a high level of development that the computer becomes an integral tool of the designer of control systems. This determines the relevance of the automation of scientific research and the development of systems for the automated design.

### **1.3 Development of the general structure of the design system and its components**

The automated design system is a system that implements information technology for the performance of design functions, is an organizational and technical

system designed to automate the design process, consisting of personnel and a complex of technical, software, and other means of automating its activities.

The relevance of the use of automated design systems is due to the following reasons:

- society needs new, complex industrial products;
- the need to perform design works in large volumes;
- the need to ensure competitive products;
- the need to ensure the quality of designed objects;
- the need to reduce the cost of technical objects.

The following varieties of CAD are distinguished:

- CAD for use in the fields of general mechanical engineering (engineering CAD or MCAD systems (Mechanical CAD));
- CAD for application in the field of radio electronics - the ECAD system (Electronic CAD) or EDA (Electronic Design Automation);
- CAD in the industry architecture and construction.

In addition, there is a large number specialized CAD that used for designing large integrated circuits (LIC); CAD for design flying devices; CAD of electric machines, etc.

Constituent structural parts of any CAD system are subsystems that have all the properties of systems and are created as independent systems. Each subsystem is a part of the CAD system that is selected according to certain characteristics and ensures the execution of some functionally completed sequences of project tasks with the receipt of relevant project decisions and project documents.

By purpose, CAD subsystems are divided into two types: design and service.

Service subsystems are object-independent and implement functions common to subsystems or CAD as a whole: they ensure the functioning of designed subsystems, design, transfer and output of data, software support, etc. Their totality is called the system environment (or shell) of CAD.

Design subsystems are object-oriented subsystems that implement a certain stage of design or a group of related design tasks. Depending on the attitude to the design object, they are divided into object and invariant.

Each one subsystem, in turn consists of components that provide functioning subsystems.

Each component performs certain function in the subsystem and is the smallest (indivisible) CAD element (program, transistor model file, graphic display, instructions, etc.). A set of components of the same type forms a means of providing CAD. The main ones are presented in fig. 1.7.

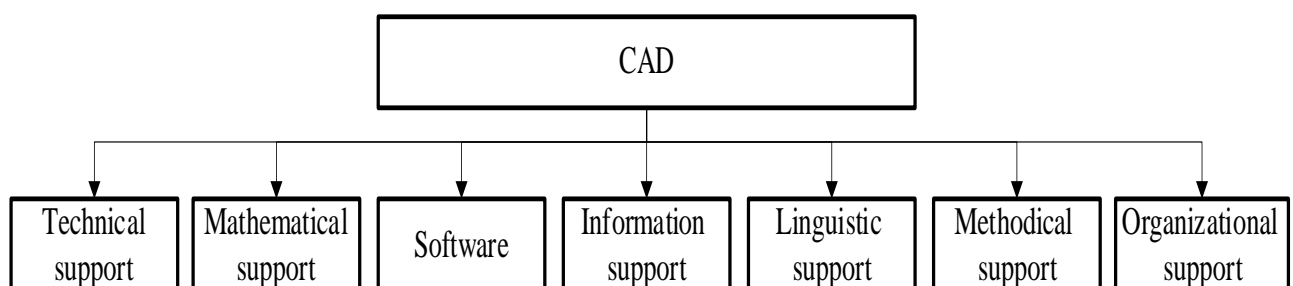


Fig. 1.7 Basic species provide CAD

*Technical support (TS)* - totality connected and interacting technical means (computers, peripherals devices, network equipment, lines communication, measuring means).

*Mathematical support (MS)* - combines mathematical methods, models and algorithms used to solve automated design problems. By purpose and methods of implementation MS is divided into two parts:

- mathematical methods and constructed on them mathematical models;
- formalized description technologies automated designing .

*Software* is divided into general system-wide and applied:

- applied software - implements mathematical software for direct implementation design procedures. Includes packages applied programs assigned for service certain stages designing or decision groups of the same type tasks within different stages (module designing pipelines, package schematic modeling, geometric CAD analyzer).

- system-wide software - intended for management components technical software and software functioning applied programs. For example component system-wide software is operational system.

*Information support (IS)* - totality information necessary for execution designing. It consists of a description standard design procedures, typical design solutions, components products and their models, design rules and regulations. The main one part of IP CAD - databases.

*Linguistic support (LS)* - a set of languages that are used in CAD for presentation information about the designed objects, process and means design, as well as for implementation dialogue designer - computer and exchange data between technical by means of CAD. Includes terms, definitions, formalization rules natural languages, methods compression and expansion.

*Methodical support (MdS)* - a description of the technology of CAD operation, methods of selection and application by users of technological techniques to obtain specific results. It includes the theory of processes occurring in designed objects, methods of analysis, synthesis of systems and their constituent parts, various design methods.

*Organizational support (OS)* - a set of documents that determine the composition of the project organization, the relationship between divisions, the organizational structure of the object and the automation system, activities in the conditions of the system's functioning, the form of presentation of design results. The OP includes staffing schedules, job instructions, operating rules, orders, regulations, etc.

Designing is one of the most complex types of intellectual work performed by a person. Moreover, the process of designing complex objects is beyond the power of one person and is performed by a creative team. This, in turn, makes the design process even more complex and difficult to formalize.



## **1.4 Analysis of the sequence of project procedures**

Stages designing consist of separate design procedures which are ending partial design decision.

Figure 1.8 shows a typical sequence of design procedures at one of the stages of bottom-up design:  $(i+1)$ -level.

At the previous stage, problems of the  $i$ -th hierarchical level are solved. One of the results of solving these problems during top-down design is the formulation of the technical task for the design of the  $(i+1)$ -level system.

System design begins with the synthesis of the initial version of its structure. To evaluate this option, a mathematical model is created based on experimental data about the object.

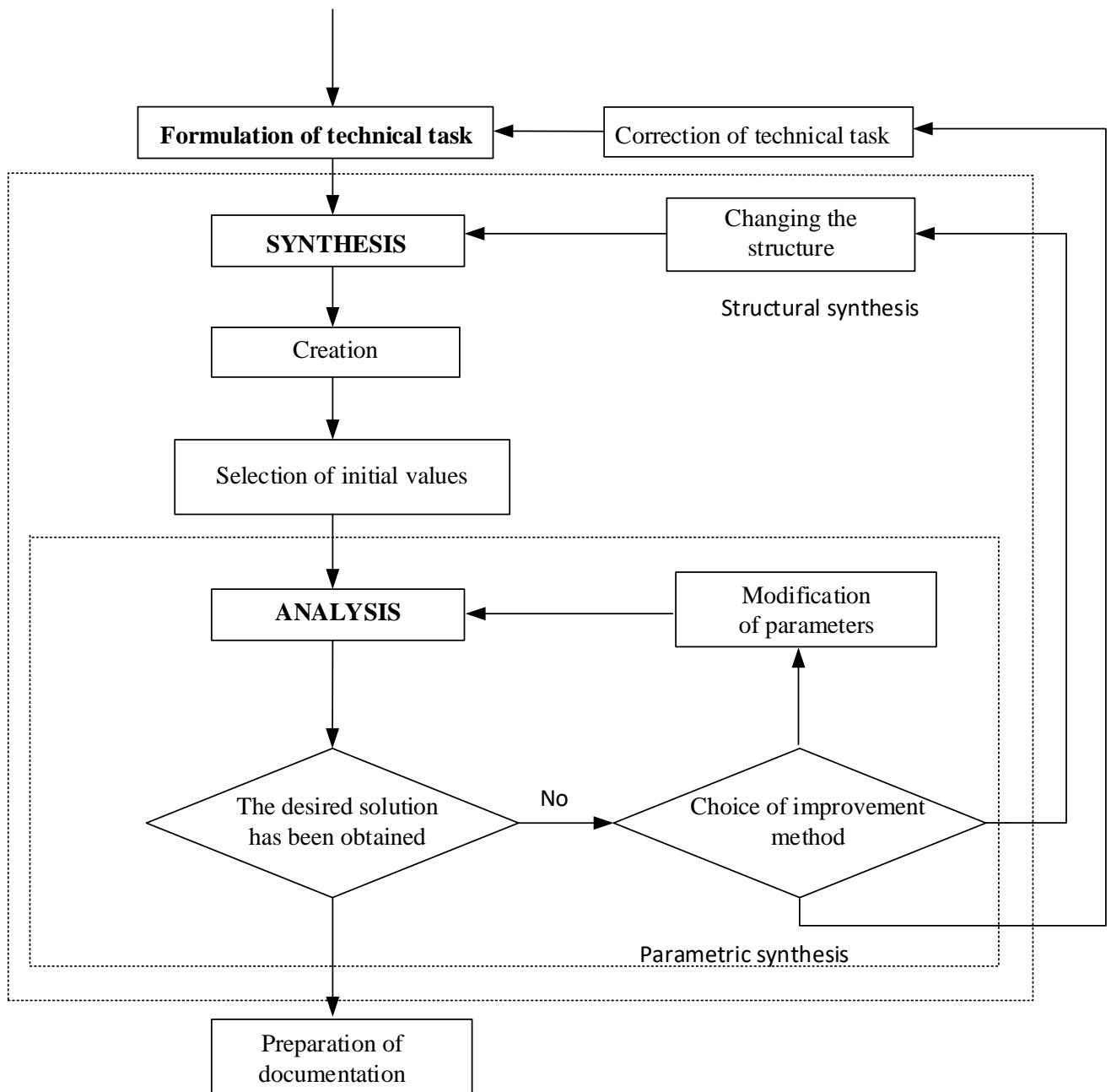


Fig. 1.8 Sequence of project procedures

After selecting the initial values of the parameters of the elements, an analysis of the option is performed, based on the results of which it becomes possible to evaluate it. Usually, the assessment consists in checking the performance of the conditions of system performance, which are formulated in the technical task.

If the operational conditions are met, then the obtained design solution of the  $(i+1)$ -level system is documented, described in a certain form, and the technical task for the design of the system elements of the next level is formulated. If this obtained

solution is unsatisfactory, then one of the possible ways to improve the project is selected.

Of course, it is easiest to change the numerical values of the internal parameters of the elements. The set of procedures for modifying a set of internal parameters, analyzing and evaluating the results of the analysis is a parametric synthesis procedure.

If the modifications of a set of internal parameters are aimed at finding the best value of some quality indicator, then the parametric synthesis procedure is an optimization procedure. When by means of parametric synthesis it is not possible to achieve an acceptable degree of fulfillment of the conditions of workability, then use another method, which is related to the modification of the structure.

A new version of the structure is synthesized and the model formation and parametric synthesis procedures are repeated for it. If it is not possible to obtain an acceptable design solution on this path, then the question arises of adjusting the TP formulated at the previous stage (level) of design. Such an adjustment may require repeated execution of a series of procedures of the  $i$ -th hierarchical level, which determines the iterative nature of the design.

Figure 1.9 illustrates a characteristic feature of the relationship between design procedures of analysis and synthesis.

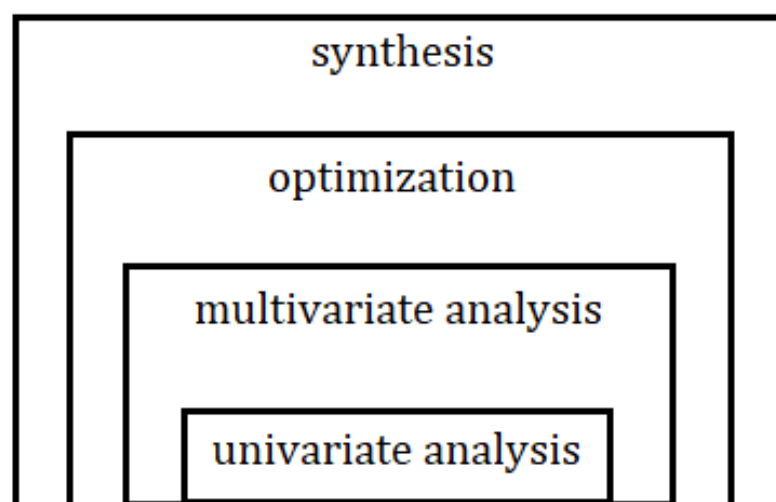


Fig. 1.9. Nesting of synthesis and analysis procedures



This relationship is characterized by nesting the analysis procedure in the optimization procedure (parametric synthesis) and the optimization procedure in the synthesis procedure, which combines structural and parametric synthesis.

Nestedness means that one-time execution of the optimization procedure requires multiple execution of the analysis procedure, and one-time solving of the synthesis problem requires multiple solving of the optimization problem. Obviously, the analysis procedures have the same character of interaction.

It is not difficult to calculate that the synthesis of a design solution at the next stage of design may require the execution of an excessively large number of analysis options.

### **1.5 Definition of the system structure automated design**

The CAD structure, in our case the CAD of extreme power regulators of solar batteries, is a set of subsystems that solve a certain task for each stage of research. At the same time, each subsystem includes technical, mathematical and informational means united by a common target function.

The CAD structure is multi-level, and its functional scheme is shown in fig. 1.10.

The most appropriate structure, which contains three levels: object, instrumental and service (basic).

The object level is characterized by a connection with the object of research. Its purpose is to organize the process of experimentation, i.e. to implement the management of the experimental setup, record data, process it, collect and present primary results to the researcher, including assisting him in interpreting the results of the experiment and making a decision on further research. Operations related to inspection and testing of experimental equipment, current registration and documentation of data are also assigned to the object level.

The instrumental level is designed for quite complex types of experimental data processing, scientific calculations and modeling. Here, information obtained as a result of research is accumulated and stored for a long time, archives and data banks are formed on specific research problems. At the instrumental level, various algorithms and programs compiled by the user are worked out, including programs that are used at the object level.

The basic (or service) level is used to perform the most complex and cumbersome scientific calculations, modeling, processing and presentation of information, the formation of large banks and databases, and the creation of an information and search system.

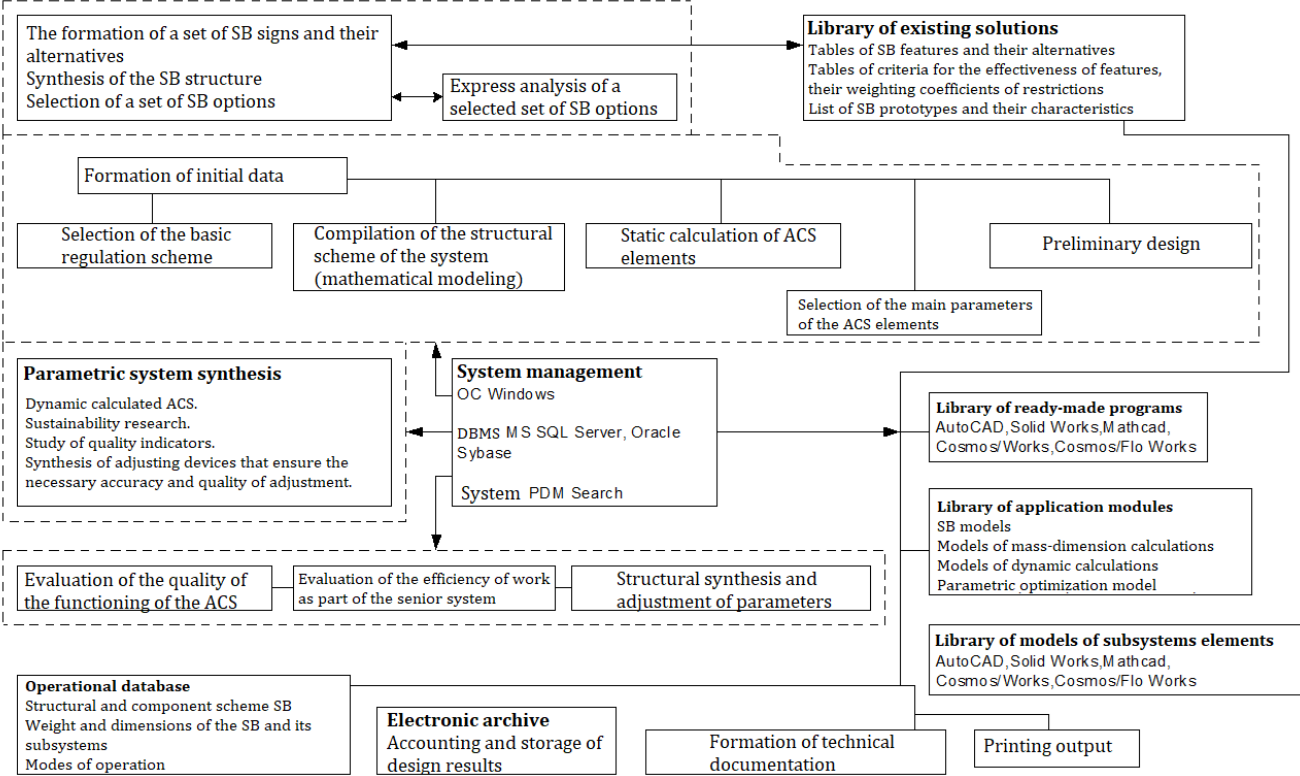


Fig. 1.10 Functional CAD diagram of the regulator

The three-level organization of modern CAD allows, on the one hand, to provide the researcher with the necessary means of computer technology and automation at all stages of research, and on the other hand, to reduce the costs of creating a system, reduce the number of computers, peripheral equipment, etc.

For CAD, the most important is the object level, because it is at this level that research appears, the role of which is key. It is at the object level that new information about the phenomenon or object under study is registered in the first place. Therefore, CAD, being a multi-level system, does not belong to the category of hierarchical systems.

It is worth noting that the mathematical support of design procedures of automated synthesis differs from the usual support and includes mathematical models of the design object, methods, synthesis and analysis algorithms.

Mathematical models mean systems of mathematical relationships: analytical - in the form of equations; graphic - in the form of structural diagrams or graphs; tabular - in the form of tables describing the researched process or phenomenon.

Mathematical methods are understood as ways of researching the solution of a problem, which includes theory related to methods of synthesis, analytical construction of dynamic systems, and techniques containing logic and justification of a solution to a design problem. Algorithms emerge from the analytical methods of solving the assigned design problem, as a component of mathematical support.

Mathematical CAD support serves to provide designer of a wide range of tools by technology designing. Mathematical CAD support is divided into general and special mathematical provision (GMP and SMP).

GMP (machine-oriented support) is a set mathematical logical methods, as well as a set of programs that implement these methods for specific tasks of the system. GMP is supplied developer (CAD) together with a computer and is intended for the maximum reduction of time and costs for preparation, adjustment and implementation of CAD tasks, as well as for increasing her productivity.

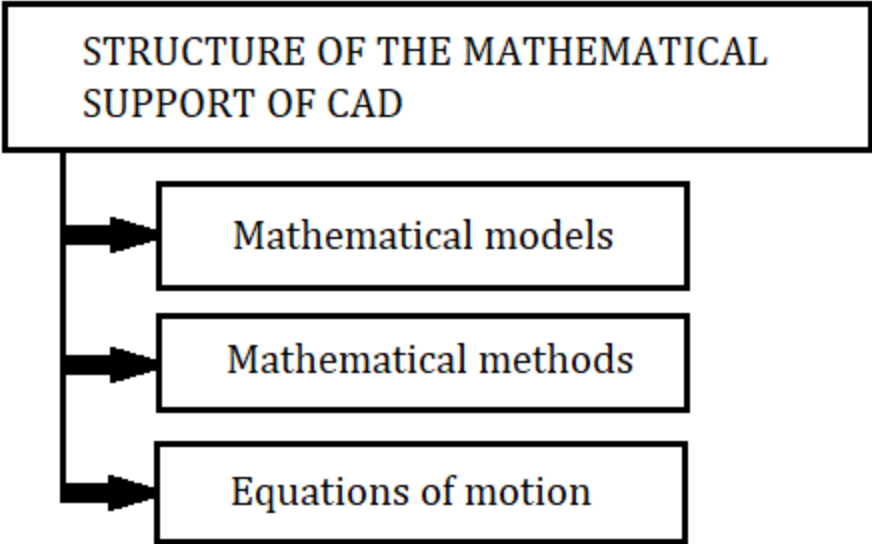


Fig. 1.11 Structure of mathematical CAD support

Special mathematical support is mathematical apparatus necessary for formalization defined class of tasks. The basis of the mathematical support of CAD is



the methods of the theory of automatic regulation and computational mathematics. However, the "adaptation" of these methods to a form that will enable their implementation by means of computer technology is a complex and time-consuming process. Therefore, one of the important, responsible and priority stages of this process is the development of algorithmic and software.

Based on mathematical software are being built the main ones CAD components - packages applied programs (PAP) (fig. 1.12). The process of creating PAP includes the development of mathematical models, methods, the compilation of computational algorithms and, in fact, the programming stage.

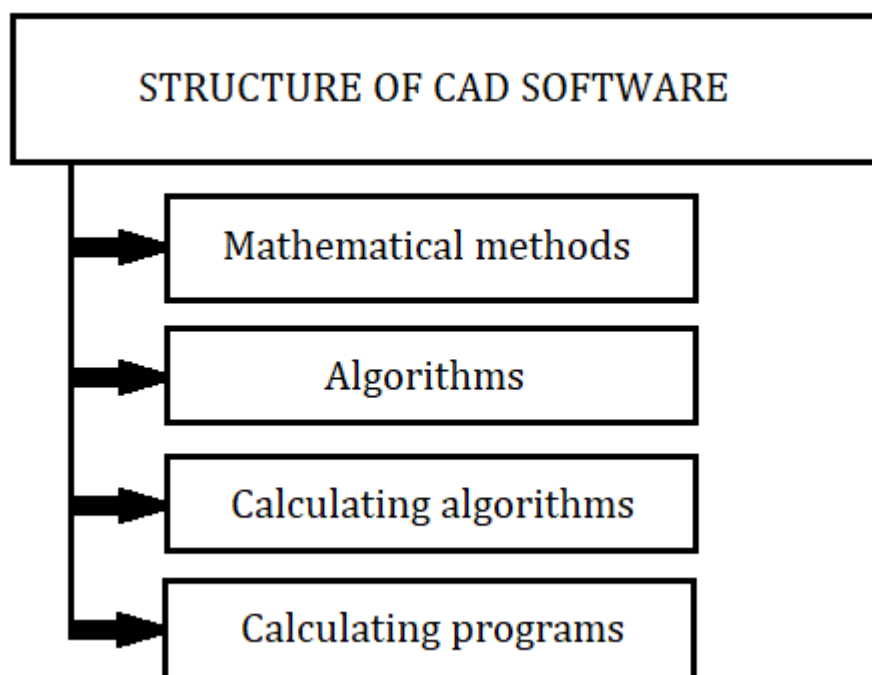


Fig. 1.12 CAD software structure

Choice methods and means mathematical provision of automated systems designing is determined by the nature of the delivered tasks and characteristics of the object, in relation to whose a stabilization and control system is being designed.

Therefore, the use of the considered functional scheme of a typical CAD, as well as the basic principles of its construction, allows to develop a unique CAD of an optimal regulator for the stabilization and control system of a specific inertial object.

**CHAPTER 2**  
**FORMATION OF DESIGN ALGORITHM**  
**SYSTEMS OF AUTOMATIC POWER REGULATION OF SOLAR**  
**BATTERIES**

**2.1 Definition basic characteristics of solar batteries**

The solar battery is the main generator of power supply for space vehicles. For high loads on the spacecraft, SB with the maximum output power is used. This parameter is increased by increasing the number of jointly fixed photocells and modules included in a single solar battery.

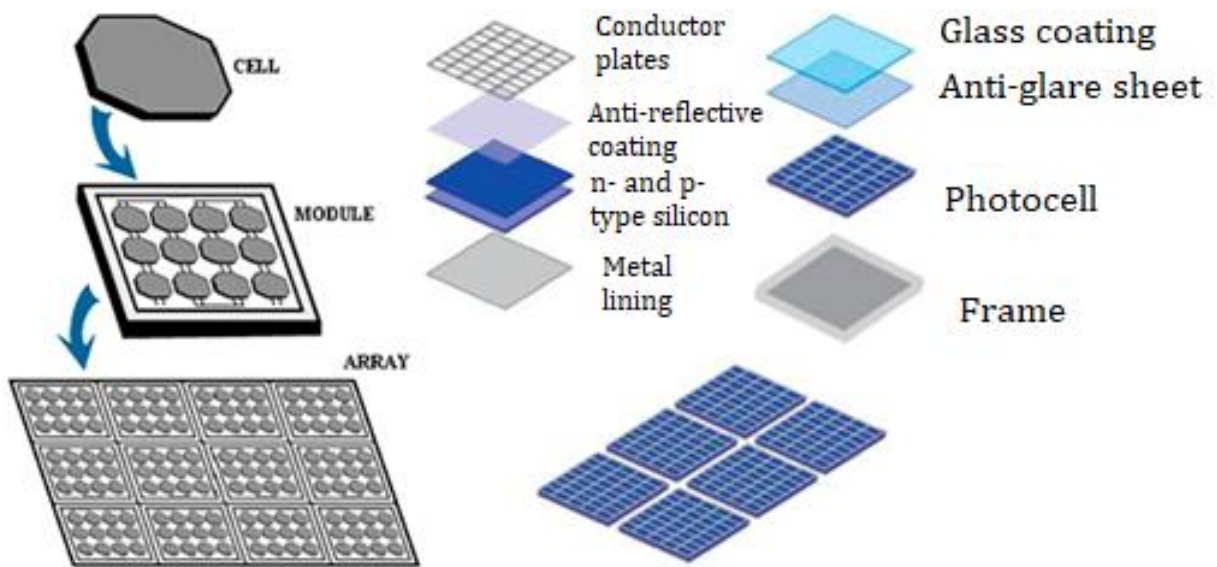


Fig. 2.1 Construction of solar batteries

A solar battery consists of photocells connected in series-parallel. All photocells are located on a frame made of non-conductive materials. This configuration allows you to assemble solar cells with the required voltage and current characteristics.

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Consultant						
S. controller	M.K. Filyashkin	<i>[Signature]</i>				
Dep. head	V.M. Sineglazov	<i>[Signature]</i>				
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Each photoconverter is a system of two semiconductors with p- and n-layers in close contact with each other. Transition zone between these regions is called an electron-hole or p-n-junction.

An excess of free electrons in the n-region will try to mutually diffuse with an excess of holes in the p-region (thermal self-diffusion).

Such diffusion of charge carriers charges the p-region of the semiconductor negatively, and the n-region - positively. During this process, holes and electrons in the form of two layers of bulk charges accumulate in the p-n-junction, which creates a potential difference between the layers. The electric field formed by these bulk charges will prevent further self-diffusion of the main current carriers through the p-n-junction.

The presence of a potential barrier allows the electron-hole junction to separate mainly diffused to it minor excess current carriers. As a result of such separation, excess electrons will accumulate in the n-region of the crystal, and excess holes will accumulate in the p-region. The accumulation of excess electrons in the n-region and holes in the p-region of the photoconverter will lead to compensation of the volume charge concentrated in the p-n-junction, that is, to the formation of an electric field opposing the field already present there.

The light electric field charges the p-type layer positively, and the n layer - negatively. A photo EMF(electromotive force) occurs between the p- and n-regions of the plate. The concentration of light-generated excess carriers at the p-n-junction, and therefore the value of the photo EMF, depend on the intensity of the light flux and the value of the load resistance  $R_{load}$  included in the external circuit of the photoconverter.

Opening the circuit of the photoconverter ( $R_{load} = \infty$ ), shown in fig. 2.2, will lead to the accumulation of all junction-separated current carriers near the p-n-junction. This compensates for the potential barrier on the transition to the maximum possible value, creating a maximum photo-EMF value equal to the no-load voltage  $U_{nlv}$ .

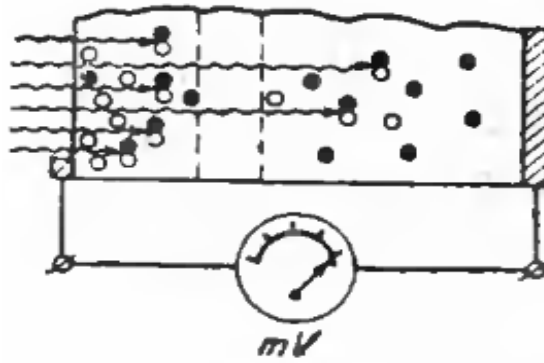


Fig. 2.2 No-load mode

Short circuit of the photoconverter ( $R_{load} = 0$ , fig. 2.3) will allow current carriers to circulate through the short-circuited circuit with an excess separated barrier, creating the maximum possible value of the current - the short circuit current  $I_{sc}$ . Accumulation of excess charges in the p-n-junction does not occur, and the photo-EMF of the converter is zero.

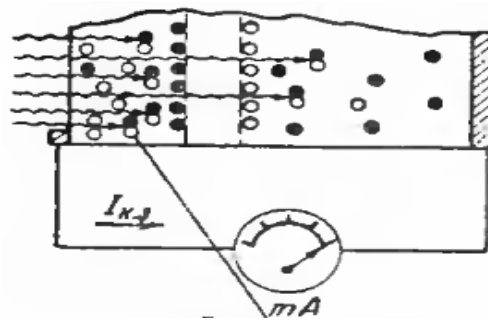


Fig. 2.3 Short circuit mode

Closing the converter to a certain final resistance  $R_{load}$  (fig. 2.4) will lead to the fact that part of the excess charge carriers separated by the junction will spend their energy on reducing the potential barrier in the p-n-junction (creating a voltage  $U_{load}$ ), and the rest of the carriers will generate a current  $I_{load}$  through the load.

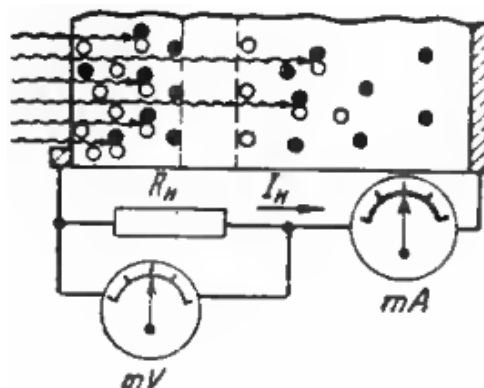


Fig. 2.4 Load mode

On the basis of the open circuit (fig. 2.2), we determine the value of the photo-EMF ( $U_{nlv}$ ):

$$I_{g.s.} - I_{r.s.} \left( \frac{q \cdot U_{nlv}}{e^{k \cdot t}} - 1 \right) = 0 \quad (2.1)$$

where  $I_{r.s.}$  – reverse saturation current;

$I_{g.c.}$  – current generated by the converter during illumination;

$q$  – charge of electrons ( $1.6 \cdot 10^{-19}$  kg);

$t$  – absolute temperature;

$k$  is the Boltzmann constant;

$$U_{nlv} = \frac{k \cdot t}{q} \ln \left( \frac{I_{g.s.}}{I_{r.s.}} + 1 \right) \quad (2.2)$$

For the case of closing the converter to the external resistance  $R_{load}$  the current  $I_{load}$  flowing through the resistance should be written into the right side of the equation (2.1). Then the voltage on the photoconverter will decrease to  $U_{load}$ , so

$$I_{g.s.} - I_{r.s.} \left( e^{\frac{q \cdot U_{load}}{k \cdot t}} - 1 \right) = I_{load} \quad (2.3)$$

From here

$$U_{load} = \frac{k \cdot t}{q} \ln \left( \frac{I_{g.s.} - I_{load}}{I_{r.s.}} + 1 \right) \quad (2.4)$$

Formulas (2.3) and (2.4) are general equations of the load characteristic of the photoconverter.

The relationship between the current flowing through the load  $I_{load}$  and the voltage on the photoconverter terminals  $U_{load}$  in steady state is determined according to the equation in the (2.3) form:

$$I_{load} = I_{g.s.} - I_{r.s.} \left( e^{\frac{q \cdot U_{load}}{k \cdot t}} - 1 \right) \quad (2.5)$$

Fig. 2.5 displays the curve of the volt-ampere characteristics (VAC) according to the equation (2.5).



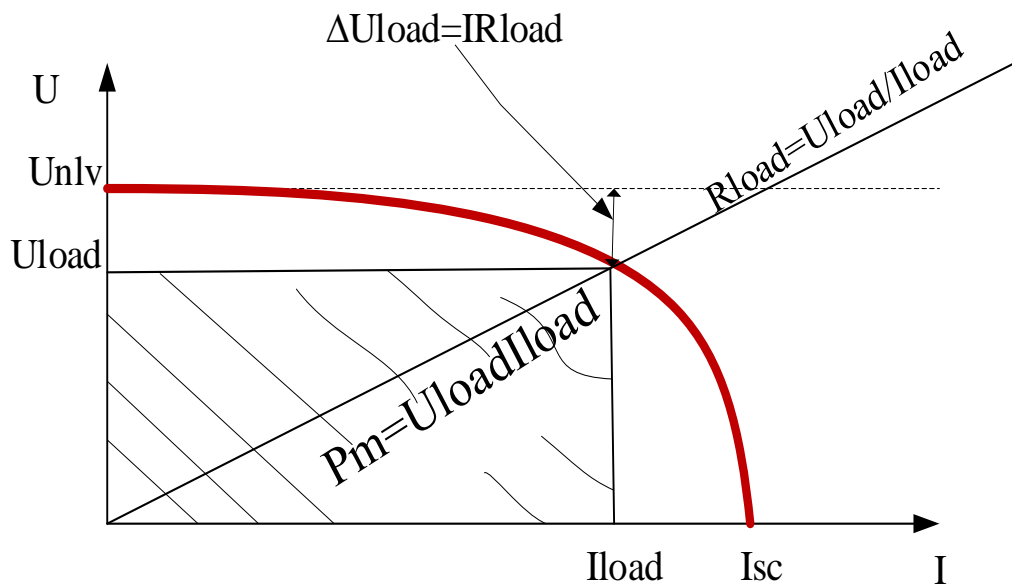


Fig. 2.5 Volt-ampere characteristic of the photoconverter

The graph shows the dependence in the case when the p-n-junction acts as a current source, and the external circuit acts as a load resistance, and different points of the characteristic correspond to different load resistances  $R_{load}$ . The point lying on the voltage axis corresponds to an open external circuit ( $R_{load} = \infty$ ;  $I_{load} = 0$ ), and reflects the no-load voltage  $U_{n-lv}$ . On the axis of currents ( $R_{load} = 0$ ) there is a point corresponding to the short-circuit current  $I_{sc}$ . If the illuminated converter is closed to a certain resistance  $R_{load}$ , then a current  $I_{load}$  is established in the circuit, the value of which is determined by the quality of the converter, the intensity of illumination and the value of the load resistance.

The power  $P$  allocated to the load is determined by the product  $I_{load}$  and  $U_{load}$ , which in fig. 2.5 corresponds to the area of the shaded rectangle. For one and the same converter at a certain level of illumination, the value of power  $P$  depends on the value of the load resistance. The greatest power is allocated to the load at some optimal value of  $R_{opt}$ , which corresponds to the greatest efficiency of conversion of light energy into electrical energy. Each converter has its own  $R_{opt}$  value, the value of which depends on the quality, size of the working surface and degree of illumination. The maximum power of the converter will be greater, the higher the short-circuit current  $I_{sc}$ , and the no-load voltage  $U_{n-lv}$ , as well as the closer the shape of the loading curve (in the working area) approaches to a rectangular.

From the equation for  $I_{load}$  can be determined  $I_{sc}$  and  $U_{n-lv}$ . Assuming that  $U_{load} = 0$  ( $R_{load} = 0$ ), we obtain:

$$I_{load} = I_{sc} = I_{g.s.} \quad (2.6)$$

Assuming that  $I_{load} = 0$  ( $R_{load} = \infty$ ), we solve the equation with respect to  $U_{load}$  and obtain:

$$U_{load} = U_{nlv} = \frac{k \cdot t}{q} \ln\left(\frac{I_{g.s.} - I_{load}}{I_{r.s.}} + 1\right) \quad (2.7)$$

Fig. 2.6 shows a simplified equivalent circuit of an ideal photoconverter

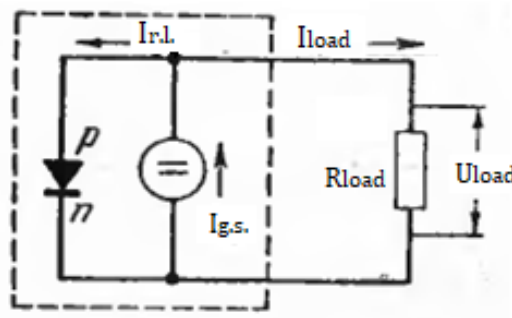


Fig. 2.6. Equivalent circuit of an ideal photoconverter

In this diagram, the photoconverter is depicted as a system surrounded by a dotted line. The ability of the converter to create a current  $I_{g.s.}$  under the influence of light is reflected by the introduction of a direct current generator into the circuit, and the ability to conduct current in only one direction - by the introduction of a diode insensitive to the influence of light.

Through such a diode passes the reverse leakage current  $I_{r.l.}$ , consisting of the flow of the main charge carriers through the p-n-junction. The current  $I_{r.l.}$  can be determined from the formula of the current-current characteristic of the p-n-junction:

$$I_{load} = I_{r.s.} \left( e^{\frac{q \cdot U_{load}}{k \cdot t}} - 1 \right) \quad (2.8)$$

and from the diagram in fig. 2.6 shows that:

$$I_{g.s.} = I_{r.l.} + I_{load} \quad (2.9)$$

That is, only a part of the light-generated current carriers can pass through the load, while the other, equal to  $I_{r.l.}$ , is lost.

The simplified equivalent circuit does not take into account the resistance present in the real device, which can be of two types:

- the series resistance of the photoconverter  $R_{load}$ , which includes the resistance of the contacts and directly the resistance of the semiconductor material from which it is made;

- the parallel (shunting) resistance of the photoconverter  $R_{sh}$ , formed due to the presence of the reverse resistance of the p-n-junction.

The scheme in fig. 2.7 corresponds to a real photoconverter

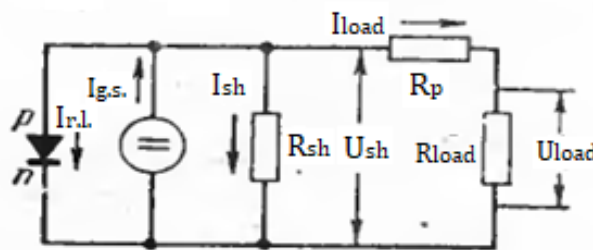


Fig. 2.7 Equivalent circuit of a real photoconverter

The resistance  $R_p$  is connected in series with the load resistance  $R_{load}$ , which corresponds to the loss of part of the EMF developed by the photoconverter.

This loss corresponds

$$\Delta U = I_{load} \cdot R_p \quad (2.10)$$

At a fixed value  $R_p$ , the value  $\Delta U$  depends on the load resistance  $R_{load}$ . The maximum losses are observed in the short-circuit mode ( $R_{load} = 0$ ), then

$$\Delta U = I_{sc} \cdot R_p \quad (2.11)$$

The resistance  $R_{sh}$  is included in parallel with the circuit  $R_{load} - R_p$ , which leads to the passage of a part of the current generated by the converter through the resistance  $R_{sh}$  to bypass  $R_{load}$  and  $R_p$ . Thus, the presence of  $R_{sh}$  creates current losses  $I_{sh}$ , which are inversely proportional to the value of  $R_{sh}$ .

The analytical expression of the current–voltage characteristic of a real photoconverter is derived using the relation

$$I_{g.s.} = I_{r.l.} + I_{sh} + I_{load} \quad (2.12)$$

where  $I_{g.s.}$  is the current generated by the converter during illumination;

$I_{load}$  – external circuit current;

$I_{r.l.}$  – reverse current through a p-n-junction;

$I_{sh}$  is the current through the resistance  $R_{sh}$ , which is joking p-n-junction;

The equivalent circuit from fig. 2.7 allows you to find

$$I_{sh} = \frac{U_{sh}}{R_{sh}} = \frac{U_{load} + I_p \cdot R_p}{R_{sh}} \quad (2.13)$$

$$I_{r.l.} = I_{r.s.} \left( e^{\frac{q \cdot U_{sh}}{k \cdot t}} - 1 \right) = I_{r.s.} \left( e^{\frac{q \cdot (U_{load} + I_p \cdot R_p)}{k \cdot t}} - 1 \right) \quad (2.14)$$

Substituting these values into the expression (2.12), we get

$$I_{load} = I_{g.s.} - I_{r.s.} \left( e^{\frac{q \cdot (U_{load} + I_p \cdot R_p)}{k \cdot t}} - 1 \right) - \frac{U_{load} + I_p \cdot R_p}{R_{sh}} \quad (2.15)$$

By logarithming (2.15), we have:

$$U_{load} = \frac{k \cdot t}{q} \left[ \ln \left( \frac{I_{g.s.} - I_{load}}{I_{r.s.}} - \frac{U_{load} + I_{load} \cdot R_p}{R_{sh}} + 1 \right) \right] - I_{load} \cdot R_p \quad (2.16)$$

Finally, the power of a real photoconverter under load will be equal to

$$P = I_{load} \cdot U_{load} = I_{load} \left[ \frac{k \cdot t}{q} \ln \left( \frac{I_{g.s.} - I_{load}}{I_{r.s.}} + 1 \right) \right] - I_{load} \cdot R_p \quad (2.17)$$

The formula (2.17) shows that the power of the solar battery is affected by both the current and the voltage on the load, on which it is directly dependent.

Consider the characteristics of a solar battery. To determine the current-voltage characteristic, connect a variable resistor to the illuminated battery, which will increase the load; we measure the current supplied to the resistor and the voltage on the solar battery. The scheme for removing the volt-ampere characteristic is shown in Fig.2.8

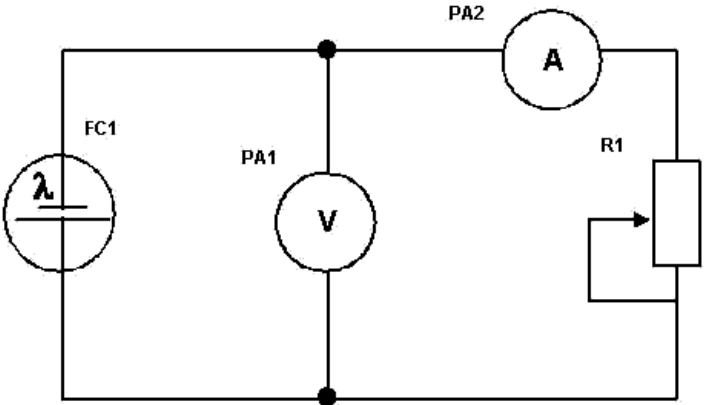


Fig. 2.8. Scheme for removing the volt-ampere characteristic of the SB

When the solar battery is operating without load, the photo-EMF voltage on it is about 10.5V, which corresponds to the idling state of the solar battery. When connecting the load and further reducing its resistance, the current in the load will begin to increase. At the same time, the voltage on the load will begin to decrease. A voltage of approximately 8.79V at the load is the optimal mode of operation of the solar cell. Increasing the current draw reduces the voltage on the solar cell, and the generated current remains practically unchanged. Supplying a larger load reduces the operating voltage, which is shown in Fig. 2.9.

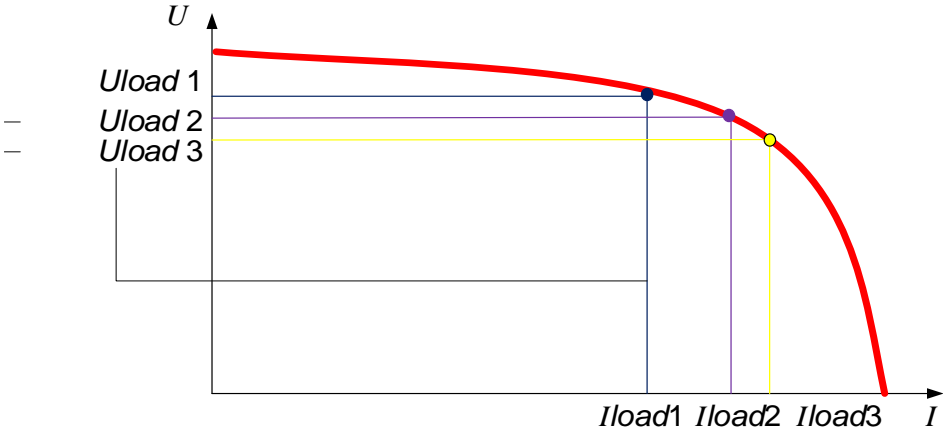


Fig. 2.9 Volt-ampere characteristic of the solar battery

For each load, certain optimal and working values of load voltage and current are determined. The VAC in fig. 2.9 clearly indicates a drop in the operating voltage when the load increases, which in turn affects the output power (according to 2.17). The formula makes it possible to obtain the volt-watt characteristic (VWC) shown in fig. 2.10 next to the VAC.

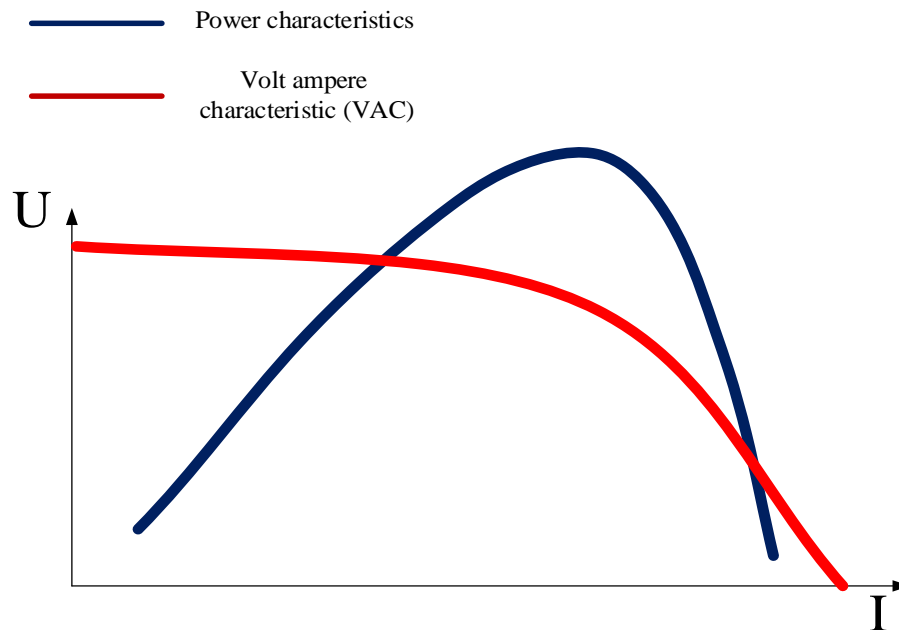


Fig. 2.10 Solar battery characteristics

The analysis shows that the optimal voltage is achieved at maximum power - in full accordance with the extreme of VWC. At the same time, the change in the load of the external circuit determines the position of the extremum and its level. This influence necessitates the introduction of an automatic control system, which should, in accordance with the extremes of the VWC, determine the optimal values of the loads and maintain the determined extremum when the operating conditions change.

## 2.2 Selection of the power regulator type

Taking into account the extreme nature of the characteristics of solar batteries, the task of choosing a power regulator turns into the plane of choosing among possible types of extreme regulators, based on the operating conditions of solar batteries.

By extreme regulation, we understand the method of automatic regulation, which consists in establishing and maintaining such a mode of operation of the controlled object, in which the extreme value of some criterion characterizing its operation is reached.

The extreme regulator is a component of the extreme regulation system. It performs an automatic search and maintenance of such a value of the regulated value, at which the indicator characterizing the quality of the functioning of the controlled object reaches its extreme.

According to the nature of adjustment, adaptive systems are divided into three groups: self-adjusting, self-organizing, and self-learning.

The fundamental difference between self-adjusting systems and self-organizing systems is that adaptation in them is achieved only by changing the parameters of the system regulator, while in self-organizing systems, adaptation is carried out by changing both the parameters and the structure of the regulator.

Self-learning systems accumulate and analyze information about the behavior of the main system, adjust control algorithms to achieve higher quality. Such systems are built using several levels of adaptation, each of which improves the algorithm of the lower level.

In this regard, the advantage of self-adjusting passive adaptation for solar power stabilization systems is quite obvious. It consists in choosing a rigid structure and constant properties of the regulator. The complexity and increase in the price of the system in this case are minimal, in addition, there is no need to control parametric multiplicative disturbances caused by a change in the physical characteristics of the system.

Based on the task of adaptation, systems with stabilization of management quality and systems with optimization of management quality are distinguished. The task of systems with stabilization of management quality is to maintain the necessary level of system quality in accordance with the selected criterion. The task of systems with management quality optimization is more difficult and consists in finding and further maintaining the optimal level of automatic control systems(ACS) quality in accordance with the selected criterion.

Obviously, it is advisable to consider opportunity and conditions application in regulatory systems power solar batteries for both stabilization and optimization quality management.

The level of quality control of solar power regulation systems is determined by the maximum of the chosen criterion  $J$  for their assessment. In our case it  $J \equiv P_{SB}$  power. The latter can be set in accordance with the input actions of the control object, regulator adjustment parameters, time.

In our case it's a current  $I_{load}$  load. Let's enter generalized marking  $\mu \equiv I_{load}$  parameter that varies.

Possible extreme characteristics of solar batteries are given in Fig. 2.11.

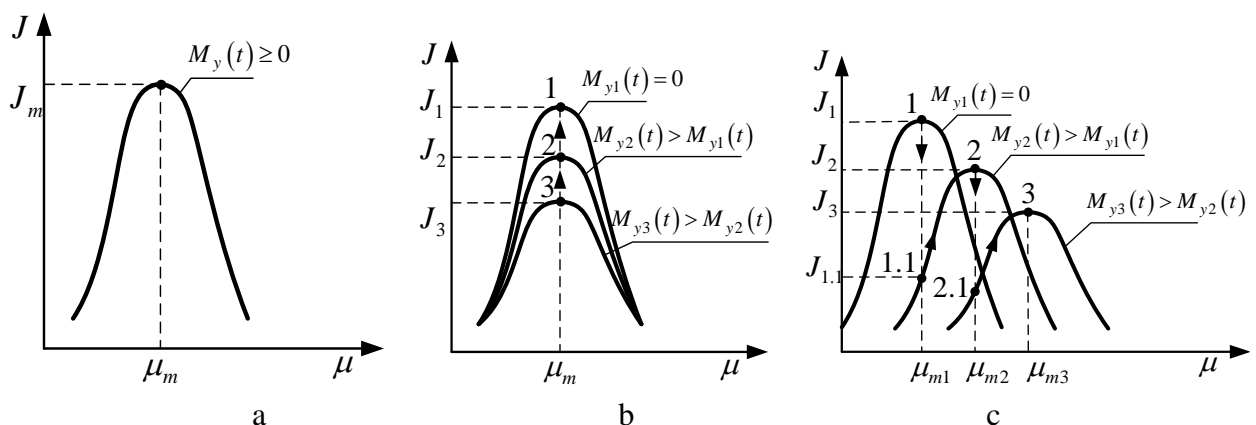


Fig. 2.11 Extreme characteristics of SB:

a - without elimination ; b - elimination vertically ; c - horizontal displacement

If the extremum of the quality criterion (fig. 2.11a) is constant ( $J_m = \text{Const}$ ), and corresponds to a certain value  $\mu_m = \text{Const}$  of the varied parameter when the disturbing influences change  $M_y \geq 0$  in the entire possible range, then the use of adaptive systems will be impractical, since the task of maintaining the given control quality  $J_m$  with the required accuracy can be solved by the usual ACS (fig. 2.12) when providing a preliminary setting  $\mu_m$ .



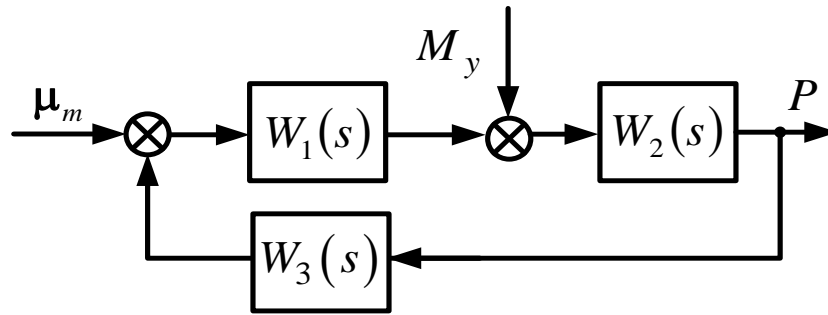


Fig. 2.12 Structural diagram of the system

As a regulator  $[W_1(s), W_3(s)]$  can be used classic proportionally - differentiating PD regulator with transfer function  $W(s) = k(1 + Ts)$ .

If extreme criterion quality (Fig. 2.11 b) corresponds the same value  $\mu_m = \text{Const}$  parameter that changes, but changes its levels  $J_3 < J_2 < J_1$  at change outrageous influences  $M_{y3}(t) > M_{y2}(t) > M_{y3}(t)$ , then quite justified will be application adaptive systems with stabilization quality management. In this case, based on the accepted criterion evaluations quality  $J_1$ , for example, workers points 2,3 will be strive to working points 1 that determines extreme quality that stabilizes.

Task quite is resolved application adaptive systems with an open adaptation circuit(AC) on the effects of are infuriating Such a structural diagram systems are shown in fig. 2.13.

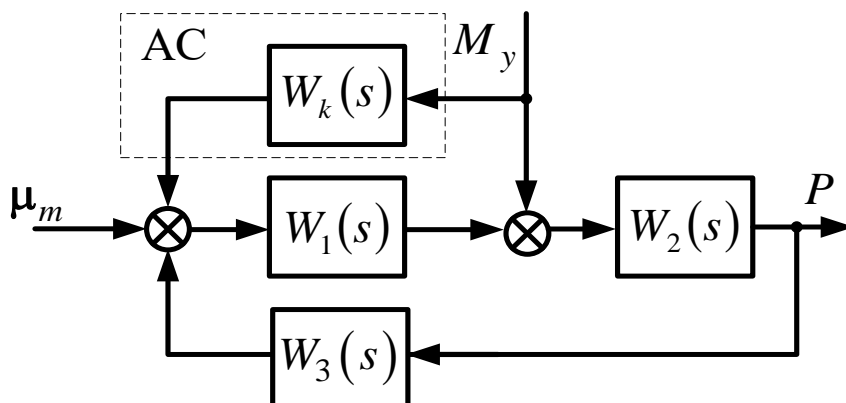


Fig. 2.13 Structural diagram of the system from open circuit of adaptation

Based on structural schemes, we get equations of motion of the system

$$P = \frac{W_1(s)W_2(s)}{1 + W_1(s)W_2(s)W_3(s)} \mu_m + \frac{(W_1(s)W_k(s) - 1)W_2(s)}{1 + W_1(s)W_2(s)W_3(s)} M_y.$$

Not hard notice that the last the equation is reduced to the form

$$P \approx \frac{W_1(s)W_2(s)}{1 + W_1(s)W_2(s)W_3(s)} \mu_m.$$

upon fulfillment of conditions

$$W_k(s) = \frac{1}{W_1(s)} \rightarrow W_k(s) \approx \frac{1}{k_1}.$$

Thus, when external influences acting on SB change, its power remains close to the extreme.

It should be noted that the power stabilization system automatically compensates the impact on the SB of only those external disturbances that are measured. Usually, the control is based on the main disturbance, which causes the largest deviations of the controlled value from the set value. Such an external disturbance is determined, as a rule, experimentally, based on the conditions of possible functioning of the system, based on the analysis of the dependencies between the controlled quantity and external disturbances.

Task can also be solved by application self-adjusting passive adaptation from closed loop on the adjustable coordinates.

Structural diagram of the system from closed circuit of adaptation on adjustable coordinates are given in fig. 2.14.

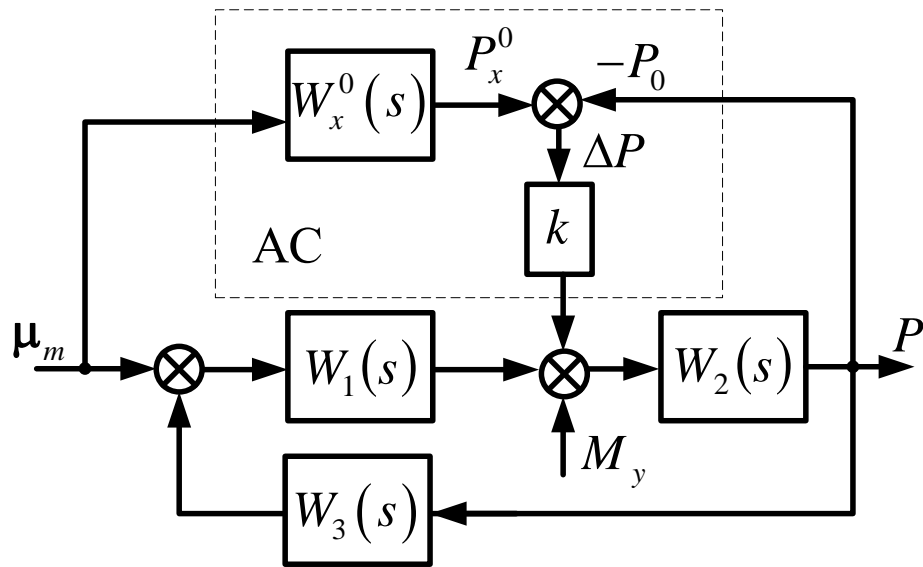


Fig. 2.14 Structural diagram of a system with closed circuit of adaptation

Adaptation circuit (AC) includes a reference model with a transfer function  $W_x^0(s) = \frac{W_1(s)W_2(s)}{1 + W_1(s)W_2(s)W_3(s)}$  equal desired transferable functions according to the control signal, the device comparison (sumimator) adjustable coordinates  $P$  with the output value  $P_x^0$  models and an amplifier with a coefficient strengthening  $k$ .

The object of control is subject to disturbing influences  $M_y$ .

Signal  $\Delta P$  disagreement adjustable coordinates and reference models after strengthening comes to the object control with transmission function  $W_2(s)$ .

We find transferable functions systems:

- control signal

$$W_x = \frac{W_1 + W_x^0 k}{(1 + W_1 W_2 W_3 + k W_2)} W_2,$$

- outrageously indignation

$$W_y(s) = \frac{W_2}{(1 + W_1 W_2 W_3 + k W_2)}.$$

By choosing the gain  $k = k_m$  quite high, that is providing  $k_m W_2(s) \gg 1 + W_1(s)W_2(s)W_3(s)$  and  $\frac{1}{k_m} \rightarrow 0$ , we get the equations of the adaptive system

$$P = W_x^0(s) \mu_m - \frac{1}{k_m} M_y \approx W_x^0(s) \mu_m.$$

Thus, when external influences change, the adjustable coordinate will remain close to the reference - the extreme of the maintained quality.

If the extremes of the quality criterion (fig. 2.11c) due to changes in disturbing influences  $M_{y3}(t) > M_{y2}(t) > M_{y1}(t)$  change both in terms of level  $J_3 < J_2 < J_1$  and direction, correspond to different values of the variable  $\mu_{m3} > \mu_{m2} > \mu_{m1}$  system parameter, it is advisable to apply adaptive systems with control quality optimization - extreme control systems (ECS).

Optimizing the quality of management means ensuring the maximum of the quality criterion  $J_i$  in the presence of an external disturbance  $M_{yi}$  due to the change of the variable system parameter to the value  $\mu_{mi}$ .

To determine the extremum of the control quality criterion, searching and non-searching ECSs can be used.

Non-searching systems solve the task of determining the extremum analytically. They have high performance, but are very complex systems, and their implementation in practice faces certain technical difficulties.

The structural diagram of the search ECS is shown in fig. 2.15.

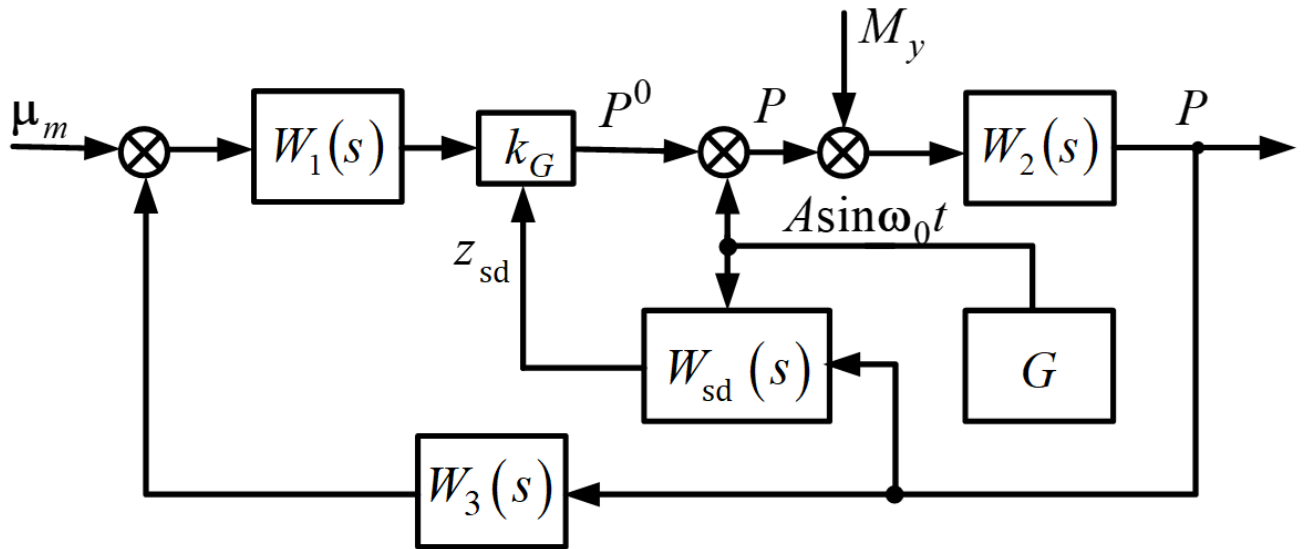


Fig. 2.15 Structural diagram of the extreme control system

A feature the system has its presence composition of the generator  $G$  trial signals and a synchronous LED detector.

### 2.3 Evaluation of methods for finding the extremum of the quality criterion

To define extreme criterion quality  $J$  management necessary calculate derivatives  $\frac{dJ}{d\mu}$  by parameters  $\mu$  that vary.

In general the case when the criterion quality is a function several parameters  $J(\mu_1, \mu_2, \dots, \mu_n)$  that vary, the condition of its extremum will be zero at the extremum point of all private derivatives

$$\frac{dJ}{d\mu_1} = 0, \quad \frac{dJ}{d\mu_2} = 0, \quad \dots, \quad \frac{dJ}{d\mu_n} = 0.$$

The direction of the moment then the extremum is determined by the vector, projections whose on axis coordinates  $\mu_i$  ( $i=1,2,\dots,n$ ) are equal to private derivatives, respectively

$$\text{grad}J = \overline{k_1} \frac{dJ}{d\mu_1} + \overline{k_2} \frac{dJ}{d\mu_2} + \dots + \overline{k_n} \frac{dJ}{d\mu_n},$$

where  $k_i$  ( $i=1,2,\dots,n$ ) - single vectors axes.

The vector  $\text{grad}J$  is directed towards the extremum  $J$  and is called the gradient of the quality criterion. At the point of extremum  $\text{grad}J = 0$ .

Figure 2.16a shows the gradient  $\text{grad}J$  of the quality criterion with two parameters  $\mu$  of systems that vary.

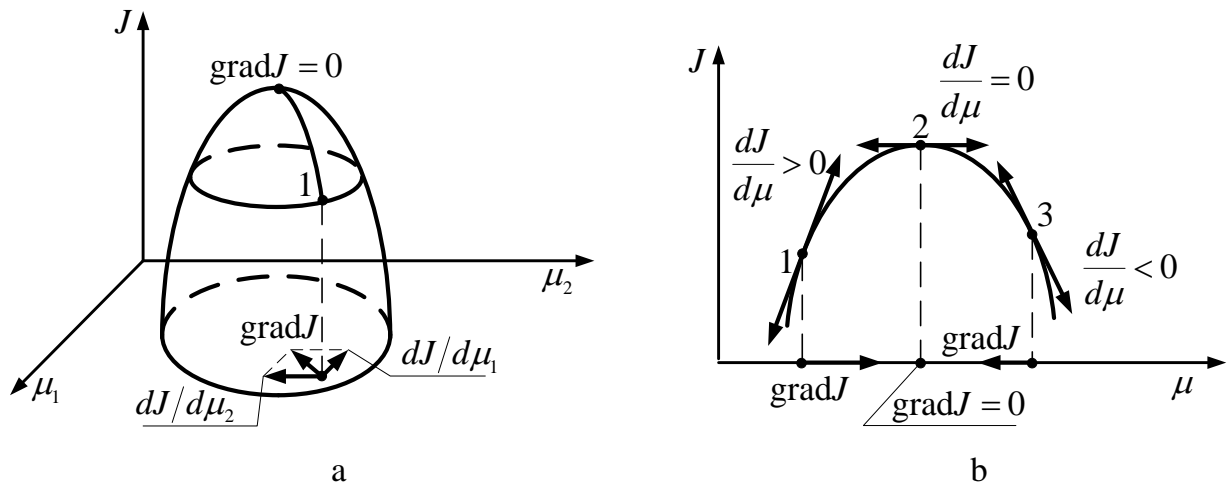


Fig. 2.16 Definitions direction of movement of the working point to the extremum:  
a – along the gradient; b - by the sign of the derivative

If quality criterion depends from one parameter that varies (fig. 2.16b), then the direction of movement towards the extremum can be determined by the sign of the derivative  $\frac{dJ}{d\mu}$ . Yes when found operating point in position 1, which responds derivative  $\frac{dJ}{d\mu} > 0$  parameter  $\mu$  that varies should be increased. When finding the operating point in position 3, which corresponds to the derivative  $\frac{dJ}{d\mu} < 0$ , parameter  $\mu$  that varies, should be reduced.

Calculation derivatives  $\frac{dJ}{d\mu_i}$  can be implemented in different way. In practice

find application:

- method of synchronous detection;
- method time derivative;
- method memorization extremum, etc.



The gradient method involves the simultaneous change of parameters that vary so as to ensure the movement of the operating point in a direction close to the instantaneous direction of the gradient vector. At the same time, the rates of change of the varying parameters should be proportional to the corresponding derivatives of the quality criterion by parameter  $\mu_i$

$$\left. \begin{aligned} \frac{d\mu_1}{dt} &\equiv \frac{dJ}{d\mu_1} \\ \dots\dots\dots \\ \frac{d\mu_n}{dt} &\equiv \frac{dJ}{d\mu_n} \end{aligned} \right\} \cdot$$

The gradient method illustrates on fig. 2.17a. The working point smoothly moves along the trajectory 1–2–3– $J_{\max}$  normal to the surface  $J(\mu_1, \mu_2) = \text{const}$ .

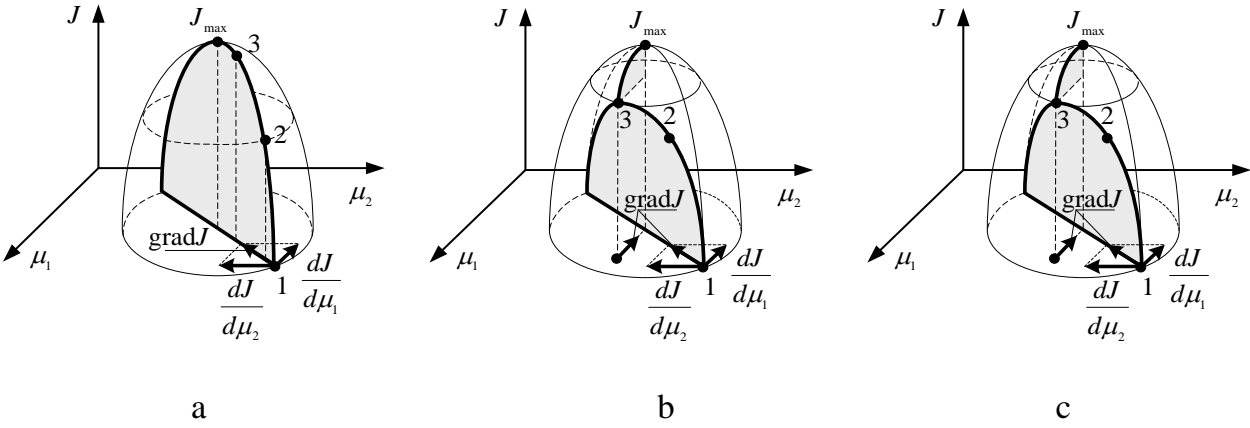


Fig. 2.17 Methods of finding extremum:  
a – gradient; b – rapid descent; c - Gauss-Seidel

When implemented step-by-step movement of the working point to the extremum it is necessary to each one fixed step  $\Delta\mu_{1,2}$  in changing the parameter that varies, was proportional to the derivative of the quality criterion for the corresponding parameter  $\mu_{1,2}$



$$\Delta\mu_1 \equiv \frac{dJ}{d\mu_1}, \quad \Delta\mu_2 \equiv \frac{dJ}{d\mu_2}.$$

The gradient method during step-by-step movement is characterized by a minimum range of oscillations near the extremum point.

The method of the fastest descent is presented in fig. 2.17b. The movement of working point 1 is organized according to the initial one in the direction of the gradient vector  $\text{grad}J$  and is carried out (trajectory 1–2–3) as long as derivative criterion quality accepted direction will not become equal to zero, (will not stop magnification criterion quality  $J$ ).

It responds point 3. At point 3 is determined new direction of gradient  $\text{grad}J$  and a new movement is being organized direction (trajectory 3– $J_{\max}$ ) until the increase in the quality criterion is stopped. In case process is repeated until the extremum point is reached. The method is characterized by a quick exit to the extremum region. In the region of the extremum, more accurate methods, such as the gradient, can be applied.

The Gauss-Seidel method consists in alternately changing the varying parameters (fig. 2.17c). At a fixed value of the parameter  $\mu_2$ , values the parameter  $\mu_1$  changes

until until the corresponding component of the gradient  $\frac{dJ}{d\mu_1} = 0$  becomes zero. The

working point moves along the trajectory 1–2–3. The next step is to change the parameter  $\mu_2$ , with fixed parameter values  $\mu_1 = \mu_1^3 = \text{const}$ , to zero rotation  $\frac{dJ}{d\mu_2} = 0$ .

The working point moves along the trajectory 3–4– $J_{\max}$ . Extremum reached. The method is not difficult in technical implementation, but it takes some time to determine the extremum of the quality criterion.

Random method search is based on a random change of parameters that vary in each of the positions of the operating point. So, from the starting point, arbitrary trial changes of the varying parameters are made. With each of them, an increase in the quality criterion is recorded. The step with the best result is remembered.

The working step is made in the direction of the vector with the best trial result. In the new position of the working point, the test measurements are repeated, and the

"best" vector is selected again. Search operations continue until the working point reaches the extremum.

Note that in practice, the methods of determining the derivatives  $\frac{dJ}{d\mu_i}$  and the choice of the method of finding the extremum of the quality criterion are mutually dependent, because their implementation is connected by the same technical solutions.



## CHAPTER 3

### DESIGN OF THE SYSTEM FOR EXTREME REGULATION OF SOLAR BATTERY POWER

#### 3.1 Extreme power regulator

Studies of the power of solar batteries have shown a significant influence on them of external factors of the operation of batteries on space vehicles. The results of such studies are presented in Fig. 3.1.

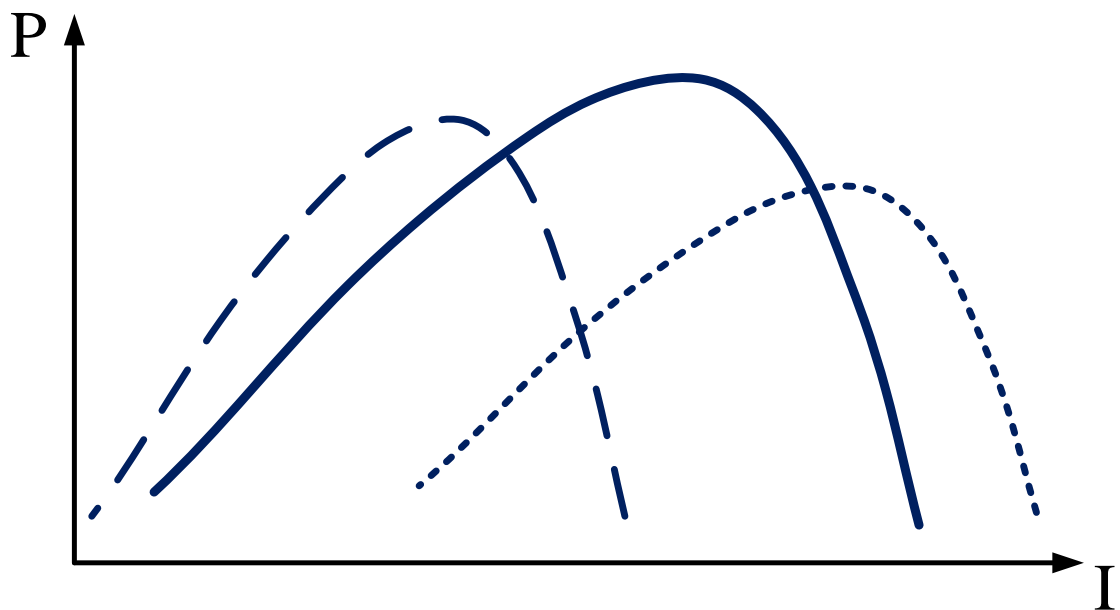


Fig. 3.1 The influence of external factors on the characteristics of SB

In connection with this suggested use in the automatic regulation system power solar batteries of an extreme regulator. As a search method extremum, the author chose the method of synchronous detection as the simplest in practice implementation.

In the algorithmic description of the regulator, the method of combined coordinates was used.

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Performed	A.A. Rud		Automated Design System of the Extreme Power Regulator of Solar Batteries	N.	Page	Pages
Supervisor	O.K. Ablesimov					
Consultant						
S. controller	M.K. Filyashkin					
Dep. head	V.M. Sineglazov					
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The functional diagram of the extreme power regulator (EPR) proposed for the solar batteries of the spacecraft is given in fig. 3.2.

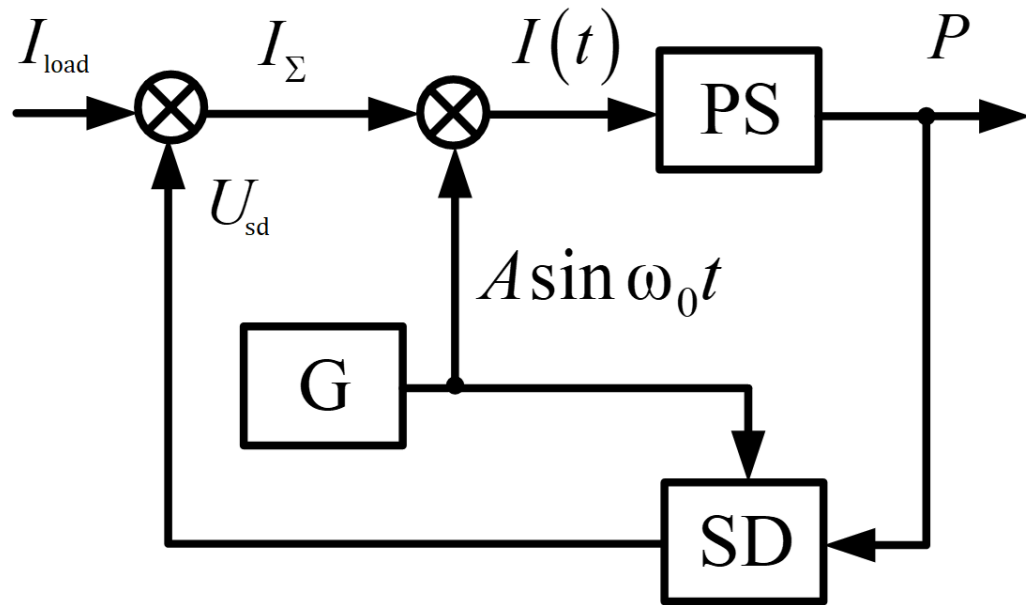


Fig. 3.2 Functional scheme of the extreme regulator

The regulator includes a battery power sensor (PS), a test signal generator (G) and a synchronous detector (SD).

The processes of finding and maintaining the optimal level of quality are presented in fig. 3.3-3.5.

The quality criterion  $J \equiv P$  is battery power, a varied parameter  $\mu \equiv I_{load} - \text{load current}$ .

The influence  $I(t)$  is formed (fig. 3.2-3.3a) by the combination of two signals: the regulator signal  $I_{\Sigma} = \text{Const}$  and a test harmonic signal  $A \cdot \sin \omega_0 t$  of small amplitude ( $A \ll I_{\Sigma}$ ), which is produced by the generator G

$$I(t) = I_{\Sigma} + A \cdot \sin \omega_0 t. \quad (3.1)$$

The signal  $I_{\Sigma} = \text{Const}$  determines the position of the operating point 1 on the extreme characteristic of the system (fig. 3.3a).

The reaction of the system to a complex signal (3.1) can be represented as a Taylor series

$$P(I_{\Sigma} + A \sin \omega_0 t) = P(I_{\Sigma}) + \left. \frac{dP}{dI} \right|_{I=I_{\Sigma}} \cdot A \sin \omega_0 t, \quad (3.2)$$

or find by graphoanalytical method (fig. 3.3a).

In such conditions, the output signal, which corresponds to the regulator signal  $I_{\Sigma} = \text{Const}$ , will be constant  $P(I_{\Sigma}) = \text{Const}$ , and its amplitude will be determined by the position of the operating point 1.

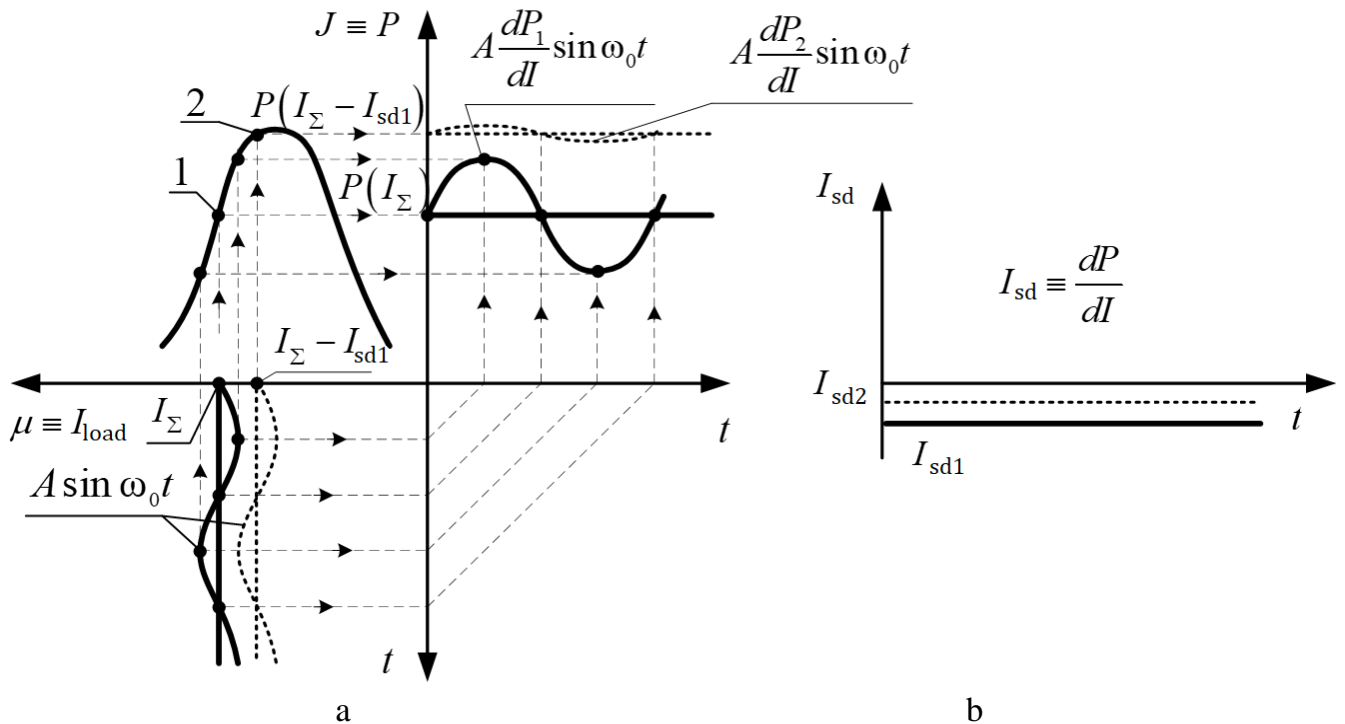


Fig. 3.3 Algorithmic description of the extreme regulator

At the same time, the harmonic component of the output signal  $P$ , according to (3.2), will be proportional to its derivative with respect to the signal  $I(t)$ , and its phase will be proportional to the sign of this derivative.

In fig. 3.3a, the amplitude of the harmonic component  $P$  is marked  $A \frac{dP_1}{dI}$ , and its phase is equal to zero  $\varphi = 0^0$ , in accordance with the derivative in the vicinity of the operating point 1  $\sim \frac{dP}{dI} < 0$ .

The synchronous detector SD separates the  $P$  harmonic component from the main output signal  $A \frac{dP_1}{dI} \sin \omega_0 t$ , turning it into a constant signal (fig. 3.3b), the level

of which  $I_{sd1}$  is proportional to the derivative  $\frac{dP_1}{dI}$ , and the polarity is determined by the phase of the harmonic component (in the case under consideration, the phase  $\varphi = 0^\circ$  corresponds to the negative polarity "-").

The signal of the synchronous detector is fed (Fig. 3.2) to the input of the regulator, which reduces the signal  $I_\Sigma$  to the value  $I_\Sigma - I_{sd1}$ . Operating point 1 moves (fig. 3.3a) to position 2 with a speed proportional to  $\frac{dP_1}{dI}$ .

Since the output signal of the system corresponds to the regulator signal, it increases to the value of  $P(I_\Sigma - I_{sd1})$ . The amplitude of the harmonic component of the signal  $P$  decreases to the value  $A \frac{dP_2}{dI}$ , due to the decrease in the steepness of the extreme characteristic in the vicinity of the operating point 2. The phase remains unchanged -  $\varphi = 0^\circ$ .

Proportionally to the decrease in the amplitude of the harmonic component  $A \frac{dP_2}{dI}$ , the SD signal, while maintaining the polarity, decreases to the value  $I_{sd2}$ . This leads to the reduction of the regulator signal to the value  $(I_\Sigma - I_{sd1} - I_{sd2})$  and movement of the operating point to the extremum with a speed proportional to  $\frac{dP_2}{dI} < \frac{dP_1}{dI}$ .

This process continues in time until the value of the regulator signal is equalized  $I_m$ , when the operating point reaches the peak of the extreme characteristic.

At the moment of reaching the extremum Extr (fig. 3.4), the output signal will reach its maximum value  $P(I_m)$ , and the amplitude of the harmonic component will decrease to zero, since at the point of extremum  $\frac{dP}{dI} = 0$ . Accordingly, the signal at the output of the SD also becomes zero  $I_{sd} = 0$ .

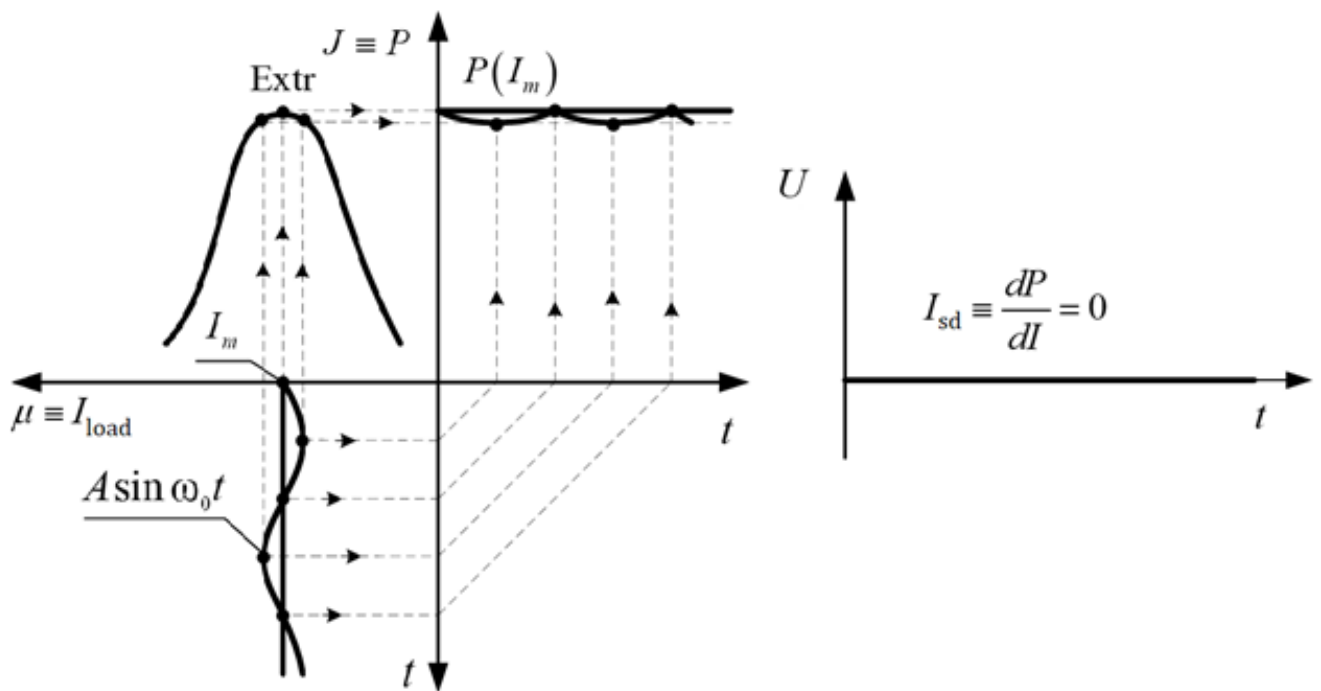


Fig. 3.4 The moment when the working point reaches the extremum

A change in the operating conditions of the system can lead to a shift of the extreme characteristic to the left, that is, working point 1 will be on its right branch (fig. 3.5).

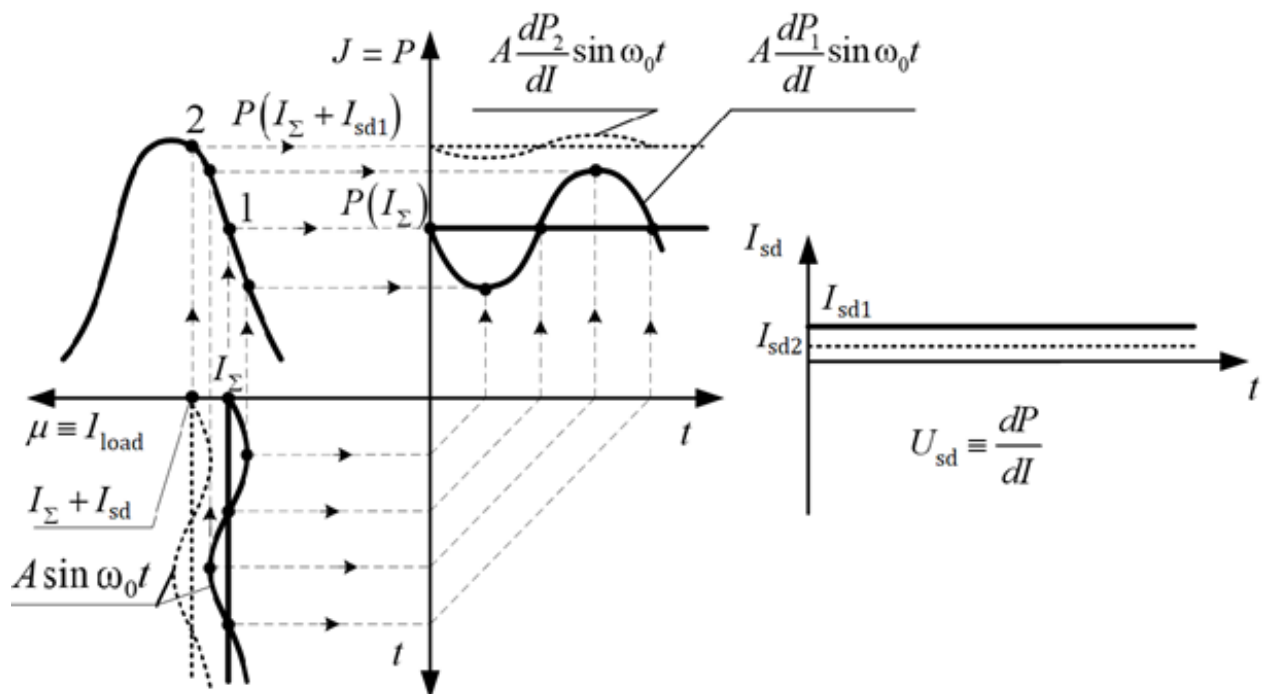


Fig. 3.5 Search for the optimum quality when the characteristic is shifted

The processes of finding and maintaining the optimal level of quality will differ from those described above only by changing the phase of the harmonic component  $A \frac{dP_1}{dI}$  of the output signal  $P$  to the value  $\varphi = 180^\circ$ , in accordance with the derivative  $\frac{dP}{dI} > 0$  around point 1. This will change the polarity of the output signal of the synchronous detector to "+", and, as a result, to the growth of the output signal regulator ( $I_\Sigma + I_{sdl}$ ). The movement of the operating point 1 will take place in the direction of the extremum from left to right.

The described processes make it possible to identify the ERP as a system with regulation based on the deviation of the derivative of the  $\frac{dP}{dI}$  regulated coordinate based on the controlling influence of the control object from the zero value. The choice of the derivative is determined by the fact that it characterizes the speed of movement of the operating point to the extremum, and the equality of this value to zero will reflect the achievement of the maximum of the extreme characteristic by the operating point.

### **3.2 Synchronous detector**

The main thing the task of the synchronous detector is to form constant signal of a certain polarity and level depending from phase and amplitude incoming alternating signal.

For extreme low-power regulators, phase-sensitive rectifier amplifiers can be used as a synchronous detector.

An example of a transistor amplifier - rectifier for the ERG of a solar battery of a small spacecraft can be the circuit shown in fig. 3.6.



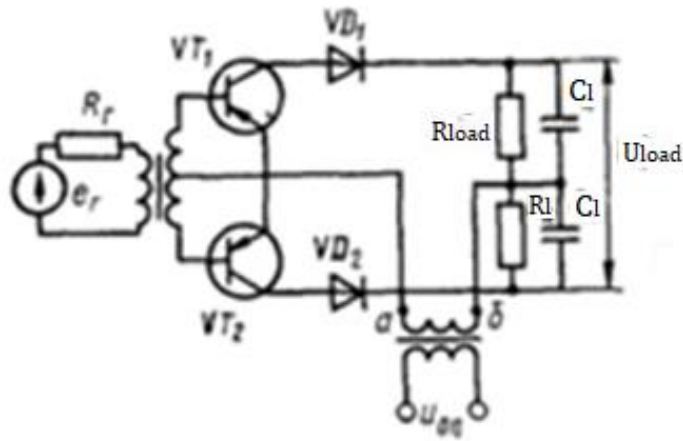


Fig. 3.6 Low-power synchronous detector

Design and calculation of such synchronous detectors are carried out on one of the shoulders circuit that is an amplifier average current value.

The author proposed a scheme for a synchronous detector EPR of general-purpose solar batteries. The functional scheme of such a device is shown in fig. 3.7.

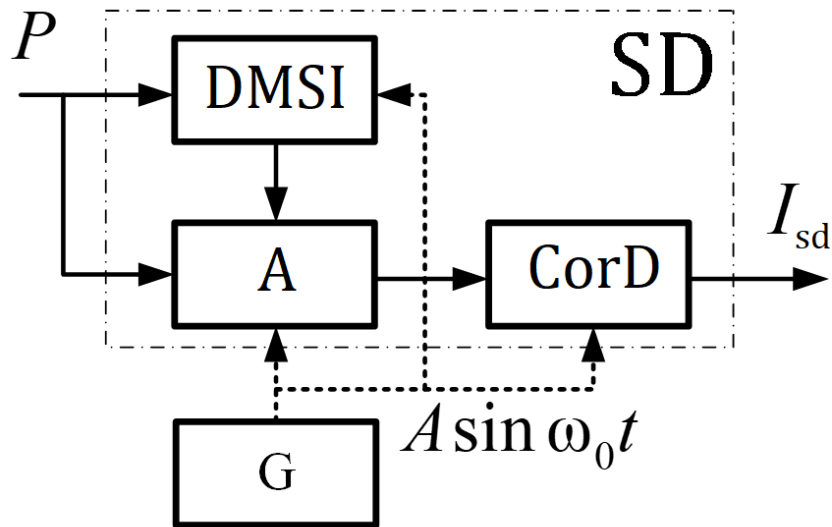


Fig. 3.7 Functional scheme of the synchronous detector

The composition of SD includes:

- generator G of harmonious signals;
- device memorization and storage information DMSI – mini-computer;
- amplifier A;

- correction device CorD, which performs the main role in the synchronous detector.

The principle of operation is generally similar to the one discussed earlier. The differences are due only to the design features of the device.

The solar battery power sensor sends its signal  $P$  to the amplifier A. The amplified signal is sent to the correcting CorD device. The harmonic signals of the generator G also arrive here. The memory and storage device also receives information from the generator G. The DMSI is a mini-computer, the output signal of which is fed to the correcting device through an amplifier. The signal  $I_{sd}$  of the synchronous detector is fed to the regulator to form the control signal of the SB power sensor.

### **3.3 Energy supply system with an extreme power regulator of solar batteries**

A solar battery is characterized by a significant dependence of the generated power on the voltage. The maximum efficiency of the operation of the power supply system (PSS) of space vehicles is achieved when the voltage on the SB is close to optimal ( $U_{sb,opt}$ ) in all modes of operation of the PSS, in which it must generate maximum power.

A natural condition for extreme power regulation of the SB is the separation of the power buses of the SB from the stable power supply bus of on-board consumers and from the buffer storage bus - the accumulator battery (AB) by power devices that convert.

Additional devices, so-called extreme power regulators (EPR), are included in the composition of PSS, which serve to determine the operating point at which the energy generated by the SB is maximum, and accordingly affect the power converters of the in order to maintain the voltage of the SB at this point.

The voltage from the current and voltage sensors of the SB comes to the inputs of EPR, and the voltage at the output of the electromotive force(EMF) corresponds to the voltage value that must be maintained on the SB bus by the converting power devices of the PSS.

EMF uses the method of synchronous detection in the search for extremum. The EMF work algorithm is as follows:

- the value of the power generated by the SB is calculated and memorized;
- EMF, affecting the power converting devices of PSS, changes (increasing or decreasing) the voltage of SB by a certain value;
- the value of the power generated by the SB at the changed voltage is calculated;
- the memorized and newly calculated value of SB power are compared.

Let's consider the PSS, which is designed with EPR. In fig. 3.8 presents an improved structural and functional scheme of the PSS with a step-type search system, which implements extreme regulation of the SB power by charging device CD and regulation of the voltage RV with using the principle of shifting the RV adjustment subrange to the level of the discharge device DD adjustment subrange.

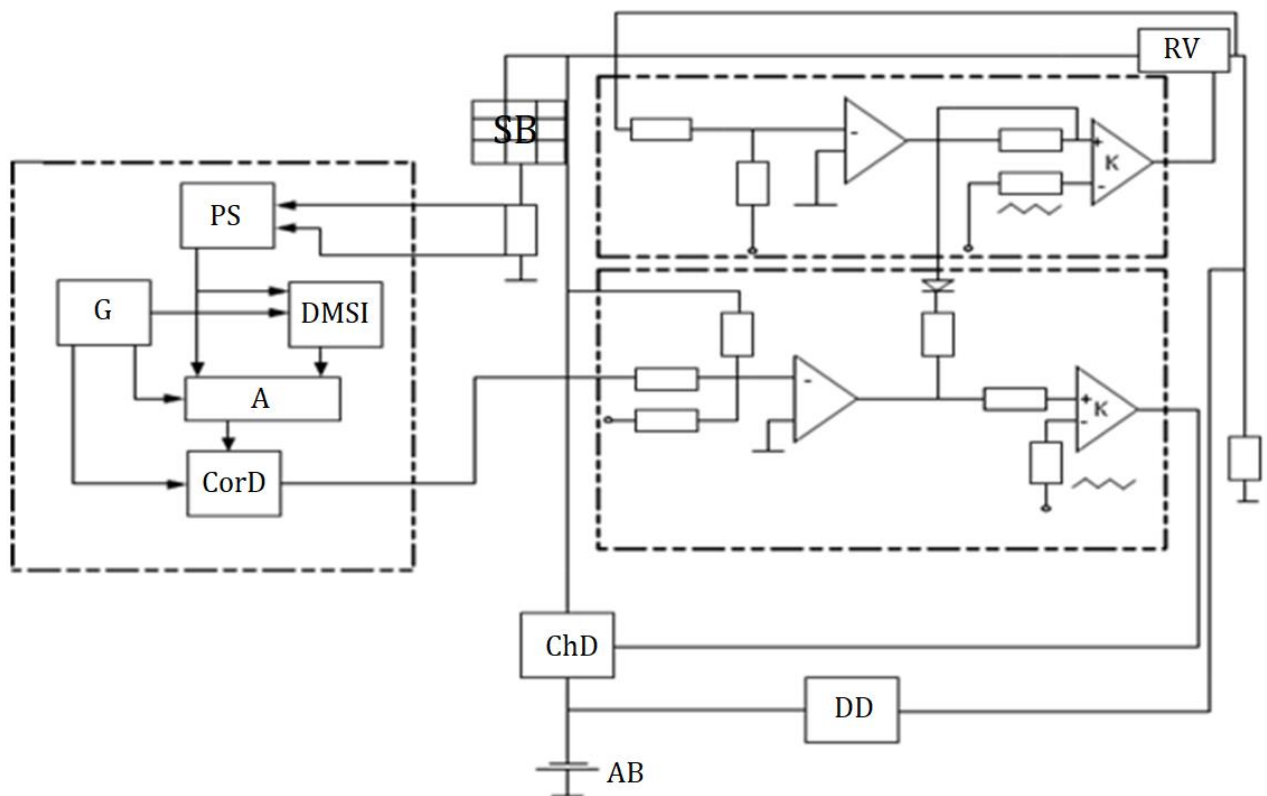


Fig. 3.8 Scheme of the system energy supply

The PS power sensor, which is part of the EPR, processing information about the voltage and current of the SB at the operating point, forms a voltage at the output proportional to the current value of the power produced by the SB. According to the signal from the synchronizing generator G, this power value is memorized in the

device of sampling and storage of the DMSI, after which, according to the next signal of the generator, the operating point on the volt-ampere characteristic of the SB is shifted due to the influence exerted by the correcting device of the CorD on the error amplifier EE PWM ChD. Then again, the measured value of the SB power is compared with the previous value using the comparison device ComD.

The output signal of the ComD affects the CorD, determining the direction of the further shift of the operating point on the VAC of the SB. When the power generated by the SB decreases, the CorD changes the direction of the search for the extremum to the opposite.

At the same time, the DMSI remembers the new value of the SB power. In the future, the process is repeated.

In this way, operation in the mode of maximum power of the SB is ensured, while continuous test (search) fluctuations of the SB voltage around the optimal point are carried out.

In the AB charge mode, the elimination of the operating point on the VAC of the SB occurs due to a change in the duration of the open state of the power switches of the ChD. When the load power exceeds the capacity of the SB, the ChD closes. The discharge device DD is included in the operation, stabilizing the voltage at the output of the VEZ. At the same time, the voltage on the SB decreases, the voltage at the output of the EE PWM ChD takes a negative value and, affecting the PWM RV comparator through the VD1 diode, shifts the RV output voltage adjustment subrange to the level of the discharge device (DP) adjustment subrange.

When designing the PSS of automatic spacecrafts with EPR SB, it is necessary to know the dependence of the accuracy of the extremum adjustment on the step change of the stabilization voltage of the SB and the necessary value of the speed of the extreme regulator, which guarantees the stability of the system at the maximum drift speed of the VAC.

In a step-type automatic optimization system, the minimum number of steps is two or three. The two- step mode of finding the power extremum is carried out when the operating point on the VAC during the next step change  $U_{sb}$  coincides with the

optimal ( $P_{sb,max}$ ) one, and the three-step mode - when it occupies a symmetrical position with respect to  $P_{sb,max}$ .

### 3. 4 Analytical design of power regulators

The functional scheme of EPR in the analog-digital version developed by the author is shown in fig. 3.9.

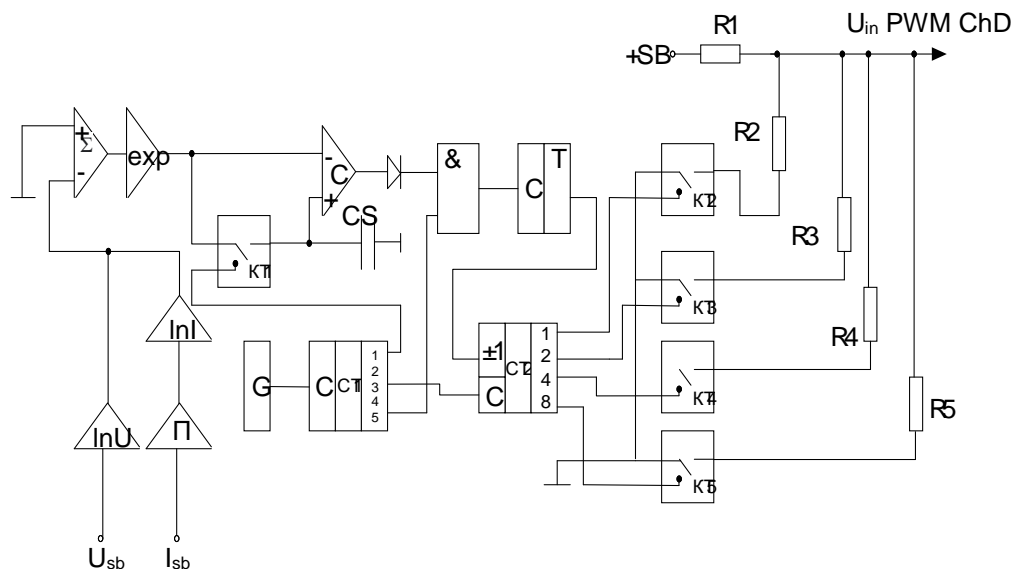


Fig. 3.9 Diagram of analog EPR

The power sensor is made of operational amplifiers.

Scaled values of voltage and current SB are logarithmized and added, after which an anti-logarithmization operation is performed. The calculated voltage value, proportional to the SB power, is sent to the comparator C, and through the KT1 key, controlled by the signal from output 1 of the CT1 counter-distributor, to the capacitive storage CS.

The appearance of a signal at output 3 of counter CT1 changes the code at the output of reversible counter CT2.

The output code of the CT2 counter controls the KT2-KT5 keys, which, when switched, change the transfer coefficient of the divider on the resistors R1-R5, and accordingly, the output voltage of the PWM ChD, determining the position of the operating point on the VAC SB.

In cases where, after the shift of the operating point, the value of the SB power decreases, a positive voltage appears at the output of the comparator C, changing the polarity of the voltage at the output of the trigger T, due to the pulse from output 5 of the CT1 counter, which enters the clock input of this trigger. At the same time, the counting direction of the ST2 counter changes.

Although the parameters of the analog devices present in the scheme depend significantly on the operating conditions and do not provide a high-precision determination of  $U_{SBopt}$ , the scheme allows for high reliability of the EPR due to its simplicity and high protection against possible electromagnetic interference and voltage losses due to the low number of elements sensitive to them.

Further development and improvement of PSS power SB took place in the direction of development of various options of digital extreme regulators.

The functional diagram of the digital EPR is shown in fig. 3.10.

In it, the power sensor is made on the basis of a digital-analog multiplier.

A voltage proportional to the SB current from the shunt meter is fed to the scaling amplifier A, after which it is converted into an eight-bit binary code using an ADC analog-to-digital converter.

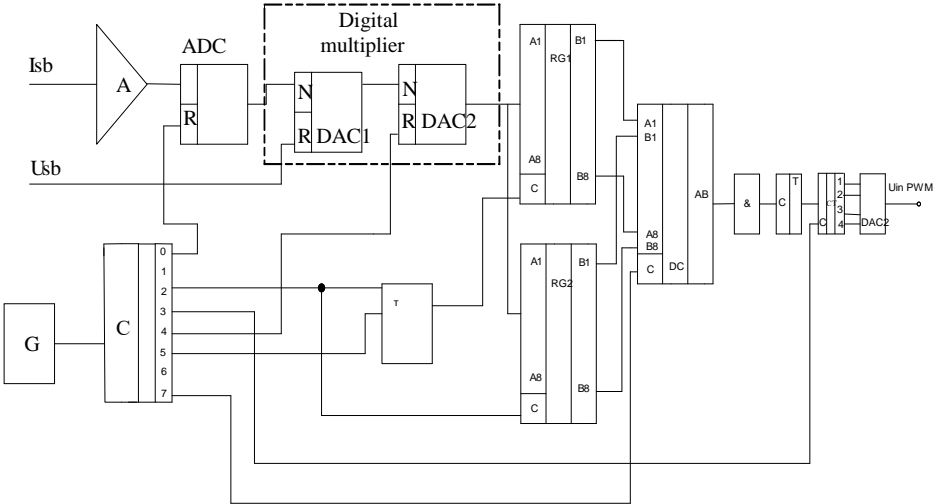


Fig. 3.10 Scheme of digital EPR

The input signals of the digital multiplier are the code from the ADC and the current value of the SB voltage.

At its output, a digital code is formed, corresponding to the value of the power currently consumed from the SB.

According to the clock pulse from the counter-distributor, this code is stored in the registers Rg1 and Rg2.

After changing the position of the operating point, the digital code corresponding to the new power value of SB is written in the Rg1 register and compared with the previous one stored in the Rg2 register using a digital comparator DC.

The appearance of a logical "1" at the output  $A < B$  of the digital comparator DC means a decrease in the power of the SB as a result of a shift in the position of the operating point. In this case, the search direction changes in the same way as in the previous scheme.

The above-considered main circuit and technical implementation of the SB power regulation principle clearly show that the insignificant hardware costs required for the correction of the ChD and RV regulation ranges allow to ensure the maximum efficiency of using the primary energy source of the spacecraft solar battery.

The analysis of literary sources showed that the EPR system of solar batteries is constantly being developed and improved.

EPR Outback FlexMax-60 can be one of the latest options for a schematic and constructive solution.

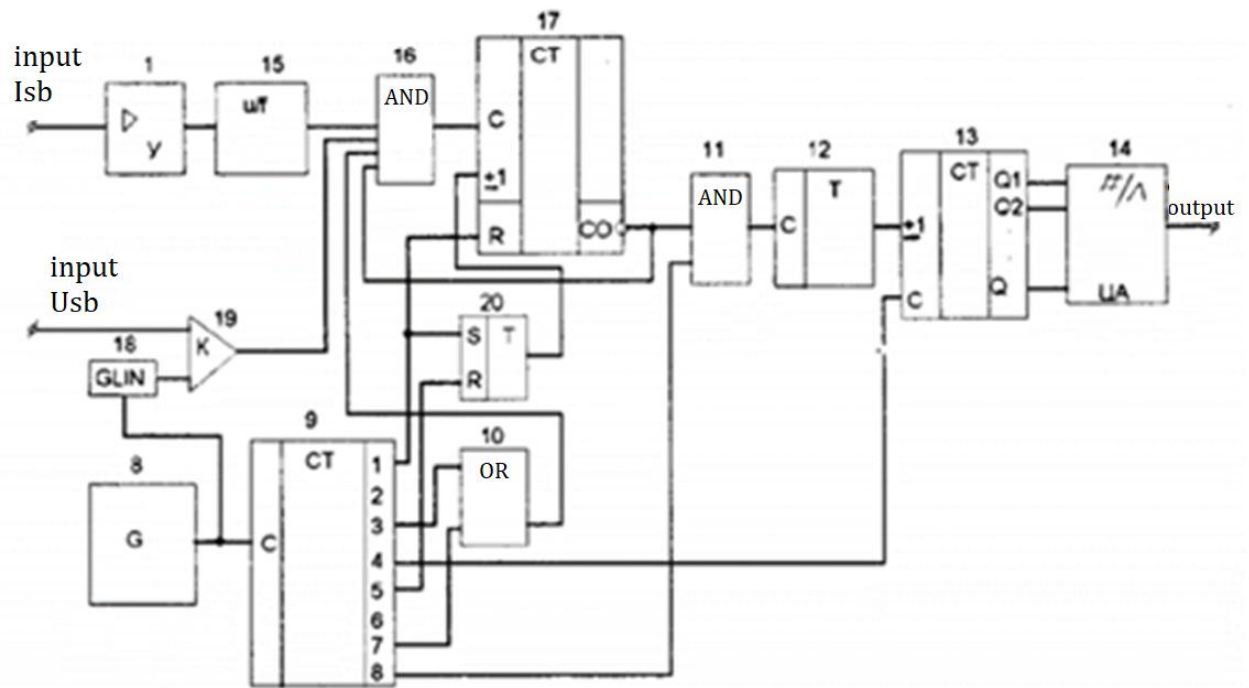


Fig. 3.11 Electrical diagram Outback FlexMax-60

The device can be used to control the power converters of energy in the power supply systems (PSS) of spacecraft with a solar battery (SB) as the primary source. The extreme power regulator (EPR) performs a step search for the SB voltage, at which it generates the maximum power and accordingly affects the PSS power converters in order to maintain the SB voltage at this point.

To measure the SB power, a second reversible counter is additionally introduced, the clock input of which receives pulses with a frequency proportional to the SB current during a time interval proportional to the SB voltage, and during one cycle, two SB power measurements take place: before and after the shift of the operating point of the SB VAC in different directions accounts of the second reversible counter.

The transfer output of this counter is used to determine the sign of the SB power change.

To generate pulses with a frequency proportional to the SB current, a voltage-frequency converter is used, and to obtain time segments with a duration proportional to the SB voltage, a comparator and a dust-like voltage generator are used.



The device, while preserving the digital method of processing information about the power of the SB, is significantly simpler than known analogues. It lacks analog-to-digital converters, registers and a digital comparator for storing and comparing information about the power of the SB, as well as multi-bit communication lines.



## CHAPTER 4

### SOFTWARE AND METHODOLOGICAL SUPPORT OF EXPERIMENTAL RESEARCH DURING DESIGN

In engineering practice, especially in the automated selection of the best design solutions, mathematical methods of analysis and synthesis of complex technical systems are increasingly used. This became possible thanks to the advent of high-speed computers.





However, the wide possibilities of computer technology are realized only with appropriate methodological support, because the application of modeling and optimization methods of complex technical systems is associated with the difficulties of implementing mathematical methods in practice, and first of all, with the difficulties of developing and implementing algorithms and programs for computers.

In this regard, the author in his thesis proposed two ways of solving the problem of software and methodological support for design automation:

- modeling and synthesis based on basic application program packages;
- software development of methods of analysis and synthesis.

One of the most important issues in solving the second task was the question of the programming language in which mathematical algorithms should be implemented.

The author chose the C++ programming language because this language provides an effective description of complex algorithms for calculations on larger data sets presented in various forms; in addition, it is quite often used in engineering practice.

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Supervisor	O.K. Ablesimov						
Consultant							
S. controller	M.K. Filyashkin						
Dep. head	V.M. Sineglazov						
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#### 4.1 Structural modeling of automatic control systems

Stabilization systems are special automatic control systems designed to preserve the set value of the initial coordinate of the control object under the influence of external disturbances.

Despite the fact that the stabilization systems differ significantly in their design, they are performed according to the same functional schemes. At the same time, the regulation processes occurring in stabilization systems are described by similar linear differential equations.

As a result, their structural diagrams are identical, which makes it possible to obtain a typical structural diagram of the stabilization system.

In most modern stabilization systems dynamic objects are controlled based on the deviation of the controlled value from given by setting its value. A typical structural scheme of such a system is shown in fig. 4.1.

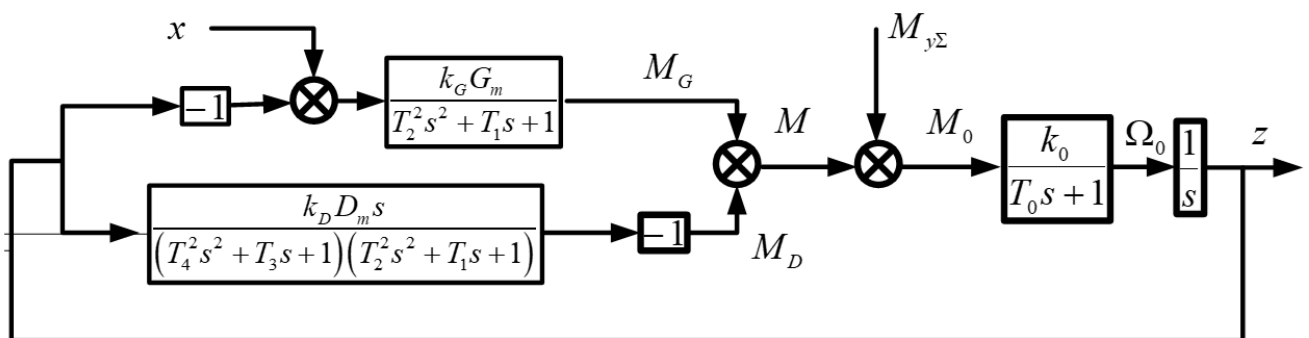


Fig. 4. 1 Typical structural scheme of the stabilization system

The scheme includes the following designations:  $G_m = k_{ds} k_{reg}$  - structural stiffness of the system;  $D_m = k_{dss} k_{reg}$  - constructive damping of the system;  $k_{ds}$  - transmission coefficient of the deviation sensor;  $k_{dss}$  - transfer coefficient of the deviation speed sensor;  $k_G$ ,  $k_D$  - stiffness adjustment and damping coefficients;  $k_{reg}$  - transfer coefficient of the regulator.

Moment of stabilization  $M_{st}$  is formed through the channels of the angular deviation sensor, the angular deviation speed sensor

$$\overline{M}_{st} = \overline{M}_G + \overline{M}_D \equiv k_G G_m + k_D D_m$$

Simultaneous and automatic compensation of the influence on the controlled value of all disturbances acting on the system is the most important advantage of the deviation control principle.

Actually use equivalent structural diagram shown in fig. 4.2. At the same time, the following were introduced value transferable functions

$$W_1(s) = \frac{k_G G_m}{T_2^2 s^2 + T_1 s + 1};$$

$$W_2(s) = \frac{k_0}{(T_0 s + 1)s};$$

$$W_3(s) = 1 + \frac{k_D D_m s}{k_G G_m} = \frac{k_G G_m + k_D D_m s}{k_G G_m}.$$

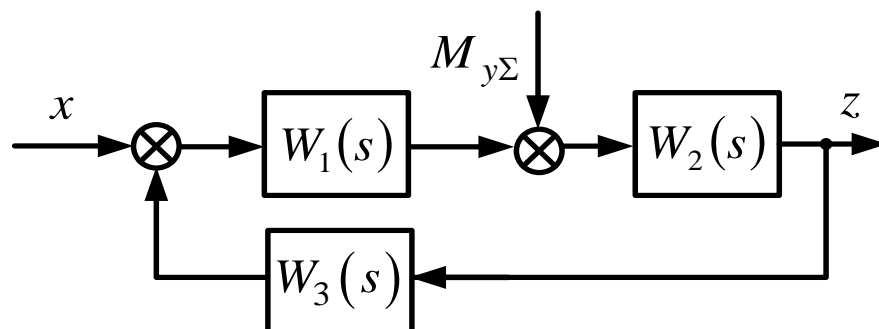


Fig. 4.2 Equivalent structural scheme of the stabilization system

The availability of the structural scheme of the stabilization system allows for its analysis and synthesis during design or modernization. Systems stabilizers operating on the principles of deviation control are static systems that have an absolute error, which depends on the value of the external disturbance.

Such systems are considered based on the premise that the nature of the disturbing influences on the control object is known, and the structure and parameters of the control object itself and the stabilization system as a whole are unchanged.

At the same time, in practice there are stabilization systems whose properties change under the influence of external and internal factors, and the very characteristics of external and internal influences may differ significantly from the nominal ones adopted during the calculation. An example is automatic regulation systems power solar batteries.

Automatic control systems capable of adapting to changes in external conditions in order to ensure the necessary control quality are called adaptive.

In order to solve tasks analysis and synthesis of adaptive automatic systems with them design necessary correction and refinement typical structural schemes systems stabilization according to the adopted adaptation algorithm.

#### **4. 2 Designing based on basic packages of application programs**

Designing means a directed calculation, which has the ultimate goal of finding the rational structure of the system and establishing the optimal values of the parameters of its individual links.

The main task of organizing and conducting research was to verify the theoretical provisions about the possibility of automatic maintenance of the output coordinate of the solar battery by the control system at the optimal level when external disturbances change.

For research, according to the structural diagram of the system (fig. 2.14), a model of the system with a closed circuit of passive adaptation was organized. The model is shown in fig. 4.3.

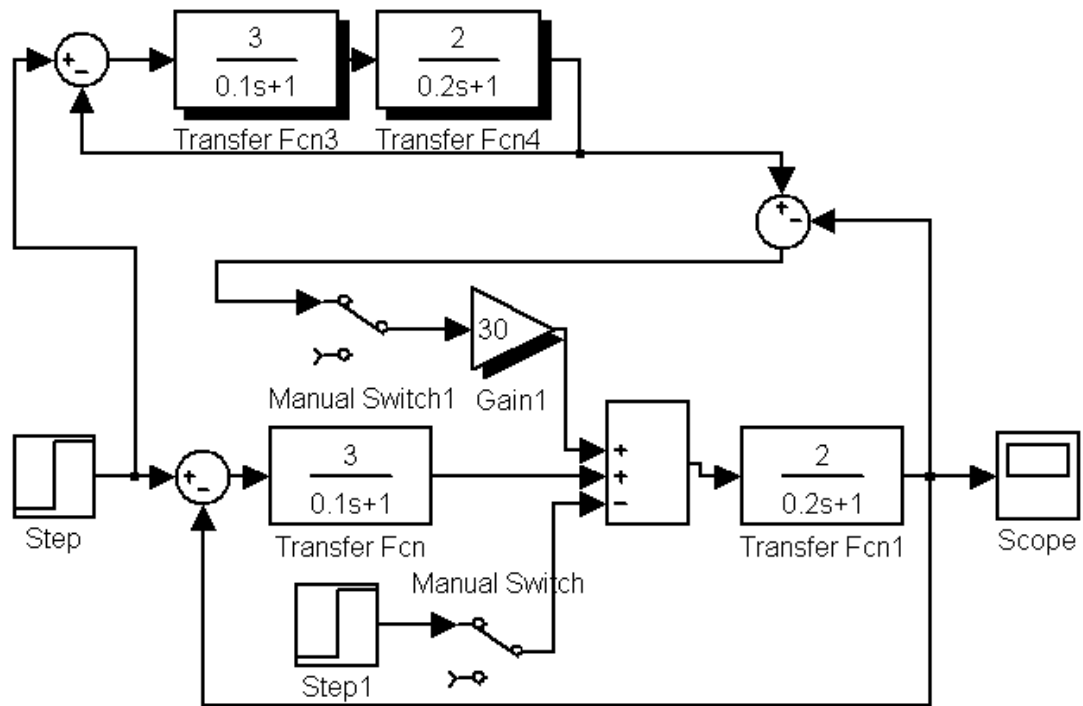


Fig. 4.3 Model of a system with a closed circuit of passive adaptation

External influences are formed in the form of stepped signals by the Step1 source. Registration of the dynamics of the control object's behavior was carried out on an oscilloscope Scope.

The methodology of the experiment was as follows:

- with the reference model turned off, given the values of external disturbances, constant values of the regulated quantity were determined by the transient characteristics

	$x(t) = 2$					
$y(t)$	0	1	2	3	4	5
$z(t)$						

- based on the obtained data, the load characteristic of the system was built;
- the experiment was repeated while connecting the reference model.

Results obtained provided in tables 4.1 – 4.2 and fig. 4.4 - 4.5.

Table 4.1

Constant values of the initial coordinate when the reference model is disabled

	$x(t) = 2$					
$y(t)$	0	1	2	3	4	5
$z(t)$	17	14.5	11.5	9	5.5	3

Table 4.2

Constant values of the initial coordinate when the reference model is included

	$x(t) = 2$					
$y(t)$	0	1	2	3	4	5
$z(t)$	17	17	17	17	17	17

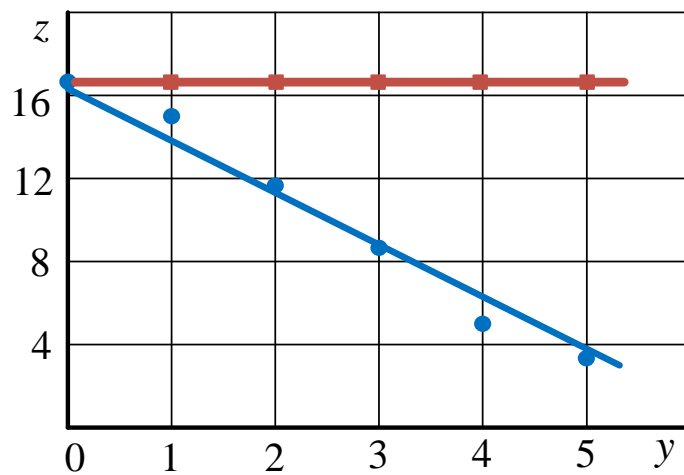


Fig. 4.4 Load characteristics

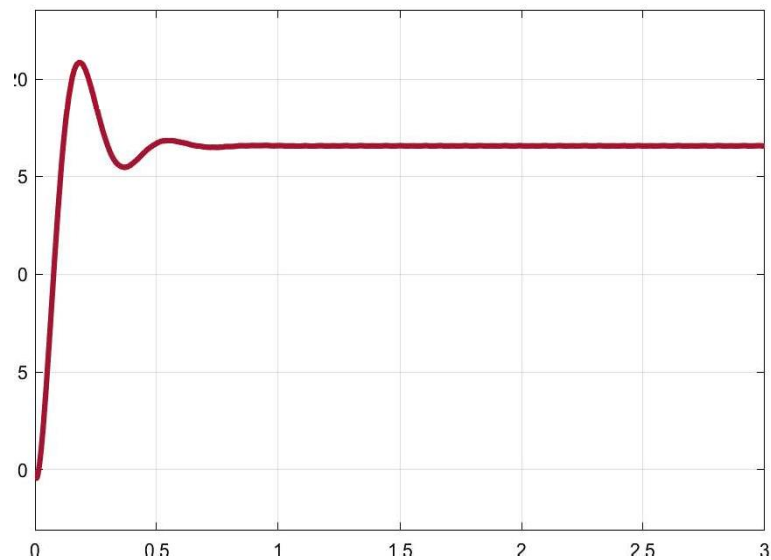


Fig. 4.5 Transition characteristic

The analysis of the results of the experiment confirms the theoretically grounded conclusions about the support of the system with a closed loop of passive adaptation of the value of the adjustable coordinate at the optimal level when the values of external disturbances vary.

For studies of the extreme control system, according to the structural scheme of the system (fig. 2.15), a model of the control object, which has an extreme characteristic, was organized. The model is shown in fig. 4.6.

After starting the modeling process, the transient characteristic of the control object was recorded on the oscilloscope screen. The researcher was interested in the established values of the initial coordinate of the control object when external influences change in the range.

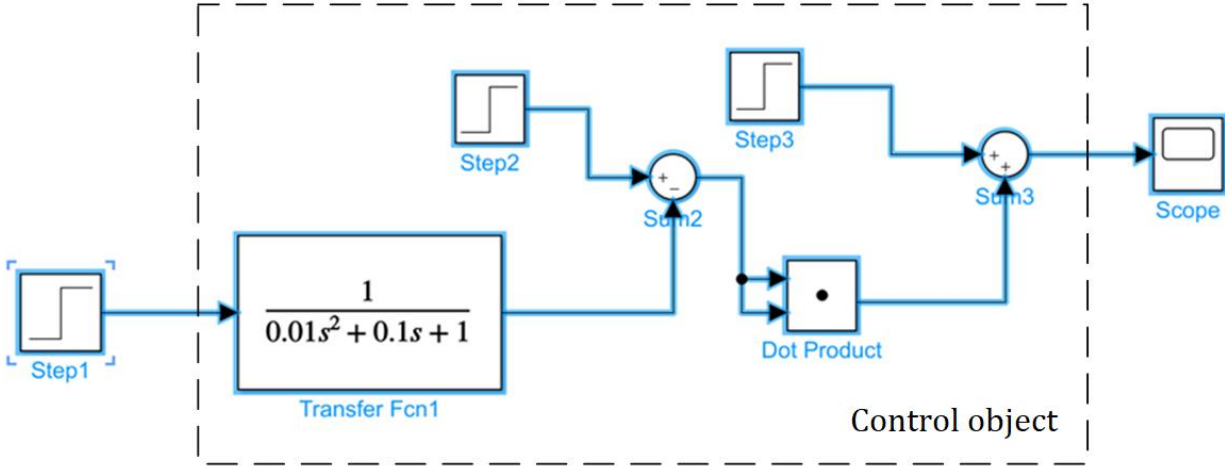


Fig. 4.6 Control object model

The results were summarized in Table 4.3.

Table 4.3

The results of the experiment

$y(t)$	1	2	3	4	5	6	7	8	9
$z(t)$	0.5	2.5	4.5	5.5	6	5.5	4	1.8	0.5



Based on the obtained data, the load  $z = f(y)$  characteristic of the control object was constructed. The characteristics are shown in fig. 4.7.

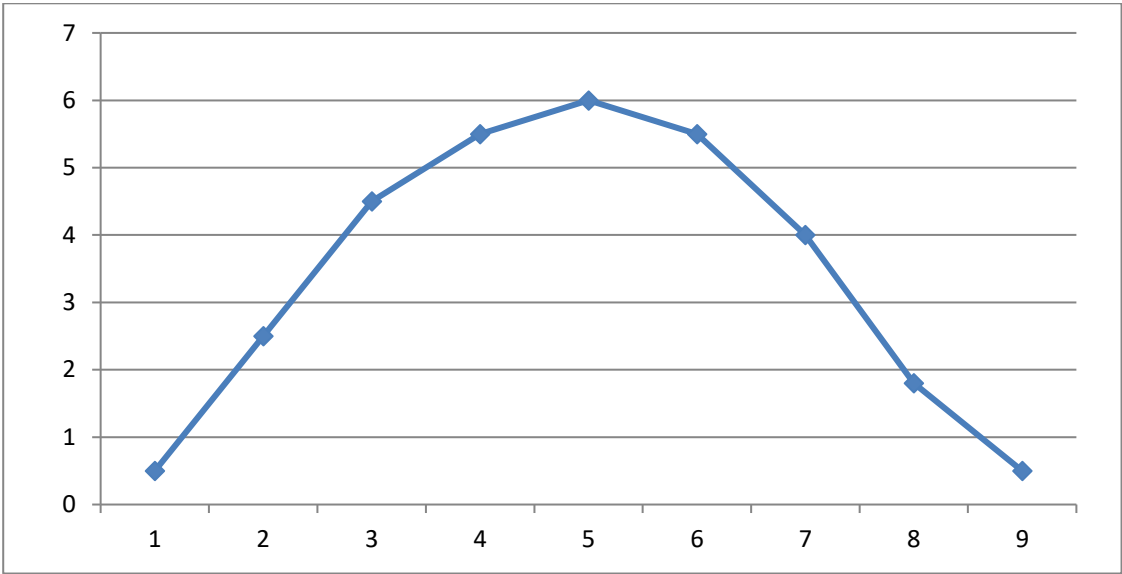


Fig. 4.7 Load characteristics of the control object

Thus, the load characteristics of the object management has a clearly expressed extreme character, reaching minimal (optimal)  $z_{\max}(t) = 6,0$  value outgoing coordinates at  $y(t) = 5$ .

Let's introduce an extreme control system with synchronous detection, collapsing the control object to the subsystem level for convenience. The EPR model is shown in Fig. 4.8.

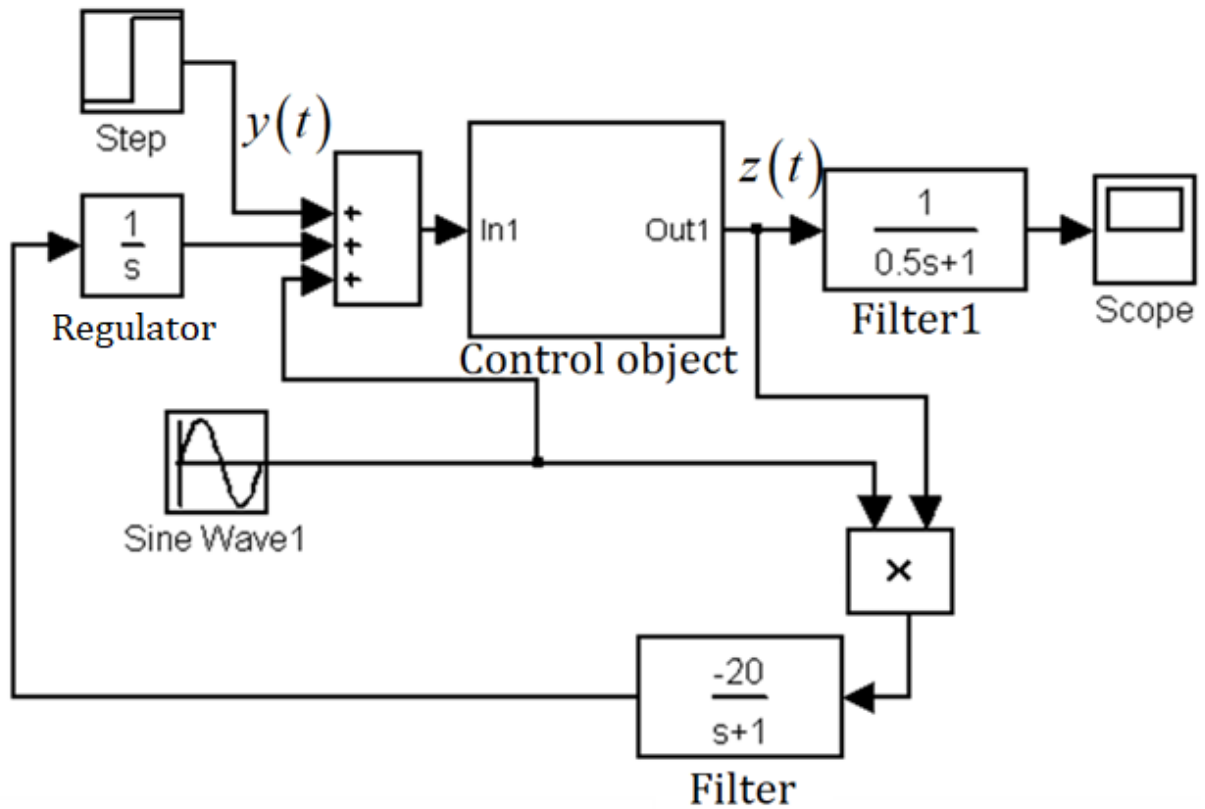


Fig. 4.8 EPR model

On the oscilloscope, fixed values of the initial coordinate  $z(t)$  of the object of control were recorded when external influences changed  $y(t)$  as in the previously discussed range.

The results were summarized in Table 4.4.

Table 4.4

The results of the experiment

$y(t)$	1	2	3	4	5	6	7	8	9
$z(t)$	6	6	6	6	6	6	6	6	6

On the basis of the received data, the loading characteristic was built with an overlay on the characteristic of the control object. The characteristics are shown in fig. 4.9.

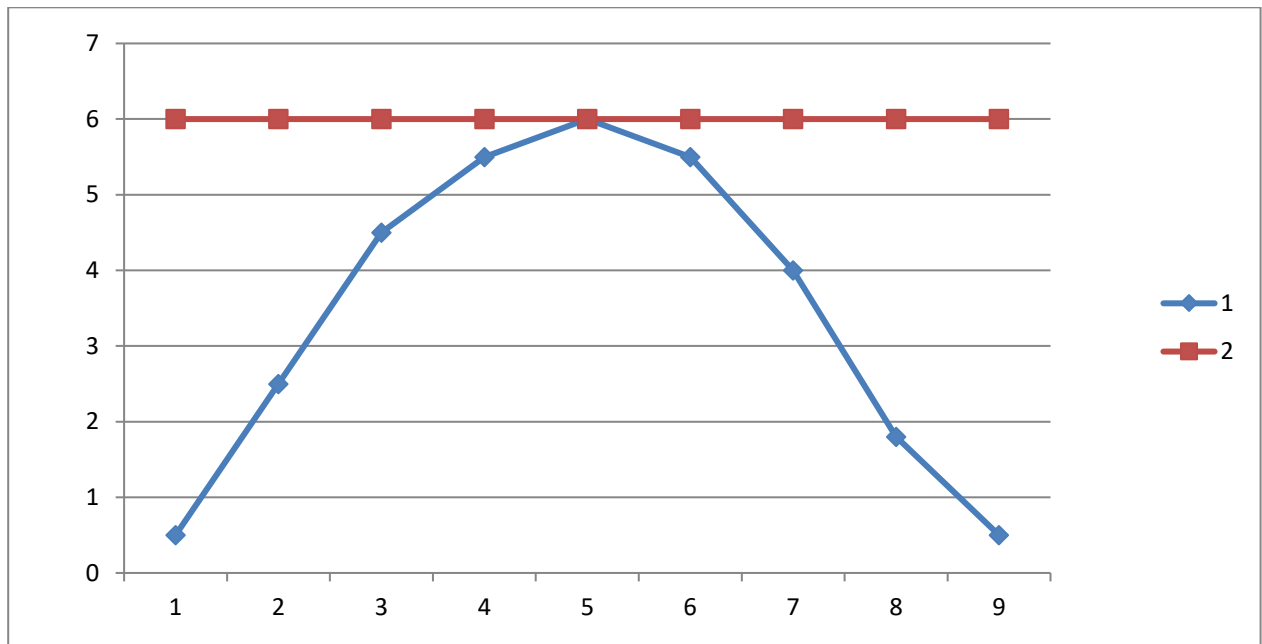


Fig. 4.9 Load characteristics

Thus, the results of the experiment confirm the theoretically grounded conclusions that the extreme control system maintains the value of the adjustable coordinate of the control object at the optimal level when the values of external disturbances acting on it vary.

### 4.3 Design software

Precise adjustment of the regulator parameters significantly reduces system fluctuations. However, the full use of the controller's advantages is ensured only with the correct calculation of the parameters taking into account the peculiarities of the characteristics of the controlled objects.

When designing systems with a regulator, there is a need to study the influence of its coefficients on transient processes (or to select coefficients according to the desired type of transient function), which requires multiple runs of the model with changed coefficients and constant editing of model properties. At the same time, it is important to have a coefficient management mechanism that would provide a convenient interface between program and user.

At this stage of development of the Python programming language, there is a possibility of its effective use for modeling and optimization of automatic control circuits containing dynamic and statistical links.

Therefore, the use of the Python programming language makes it possible to develop a universal and modern application for the study of stabilization and control systems, which will ensure a quick and convenient selection of the optimal coefficients of the PID controller.

The graphical user interface (GUI) is implemented using the Tkinter library. To configure the PID controller, the following will be placed in the GUI:

- an interface element for outputting a graph of the transition process of the system under study;
- three sliders for setting the numerical values of the regulator coefficients K1 (P-component), K2 - (I-component) and K3 (D-component);
- six Entry elements for setting the limit values of these coefficients (Max and Min);
- three label text elements for displaying the current values of the coefficients (Current);
- six text elements for corresponding captions.

Limit values of the regulator coefficients can be set experimentally. In the work, they are chosen taking into account the values obtained in the previous sections.

Let's display the elements of the graphical interface (GUI) programmatically:

```
label_1 = tk.Label (root, text = "P")
label_1.grid(row =8, column =1)
label_2 = tk.Label (root, text = "I")
label_2.grid(row =9, column =1)
label_3 = tk.Label (root, text = "D")
label_3.grid(row =10, column =1)
```

```
label_4 = tk.Label (root, text = "Min")
label_4.grid(row =7, column =2)
label_5 = tk.Label (root, text = "Max")
label_5.grid(row =7, column =4)
label_6 = tk.Label (root, text = "Current")
label_6.grid(row =7, column =5)
```

```
label_10 = tk.Label (root, text = " ").grid(row =6, column = 3)
```

```
min_k1 = tk.Entry (root, width = 5)  
min_k1.grid(row =8, column =2)  
min_k2 = tk.Entry (root, width = 5)  
min_k2.grid(row =9, column =2)  
min_k3 = tk.Entry (root, width = 5)  
min_k3.grid(row =10, column =2)
```

```
k1= tk.Scale (root, from_=0, to=3, orient = tk.HORIZONTAL, resolution = 0.01,  
length = 210, command = change_scale_P)  
k1.grid(row =8, column =3)  
k2= tk.Scale (root, from_=0, to=1, orient =tk.HORIZONTAL, resolution = 0.01,  
length = 210, command = change_scale_I)  
k2.grid(row =9, column =3)  
k3= tk.Scale (root, from_=0, to=1, orient =tk.HORIZONTAL, resolution = 0.01,  
length = 210, command = change_scale_D)  
k3.grid(row =10, column =3)
```

```
label_7 = tk.Label (root, text = k1.get())  
label_7.grid(row =8, column =5)  
label_8 = tk.Label (root, text = k2.get())  
label_8.grid(row =9, column =5)  
label_9 = tk.Label (root, text = k3.get())  
label_9.grid(row =10, column =5)
```

```
max_k1 = tk.Entry (root, width = 5)  
max_k1.grid(row = 8, column = 4)  
max_k2 = tk.Entry (root, width = 5)  
max_k2.grid(row = 9, column = 4)  
max_k3 = tk.Entry (root, width = 5)  
max_k3.grid(row = 10, column = 4)
```

The developed graphical interface is ready for programming. Let's add functions for processing commands of GUI elements:

```
def change_lim():  
    k1_to=min_k1.get()  
    k1['from_']= k1_to  
    k2_to=min_k2.get()  
    k2['from_']= k2_to  
    k3_to=min_k3.get()  
    k3['from_']= k3_to  
    k1_to=max_k1.get()  
    k1['to']= k1_to
```

```

k2_to=max_k2.get()
k2['to']= k2_to
k3_to=max_k3.get()
k3['to']= k3_to
return

```

```

def change_scale_P(self):
    change_lim()
    label_7['text'] = k1.get()
    global P
    P=float(label_7['text'])
    calculate(P,I,D)

```

```

def change_scale_I(self):
    change_lim()
    label_8['text'] = k2.get()
    global I
    I=float(label_8['text'])
    calculate(P,I,D)

```

```

def change_scale_D(self):
    change_lim()
    label_9['text'] = k3.get()
    global D
    D=float(label_9['text'])
    calculate(P,I,D)

```

We will supplement the generated program code with a function with direct calculations:

```

def calculate (a,b,c):
    w_ob = cn.TransferFunction(30,[0.01,0.2,1,0]) #tf of control object
    w_gain = cn.TransferFunction(0.09,[0.01,1]) #tf of gain

    N=100
    w_con = cn.TransferFunction([(a/N+c),(a+b/N),b],[1/N,1,0])
    #tf of PID controller

    w_m = cn.series(w_gain, w_ob)
    w = cn.series(w_con, w_m) # open-loop system
    sys = cn.feedback(w,1) #closed-loop system

    t=np.arange(0,5,0.001)
    T, yout = cn.step_response(sys, t, 0)

```

```
plt.cla()
```

```
fig = plt.figure(1)  
plt.plot(T, yout,"b")  
plt.title('Step Responsse ' )  
plt.ylabel('Amplitude')  
plt.xlabel('Time(sec)')  
plt.grid(True)
```

```
canvasAgg=FigureCanvasTkAgg(fig, master=root)  
canvas=canvasAgg.get_tk_widget().grid(row =0, column =1, columnspan=6,  
rowspan=5)
```

As a result of running the program code described above, the dialog box shown in fig. 4.10.

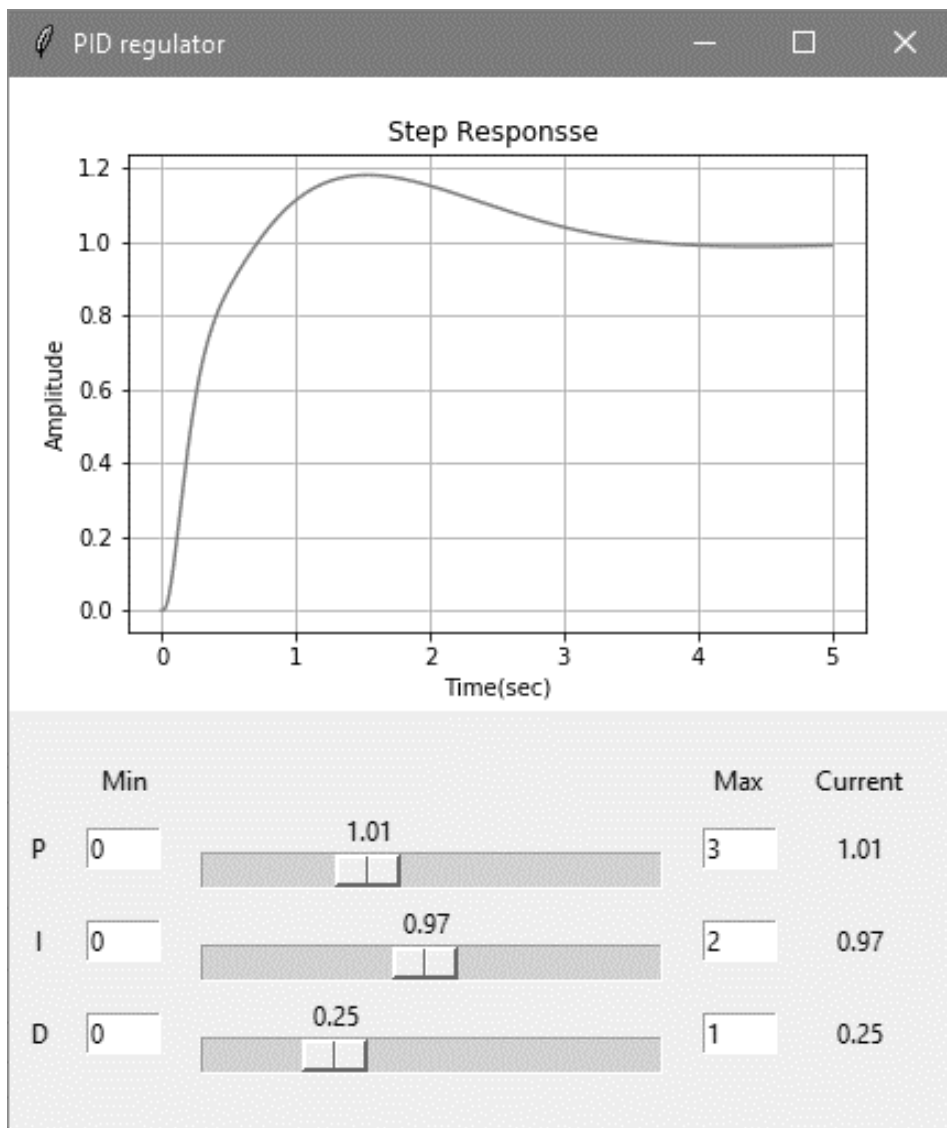


Fig. 4.10 Interface dialog box

The developed interface allows you to determine the coefficients of the regulators by moving the sliders in the dialog window of the received transient characteristics.

In fig. 4.10, as an example, a transitional function with setting the sliders to a position corresponding to the optimal regulator coefficients obtained as a result of research and calculations in the previous sections is given.

By removing the `plt.cla()` current graph cleaning command from the program code, you can get a family of transient characteristics for any set of regulator parameters, which can be convenient when choosing a characteristic with the desired quality indicators (fig. 4.11).

So, the developed program for adjusting the regulator coefficients in the graphical interface allows you to quickly calculate the optimal coefficients for any object and any type of regulator, removing and combining the necessary channels in the regulator.

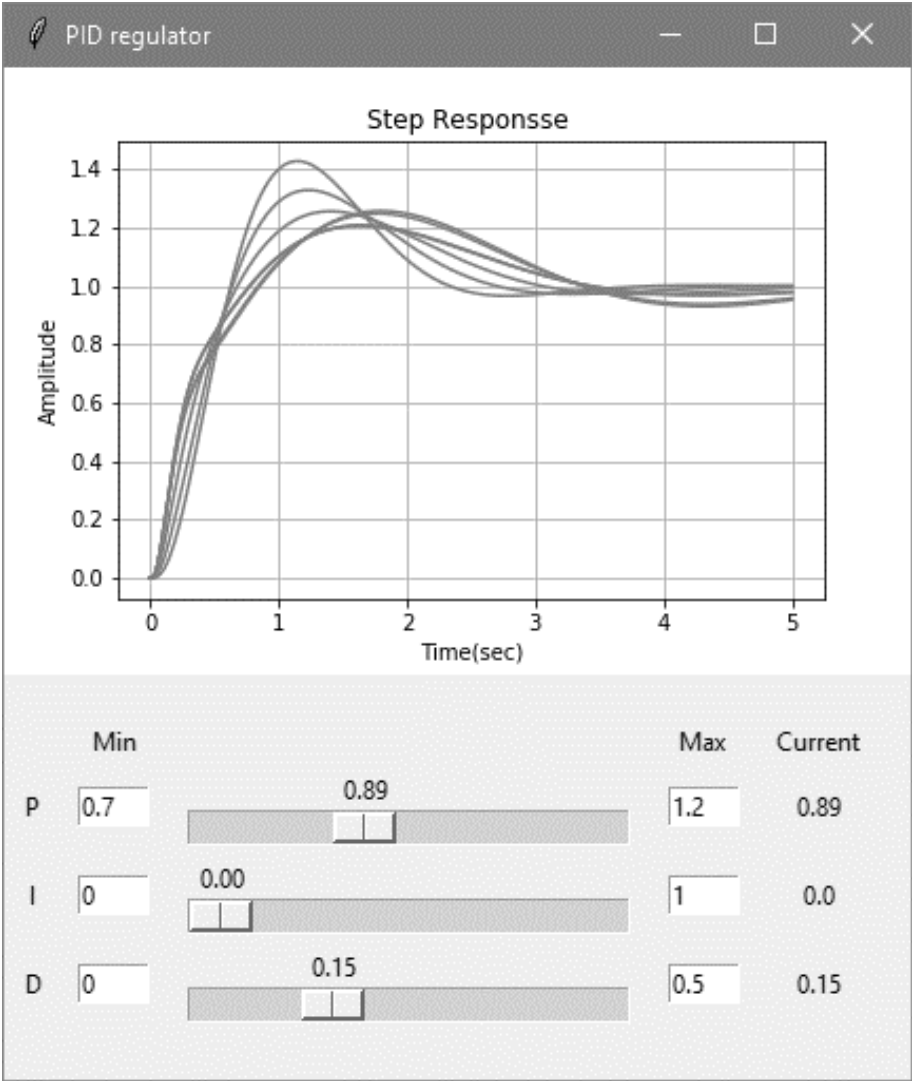


Fig. 4.11 An example of a family of characteristics



The given program listing can be easily adapted and successfully applied to the stabilization system of any inertial object.

Note that the PID controller synthesis software developed using Python illustrates the possibility of effective use of this programming language for modeling and optimization of automatic control circuits.



## CHAPTER 5

### PROTECTION OF THE NATURAL ENVIRONMENT

Environmental protection is the regulation of relations in the field of protection, use and reproduction of natural resources, ensuring environmental safety, prevention and elimination of the negative impact of economic and other activities on the natural environment, preservation of natural resources, the genetic fund of living nature, landscapes and other natural complexes, unique territories and natural objects related to historical and cultural heritage.

Environmental pollution is the actions that brought to the ecological system non-proper living or non-living components, physical or structural changes, as a result of which the processes of circulation and metabolism of substances are disturbed, as well as energy outflows, as a result of which productivity decreases or this ecosystem is destroyed.






Pollutants are usually grouped by their nature:

- physical pollution, they include: noise pollution and low-frequency vibration, electromagnetic pollution, radioactive elements;
- chemical and biological pollutants, they include: synthetic organic substances, heavy metals, fluorine compounds;
- mechanical, they include: dust and solid particles.

The science of ecology deals with solving issues in the field of environmental protection. Ecology is the economy of nature and the simultaneous study of all relationships between living things and organic and inorganic components of the environment.

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## **5.1 Impact of the research object on the environment**

At the moment, the TCO99 standard is the most stringent of the existing global environmental standards for computer equipment. Compared to the previous ones, it contains additional restrictions in terms of ecology, ergonomics, energy consumption and emission of devices.

The most significant labels, such as the "Blue Angel", issued by the German certification organization as a mark of compliance with environmental standards, are very rare in the field of electronics. On the contrary, the logo "Energy Star", which is awarded to energy-saving devices. However, in his case, the problem is that each manufacturer has the right to independently label his products without passing inspections.

Considering the fact that this emblem does not carry any information about the actual energy consumption of devices, it can be completely ignored.

Since 2006, the environmental protection organization Greenpeace has been evaluating electronics manufacturers by the amount of heavy metals and toxic substances, such as flame retardants, used by them in production (an inhibitor is a substance whose presence in small quantities leads to the prevention or slowing down of combustion or corrosion processes; inhibitors reduce speed of chemical reactions or suppress them).

However, even the assessments of such an organization as Greenpeace, which cannot claim objectivity. After all, in some cases it uses verified information, which concerns, for example, waste disposal measures, and in others it relies only on the manufacturer's data. And if the company does not report any information, it automatically finds itself on the bottom lines of the rating.

In addition, energy costs for production and transportation of products must also be taken into account when evaluating environmental efficiency. After all, the times when equipment was manufactured only at one factory are long gone. Today, individual components are purchased at various enterprises around the world, after which devices are assembled. Therefore, most often, even the companies themselves cannot know which harmful substances enter the atmosphere during the manufacture

of their products and which metals or toxins are contained in it.

LCD screens are one of the sources of greenhouse gases, which are much more harmful than carbon dioxide. Liquid crystal monitors quickly gained popularity, replacing bulky CRT models. And this is not surprising, because they have thin bodies and consume much less electricity.

In other aspects of environmental safety, liquid crystal displays were also considered a breakthrough because they did not use lead-containing gas. For quite a long time, no one paid attention to nitrogen trifluoride (NF<sub>3</sub>), used for cleaning LCD panels, and only in the middle of 2008, scientists proved the presence of this chemical substance in the atmosphere. The discovery was impressive: compared to carbon dioxide (CO<sub>2</sub>), NF<sub>3</sub> is 17,000 times more active as a greenhouse gas, and its atmospheric half-life can range from 550 to 740 light years (for CO<sub>2</sub>, from 30 to 40 years). The law that would limit the level of NF<sub>3</sub> emissions does not yet exist.

Identifying energy consumption is as problematic a process as determining the amount of recyclable materials and heavy metals contained in devices. An amazing result was obtained by the Greenpeace organization during a comparative analysis of several models of identical laptops from different countries. Traces of bromine were detected in the touchpad of the Dell Vostro V13 available on the Chinese market. In the model from Germany, this substance is also present, but not in the touchpad, but in the buttons. In a laptop bought in the US, bromine was found in the power supply.

A similar picture is observed in other manufacturers: during the study of Apple products, experts found that in the cable of the MacBook laptop Pro 13 from the USA and the Netherlands contains three times more bromine than devices from the Philippines and Russia. When analyzing another cable, traces of bromine were found already in devices from Russia and the Netherlands, but there were none in the model from the USA. Thus, only the level of energy consumption remains a reliable indicator of environmental friendliness - among sub-notebooks, only a few models have the lead, and the rest differ sharply from the leaders in terms of their characteristics.

Mining operations destroy the Earth's surface and often pollute the surrounding air and water. Extraction of rare earth minerals is impossible or unprofitable without

the use of processes that cause serious damage to the environment. Polyvinyl chloride, usually denoted by the abbreviation PVC, is a type of plastic used for a variety of purposes. It is made of the outer shell of the cables that connect the devices, it surrounds the electric wire of the laptop computer. PVC is present in the music collection of lovers of vinyl records. Pipes and clothes are made from it. This is a cheap, strong and very common material.

Long-term use of computers leads to a decrease in the concentration of oxygen in the air, the amount of ozone, on the contrary, increases. Ozone is a strong oxidizer. Its concentration above the maximum allowable values leads to adverse metabolic reactions of the body. Monitors have a great impact on the ionic composition of the air in the working area. A change in this balance caused by an increase in the number of positive ions leads to negative consequences. It was established that the background spectrum of ions in rooms with monitors is characterized by an excess of negative ions. During the operation of the terminal, the structure of the spectrum of the ionic composition of the air in the working area changes significantly. During 5 minutes of monitor operation, the concentration of light negative ions decreased by 8 times, and after 3 hours, it decreased to a level close to zero. The number of medium and heavy negative particles decreased significantly. At the same time, the concentration of positive ions increased, and after 3 hours. positive particles prevailed during the monitor operation in the air of the working area. It should be noted that even in geopathic zones, the devices also register a sharp decrease in negatively charged oxygen ions, which emphasizes the fact that the torsion fields of the Earth's zones and the torsion fields generated by monitors, televisions, and other electronic equipment are of the same physical nature.

Personal computers, laptops and other information technology, as you know, are widely used in the field of scientific research, industry, as well as in everyday home use. But any technology rapidly ages, it is replaced by new, more powerful, more modern PCs and office equipment. Gradually, the problem arises of what to do with old equipment, morally obsolete or for one reason or another, out of order, which clutters utility rooms and warehouses.

Disposal of computers is a process that is carried out in several stages. The very

first action is writing off the equipment directly from the enterprise. The second stage is the disassembly of the equipment and the sorting of the received materials. If the parts are able to serve as raw materials, for example, a kinescope, parts that contain precious metals, then they are sent for cleaning and then for reuse.

## **5.2 Calculation of the impact of the research object**

At the moment, it is believed that the entire IT sector accounts for about 2% of harmful emissions on a global scale. This is a significant number, especially if you consider that this sector is developing and increasing at a high speed.

According to United Nations (UN) researchers, the time has come to take coordinated international steps to reduce the environmental damage caused by computer equipment. According to their data, when creating one average personal computer, the total weight of various chemicals and fossil fuels exceeds the weight of the final product by 10 times. Moreover, many of these chemicals are toxic, and the use of fossil fuels worsens the process of global warming. This waste is then either disposed of in huge landfills or processed, often under inadequate conditions in developing countries, which poses a significant threat to health.

It is impossible not to note the incredible energy efficiency of the new devices. If we consider, for example, the products of the MacBook line of Apple Inc., which are considered to be among the most environmentally friendly in the industry, then we can find a previously impossible low power consumption.

Even the most inefficient of these products triple the requirements of the strict Energy Star 6.0 energy consumption standards of 25 kWh per year for a laptop. If converted to watts, it turns out that the Mac Book consumes less than 1 watt of energy per hour - a hundred times less than a conventional 100 W incandescent light bulb. However, not everything is so simple. 75% of all energy (used during the entire life cycle of the device) goes into the production of the Mac Book, not into its operation. It is the energy consumed when using the device that is taken into account by the Energy Star standard. And it is only 19%. The rest is processing and transportation.

In a report from the same Apple company, it is said that, for example, a 15-inch

MacBook Pro with retina display emits 690 kg of carbon dioxide into the atmosphere during its lifetime. In fact, it is the same energy consumption expressed in kilograms of CO<sub>2</sub>. With the help of a simple coefficient, these kilograms can be converted into kilowatt-hours of electricity produced at the power plant. Such coefficients are calculated by special organizations according to internationally approved protocols, such as, for example, Green house Gas Protocol, and are widely used by businesses to calculate the impact of their production on the environment.

It is clear that the coefficients are different for different energy sources and different countries. For example, in America, when one kilowatt-hour of energy is obtained, about half a kilogram of carbon dioxide is produced. In China, where most of the electronics factories are located, the coefficient is about 0.87 kg/kWh. In the world, the "average hospital temperature" turns out to be about 0.44 kg of CO<sub>2</sub> per kWh.

If we convert 690 kg of CO<sub>2</sub> into kilowatt-hours using these factors, even using the conservative Chinese factors, we get 800 kWh. That's 200 kW/h per year, nearly 10 times more than Energy Star standards. This may be surprising at first, but it is enough to consider the intricacies of the production of processors, which are among the most harmful in the production of computer components.

Production of microchips with submicron size elements is one of the most complex processes in modern industry. This technology has absorbed many physical and chemical processes and requires nanometer precision, which is achievable only with absolute sterility of the production room. In the workshop, where the work is carried out, the so-called "electronic hygiene" is observed: in the working area of processing semiconductor wafers and in crystal growing operations, there should not be more than five dust particles of 0.5 micron in size in a liter of air. For comparison, the cleanliness standards of surgical operating rooms allow the content of thousands of times more dust.

A chip is not just a silicon wafer, but a complex multilayer semiconductor structure built on a silicon substrate. Chip production consists of more than three hundred operations, and one production cycle can last up to several weeks. Harmful chemicals, ultra-precision equipment, and energy-intensive physical techniques such

as radiation etching and ion implantation are used at virtually every stage. Moreover, these operations are repeated for each pair of dozens of layers that make up the processor. Plus energy consumption for a powerful ventilation and filtration system that ensures sterility.

Therefore, it is not surprising that the mass of fuel required for the production of one processor is thousands of times greater than the mass of the chip itself (only a couple of grams). The total energy consumption is hundreds of thousands of times more than in the usual production of, say, plastic or metal, from which computer cases are later made.

Today, it is believed that the production of a processor weighing 2 grams requires 1.6 kg of fuel, 72 g of chemical reagents and 32 kg of water.

### **5.3 Ways to improve the situation**

The composition of the computer includes many metals such as gold, silver, aluminum, copper and others. Success in utilization personal computers can be achieved through recycling.

Computer recycling, electronic recycling — disposal of computers and any other electronic devices. This is a complete deconstruction of electronic devices in order to reduce the cost of raw materials and save as much material as possible from old and broken equipment.

In 2009, 38% of computers and 25% of total e-waste was recycled in the United States, compared to 5% and 3% in 2006, respectively. Since its inception in the early 1990s, more and more devices are being recycled worldwide due to increased awareness and investment. Basically, electronic processing takes place in order to recover valuable rare earth and precious metals that are in short supply, as well as plastics. These will be resold or used in new devices after cleaning, creating a circular economy.

Recycling is environmentally friendly because it prevents hazardous waste, including heavy metals and carcinogens, from entering the atmosphere or water bodies, as well as landfills. Although electronics make up a small proportion of the



total amount of waste generated, they are much more dangerous. There are strict laws aimed at enforcing and encouraging the recycling of household appliances, the most influential of which are the European Union's Electronic Waste and Electronic Equipment Directive and the United States' National Computer Recycling Act.

Obsolete computers and old electronics are a valuable source of secondary raw materials for recycling, on the other hand they are a source of toxins and carcinogens.

The rapid development of technology, low initial cost and anticipated obsolescence have led to a rapidly growing surplus of computers and other electronic components around the world. Technical solutions are available, but in most cases, regulatory frameworks, fee systems, logistics, and other services must be implemented before applying a technical solution. The US Environmental Protection Agency estimates that between 30 and 40 million PC scraps are classified as "household hazardous waste". The National Security Council estimates that 75% of all personal computers once sold are now e-waste.

In 2007, the US Environmental Protection Agency stated that more than 63 million computers in the US were either sold or discarded for replacement. Today, 15% of electronic devices and equipment are recycled in the United States. Most e-waste is sent to a landfill or incinerator, which releases harmful elements such as lead, mercury, and cadmium into the soil, thereby adversely affecting the environment.

Many materials used in computer devices can be recovered for use in future manufacturing. Reusing tin, silicon, and iron, which are present in sufficient quantities in computers or other electronic devices, can reduce the costs of building new systems. Components often contain lead, copper, gold and other valuable materials suitable for disposal.

Computer components contain many toxic compounds, such as dioxins, polychlorinated biphenyls (PCBs), cadmium, chromium, radioactive isotopes, and mercury. A typical computer monitor can contain over 6% lead, most of which is in the cathode ray tube leaded glass. A standard 15-inch (38 cm) computer monitor may contain 1 kilogram (1.5 pounds) of lead, but other monitors may contain up to 4 kilograms (8 pounds) of lead. Printed circuit boards contain significant amounts of lead and tin, solders that are likely to enter groundwater. Processing (eg, incineration

and acid treatments) should preserve these valuable compounds, but may create or synthesize toxic byproducts.

Export of waste to countries with lower environmental standards is a major problem. The Basel Convention includes hazardous waste but does not regulate quantity limits, such as CRT screens, which cannot be exported transcontinentally without prior consent of both countries of export to receive the waste. Companies may find it cost-effective in the short term to sell obsolete computers to less developed countries with less stringent regulations. It is believed that most surplus laptops are sent to developing countries under the guise of "e-waste landfills". The high cost of operation and multiple use of laptops, computers and components (for example, RAM) can help pay for the cost of transporting many unnecessary "goods".

Processing methods:

- Disposal by consumers. Consumer disposal options include selling, donating computers directly to organizations, sending devices directly to their manufacturers, or receiving components for recovery or recycling.

- Corporate disposal. Businesses are looking for cost-effective ways to recycle large amounts of computer equipment, but face more complex technological processes. Businesses are also looking at selling or liaising with Original Equipment Manufacturers (OEMs) and recycling organizations. Some companies take the unnecessary equipment of other enterprises, erase data from the systems and give an estimate of the residual value of the product. For devices that have value, companies buy parts, repair and sell refurbished products to those looking for cheaper options than buying new.

- Selling. Internet auctions are an alternative for consumers who want to resell the product for cash, including the commission, without risking additional costs, because the product may not be sold under a paid advertisement. Online classified ads can be risky due to fraud, forgery and user volatility.

One of the innovations for the disposal of printed circuit boards was invented by employees of the National Physical Laboratory of Great Britain, who demonstrated the possibility of a special solution that is dissolved in hot water. The action of which causes the detachment of electronic components.

Thus, 90% of the components of new printed circuit boards can be reused, while in the case of conventional methods - only 2%.

Practically no enterprise will be able to independently dispose of computers and office equipment, as this process requires modern equipment and specific knowledge. Therefore, you can entrust such work only to professionals who have extensive experience in this field.

The problem of disposal of used computers and peripheral equipment is becoming more acute every year. The volume of production of information and telecommunication technology products and the frequency of their replacement with new models force companies to think about the problem of biodegradation. The researchers believe that more incentives should be given to both computer manufacturers and users to improve and reuse their equipment instead of throwing it away.

Advances in this area will help, among other things, manufacturers reduce the taxes they currently pay for disposing of obsolete models. The latter is all the more important because it makes greening economically profitable, so it directs more and more efforts of researchers and long-term capital investments into this area. Thus, the further spread of information technologies will not increase, but on the contrary - reduce the man-made load on the environment.

**So:**

Issues of environmental protection in the process of computer production arose a long time ago and are regulated now. In recent years, numerous regulations and standards (international NPR or TCO95, TCO99) have appeared all over the world, designed to reduce negative impacts.

A computer manufacturer these days usually advertises its product as meeting several environmental requirements. Example:

- low electricity consumption;
- environmentally friendly production;
- not using freon, which destroys the Earth's ozone layer;
- production of containers, documentation and packaging from secondary processing materials, etc.

Computer technology, being a great achievement of mankind, can have negative consequences for the surrounding world. The technical level of modern monitors does not allow to completely exclude the existence of harmful effects, however, this effect must be minimized by regulating a number of parameters. In order to reduce the loss, it is necessary to comply with the established requirements and norms. The main purpose of their implementation is to protect animal and plant life from the harmful effects of computer and other electronic equipment.

The Greenpeace organization closely monitors how large companies treat environmental protection and regularly publishes a Greenpeace report Guide that Greener Electronics , in which manufacturers (HP, Sony , Toshiba , etc.) are assigned ratings in three main categories: rationality of operations, energy and climate, environmentally friendly products. We can conclude that we can only hope that the time will come when technology will help people without causing irreversible damage to the health of the environment.

## CHAPTER 6

### LABOR PROTECTION






Labor protection management carries out a purposeful effect on the "man-production" system, which is the entire set of elements with which a person interacts in the work process and which can have a corresponding effect on it. Occupational health and safety issues are regulated by the Labor Code of Ukraine, "On mandatory state social insurance against accidents at work and occupational diseases that have caused the loss of working capacity", as well as a number of resolutions of the Cabinet of Ministers of Ukraine. One of the most important legal acts on labor protection is the Law "On Labor Protection".

The object considered in the thesis requires the use of a personal computer (PC), which, in turn, are complex electronic devices characterized by the presence of certain dangerous sources of influence on the designer and the environment in which he is.

#### 6.1 Analysis of working conditions with electronic computing machines

According to the nature of labor activity, three professional groups are distinguished according to the current classifier of professions (DK - 003 - 95 and Amendment No. 1 to DK - 003 - 95):

- program developers (programmer engineers) - perform work mainly with a video terminal and documentation if necessary and intensive exchange of information with computers and a high part of decision-making. Work characterized by intensive mental creative work with increased visual strain, concentration of attention against the background of neuro-emotional stress, forced working posture, general hypodynamia, periodic strain on the hands of the upper

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limbs. The work is performed in dialogue mode with a computer at a free pace with periodic search for errors in conditions of time shortage;

- operators of electronic computing machines - perform work that is related to the accounting of information received from visual display terminals (VDT) according to a previous request, or that comes from it, is accompanied by breaks of different duration, is related to the performance of other work and is characterized as work with eye strain, with little physical effort, moderate nervous tension and performed at a free pace;

- computer operator - performs monotonous work with documentation and a keyboard and infrequent short-term switching of the gaze to the display screen, with high-speed data entry, the work is characterized as physical work with an increased load on the hands of the upper limbs against the background of general hypodemia with visual strain (fixation of sight mainly on documents), nervous and emotional tension.

The following intra -shift modes of work and rest are established when working with a computer during an 8-hour day shift, depending on the nature of the work:

- for developers of programs with the use of computers, a regulated rest break of 15 minutes should be assigned after each hour of work according to VDT;

- for computer operators, regular 15-minute rest breaks should be scheduled every two hours;

- for computer set operators, regulated rest breaks lasting 10 minutes should be assigned after each hour of work according to VDT.

In all cases, when production circumstances do not allow the application of regulated breaks, the duration of continuous work with VDT should not exceed 4 hours.

In the case of a 12-hour work shift, regulated breaks must be established in the first 8 hours of work in the same way as breaks in an 8-hour work shift, and during the last 4 hours of work, regardless of the nature of work, after every hour lasting 15 minutes.

In order to reduce the negative impact of monotony, it is advisable to use alternating operations of the realized text and numerical data (changing the content of the work). Alternation of data entry and text editing.

To reduce neuro-emotional stress, fatigue the visual analyzer, improve cerebral blood circulation, overcome the adverse effects of hypodynamia, and prevent fatigue, it is advisable to use some breaks to perform a set of exercises.

In some cases - in the case of chronic complaints of visual fatigue of workers with VDT computers and personal computers despite compliance with sanitary and hygienic requirements for work and rest regimes, as well as the use of local eye protection - an individual approach to limiting the time of work with VDT, changing the nature of work is allowed, alternation with other types of activities not related to VDT.

Active rest should consist of performing a complex of gymnastic exercises aimed at relieving nervous tension, muscle relaxation, restoring the functions of physiological systems that are disturbed during the work process, relieving eye fatigue, improving cerebral blood circulation and working capacity.

Given the high level of intensity of work with VDT, psychological relief during regulated breaks or at the end of the working day is indicated.

## **6.2 List of harmful and dangerous production factors**

The production environment refers to a set of physical, chemical, biological, psychophysiological factors in production that affect a person. All these factors are classified as dangerous and harmful.

Dangerous production factors are those whose influence on the employee leads to injuries, sharp deterioration of health or death.

Harmful production factors are those whose impact on the employee can lead to illness and reduced work capacity.

Workers engaged in work related to periodic or permanent work at a computer are exposed to industrial hazard factors, the main of which are:

*Physical:*

- increased level of voltage in the electrical circuit, the short circuit of which can pass through the worker's body;

- increased level of X-ray radiation;

- increased level of ultraviolet radiation;

- increased level of infrared radiation;

- the possibility of being affected by static electricity;

- dustiness of the air in the working room;

- increased content of heavy (+) aeroions;

- uneven distribution of brightness in the field of vision;

- increased level of light flux pulsation.

*Chemical:*

- Increased content of carbon dioxide, ozone, ammonia, phenol, formaldehyde, etc. in the air.

*Psychophysiological:*

- visual tension;

- memory voltage;

- tension of attention;

- long-term static tension;

- a relatively large amount of information processed per unit of time;

- monotony of work in some cases;

- irrational workplace organization.

When working with a PC, a person can be exposed to all harmful and dangerous factors. Harmful and dangerous factors faced by a designer when working with a PC are listed in Table 6.1.



List of harmful and dangerous production factors

<b>The name of the factors</b>	<b>Possible sources of their occurrence</b>	<b>The nature of the action</b>
Risk of electric shock	Power network	Dangerous
Fire hazard of premises	The presence of flammable materials and sources of ignition (electrical equipment)	Dangerous and harmful
Electromagnetic radiation, including X-rays	CRT (the display is a source of X-ray, radio frequency, ultraviolet, infrared radiation and sound range radiation)	Harmful
Static electricity	CRT of the monitor and the dielectric surface of the screen	Harmful
Air ionization	Static electricity and X-ray radiation	Harmful
Increased noise level	The noise is created by the voltage converter of the computer, its technical peripherals, as well as people working in the audience	Harmful
Unfavorable lighting	Insufficient artificial and natural lighting	Harmful
Unsatisfactory microclimate parameters	Unsatisfactory state of ventilation and heating systems	Harmful
Psychophysiological stress	Monotony of work, overstrain of visual analyzers, mental tension, discomfort and static postures	Harmful

Computers and telephones are also the main sources of noise in rooms. The noise level in the room should correspond to the optimal level according to DSN 3.3.6.037-99.

### **6.3 Analysis of harmful and dangerous production factors acting on the subject at the workplace**

The main harmful factors when working with a computer include: prolonged sitting, electromagnetic radiation, eye strain, overloading of hand joints, the possibility of respiratory diseases, allergies, disruption of the normal course of pregnancy, etc.

A long sitting position leads to tension in the muscles of the neck, head, arms and shoulders, osteochondrosis, and even scoliosis in children. A long sitting position also leads to blood stagnation in the pelvic organs and, as a result, to prostatitis and hemorrhoids. It's no secret that a sedentary lifestyle leads to obesity.

Load on vision. The human eye reacts to the slightest vibration of the text and to the flickering of the screen. The muscles of the eye, which control the lens, are in constant tension, which necessarily leads to a loss of visual acuity. Long-term work at the computer is a huge strain on the eyes, because the image on the monitor does not consist of continuous lines, as on paper, but of individual points that glow and flicker. The user's eyesight inevitably deteriorates, the eyes begin to water, headache, fatigue appear, the image is doubled and distorted.

Chemical dangerous and harmful production factors include chemicals that are classified as toxic, irritating, sensitizing, carcinogenic, and mutagenic based on the nature of their action on the human body. These chemicals affect human reproductive function. According to the ways of penetration into the human body, they are divided into those that penetrate through the respiratory system, the gastrointestinal tract, the skin and mucous membranes.

Biologically dangerous and harmful production factors include pathogenic microorganisms (bacteria, viruses, rickettsiae, spirochetes, fungi, protozoa) and their life products, as well as macro-organisms (plants and animals).

Psychophysiological dangerous and harmful production factors include physical (static and dynamic) and neuropsychological overloads (mental overstrain, overstrain of analyzers, monotony of work, emotional overloads).

In order to objectively analyze the compliance of the working conditions with the current legal acts, it is necessary to carry out a sanitary and hygienic characterization of the working conditions, certification of the workplace according to indicators of the harmfulness and danger of the factors of the production environment, the difficulty and tension of the labor process.

Work at the computer and stress. Stress is emotional experiences, internal tension caused by events in life. Stress occurs, first of all, when information is lost or damaged. Reasons: lack of backup copies, computer viruses, hard disk failures,

operational errors. Working at a computer is one of the factors that cause stress (a stressor).

The body's reaction to stress is the launch of biochemical processes aimed at suppressing an extreme situation. Diseases of the respiratory organs when working with a computer in this context are mainly allergic in nature. This is explained by the fact that during the long operation of the computer, the body and boards of the latter emit a number of harmful substances into the air, and the computer also creates an electrostatic field around itself, which attracts dust that settles in the lungs.

The computer also deionizes the environment and reduces air humidity. The computer is a serious source of a number of allergens. For example, the body of the monitor, heating up to 50-55 ° C, begins to emit triphenyl phosphate vapors into the air.

In addition to the monitor, the motherboard, power supply unit, processor, and video card also heat up, which can also release harmful organic and inorganic substances (fluorine, chlorine, and phosphorus) into the environment. In addition, there are many places in the computer where dust and dirt accumulate, germs and fungi multiply. The dust receives a weak static charge from the monitor screen, which is enough for the dust to settle on the user's body and in his respiratory tract.

#### **6.4 Development of labor protection measures**

On the basis of DNAOP 5.2.30-1.08-96 and VSN 4559-88 "Temporary sanitary norms and rules for employees of computer centers":

- persons over 18 years of age who have no contraindications according to the results of a preliminary medical examination and who have undergone instruction, training and knowledge testing on labor protection and have 1 qualification group in electrical safety are allowed to work on personal computers;

- admission to work on personal computers of persons under 18 years of age (trainees, students) is carried out under the guidance of experienced employees who have a qualification group in electrical safety not lower than 3.

To reduce and prevent the harmful effects of the above factors, it is recommended:

- to reduce the level of static electricity, place the display screen at a distance of no closer than 550 - 700 mm. from the user's eyes;

- to reduce glare , the display screen should be located perpendicular to the light flow from window openings or from electric lamps;

To reduce eye fatigue:

- the lighting of the workplace should be at least 300 - 500 lux; the brightness of the screen glow is at least 100 cl/sq. m.;

- the minimum size of the light spot - no more than 0.6 mm.;

- contrast of the image of the sign - at least 0.8;

- regeneration frequency - at least 72 Hz.

To reduce the impact of hypodynamia and emotional overload, it is worth using technological breaks and performing a set of physical exercises.

For safety before starting work:

- leave street clothes and personal belongings in the wardrobe;

- remove from the workplace objects that will not be used in work;

- it is forbidden to put paper, books, documents and other objects on the computer blocks;

- in order to avoid network overload, it is forbidden to connect the computer through tees together with other electrical devices;

- turn on, if necessary, artificial lighting, a table lamp;

- by an external inspection, make sure of the serviceability of the connecting wires, plug sockets, grounding busbars and switches, the reliability of fastening of the protective casings and covers of the computer blocks;

- check the absence of dust on the display screen. Do not allow dust and foreign objects to block ventilation openings for heat removal from computer units;

- adjust the height of the chair seat and footrest. Adjust the position of the monitor screen in relation to your field of vision;

- upon detection of malfunctions and other deficiencies that create danger or significant inconvenience in work, report this to the head of the department, section.

For safety during work:

- when connecting a personal computer and lighting to the power grid, handle only the isolated parts of the plug sockets;
- observe the sequence of turning on the computer units specified in the operating instructions;
- to avoid static electricity discharges, it is forbidden to touch the display screen;
- when entering data, editing programs, reading information from the screen, the continuous duration of work in front of the screen should not exceed 1 hour, with subsequent regulated breaks of 10 minutes for rest and performing a complex of physical exercises, relaxation gymnastics and autogenic training.

Prohibited when the computer power supply is not turned off:

- open protective casings and covers of computer units, adjust and clean internal parts, change fuses;
- switch connecting cords of computer blocks;
- change the established configuration of the workplace, rearrange computer blocks;
- do wet cleaning of computer surfaces;
- take food directly from the computer keyboard.

The following are strictly prohibited at the computer operator's workplace:

- smoking, using open fire;
- store flammable, explosive and chemically active products that destroy insulation.

Signs of an emergency situation at the workplace of a computer operator are:

- appearance of computer malfunctions, paper jams in the printer, disappearance of the image on the display screen;
- short circuit, sparking, the appearance of a burning smell, increased heating of the housing, plug sockets, connecting wires, reduction or disappearance of voltage in the network, etc.

In an emergency situation, it is necessary:

- stop work, disconnect the computer from the network;
- in case of fire, use carbon dioxide or powder fire extinguishers;



- take measures to evacuate people and provide first aid to victims;
- report what happened to the head of the department, section;
- if necessary, call an ambulance, fire brigade.

Safety after work:

- end running programs, close all directories, prepare the computer for shutdown;
- disconnect the computer and local electric lighting from the network;
- arrange the workplace, take away the documents that were used;
- make sure there is no fire hazard.

## **6.5 Electrical safety and fire safety when working with electronic computers**

The main cause of electric shock is violation of safety rules when operating electrical installations.

Electrical safety requirements in premises where electronic computing machines and personal computers (hereinafter - PCs) are installed are reflected in DNAOP 0.00-1.31-99. According to this regulatory document, during the design of power supply systems, installation of main electrical equipment and electrical lighting of buildings and premises for computers, it is necessary to comply with the requirements of the Rules for the installation of electrical installations (RIE), GOST 12.1.006-84, GOST 12.1.019-79, GOST 12.1.030 -81, GOST 12.1.045-84, PTE, PBE, VSN 59-88 "Electrical equipment of residential and public buildings. Design standards", CH 357-77 "Instructions for the design of power lighting equipment for industrial enterprises", Rules of fire safety in Ukraine and other regulatory documents relating to artificial lighting and electrical devices, as well as requirements of regulatory and technical operational documentation of the manufacturing plant.

The electric network line for powering the computer, computer peripheral devices and equipment for maintenance, repair and debugging of the computer is performed as a separate group three-wire network, by laying the phase, zero working and zero protective conductors. The zero protective conductor is used for grounding (zeroing) electrical receivers and is laid from the rack of the group distribution board, the distribution point to the power sockets.

In a room where more than five personal computers are operated or serviced at the same time, an emergency backup switch is installed in a visible and accessible place, which can completely turn off the electrical power of the room, except for the lighting.

It is unacceptable to connect a computer, computer peripheral devices and equipment for maintenance, repair and debugging of a computer to a conventional two-wire electrical network, including using transitional devices.

When placing up to 5 personal computers in a room around its perimeter, using a three-conductor shielded wire or cable in a sheath made of non-combustible or flame-resistant material, it is allowed to lay them without metal pipes and flexible metal sleeves.

Metal pipes and flexible metal sleeves must be grounded. Grounding must meet the requirements of DNAOP 0.00-1.21-98 "Rules for the safe operation of consumer electrical installations". Grounded structures located in the premises (heating batteries, water pipes, cables with a grounded open screen, etc.) must be reliably protected by dielectric shields or nets from accidental contact.

The following are unacceptable:

- operation of cables and wires with damaged or insulation that has lost its protective properties during operation; leaving live cables and wires with non-insulated conductors;

- the use of self-made extenders that do not meet the requirements of RIE for portable electrical wiring;

- use of non-standard (self-made) electronic heating equipment or incandescent lamps for room heating;

- using damaged sockets, junction and junction boxes, switches and other electrical products, as well as lamps, the glass of which has darkening or protruding traces;

- hanging lamps directly on current-carrying wires, wrapping electric lamps and lamps with paper, fabric and other combustible materials, operating them with the caps (diffusers) removed;

- use of electrical equipment and devices in conditions that do not correspond to the instructions (recommendations) of the manufacturing companies.

## **6.6 Attestation of workplaces**

For an objective analysis of compliance of working conditions with the current legal acts, it is necessary to carry out a sanitary and hygienic characterization of working conditions, attestation of the workplace according to indicators of harmfulness and dangerous factors of the production environment, difficulty and tension of the labor process.

Attestation of workplaces according to working conditions on a computer involves:

- a comprehensive assessment of the factors of the production environment and the nature of work, compliance of their characteristics with labor safety standards, construction and sanitary norms and rules;

- identification of factors and causes of unfavorable working conditions;

- sanitary and hygienic study of the factors of the production environment;

- establishing the degree of harmfulness and dangerousness of work and its nature according to hygienic classification;

- justification for assigning the workplace to the category with harmful (especially harmful) working conditions;

- determination (confirmation) of employees' right to benefits;

- analysis of the implementation of technical and organizational measures aimed at optimizing the level of hygiene, the nature and safety of work.

The entire building must be electrified in accordance with all relevant regulations. All computers must be used exclusively for their intended purpose, as they can be electrically dangerous if used incorrectly. It is advisable to use liquid crystal monitors, as X-ray radiation from them does not pose a danger to the user, since the intensity of such radiation is much lower than the maximum permissible level. The level of electromagnetic radiation should provide for a possible 12-hour stay in the



radiation zone. The level of electrostatic field strength should be within the normal range.

The room also has tables, chairs and filing cabinets. All of them can be placed only in accordance with their functional purpose, and their number should correspond to the nomenclature of work tools, content and features of the work being performed.

The design of the desktop must meet modern ergonomics requirements and ensure optimal placement of the used equipment (display, keyboard) and documents on the work surface.

The work chair should be lifting and swiveling, adjustable in height, with a rounded front edge. The height of the seat surface can be adjusted between 400 and 500 mm, and the width and depth should be between 450 and 500 mm. The angle of inclination of the backrest can be adjusted in the range from 0° to 30° relative to the vertical position. Stationary armrests 250 mm long are installed to reduce the static tension of the muscles of the upper limbs. The seat surface meets all requirements.

The computer monitor should be at a sufficient distance from the user's eyes. The keyboard should be located on the surface of the table at a distance of 200 mm from the edge facing the worker. The design of the keyboard should include a support device that allows you to change the angle of the keyboard surface in the range from 5 to 15.

Thus, the ergonomic parameters of the workplace will meet the requirements for their organization and design and ensure the maintenance of an optimal working posture.

In the cold period of the year, it is recommended to use your own independent heating system for heating the building. This has a positive effect on the well-being of employees, as it is possible to control the heating of the premises.

Ensuring meteorological working conditions and air cleanliness in the room must be carried out with the help of a supply-exhaust ventilation system, regular ventilation, and wet cleaning.

It is necessary to use artificial and natural lighting. The standard value of the coefficient of natural lighting (CNL) for the fourth light zone, in which Ukraine is

located, is 0.81. In addition, the room should be additionally illuminated with the help of lamps with incandescent lamps with a power of 200 W.

Thus, the working conditions of the employee as a whole will correspond to the existing sanitary and hygienic standards. But due to the fact that most of the time the employee occupies a sitting position and moves little, it is proposed to introduce five-minute industrial gymnastics, which must be carried out after every 60 minutes of sedentary work, and which will be aimed at improving the physical and moral state and well-being employee.

**So:**

Labor protection is a system of legislative acts, socio-economic, organizational, technical, sanitary-hygienic and medical-prophylactic measures and means that ensure the safety of health and working capacity of a person in the process of work.

Working conditions are understood as a set of factors of the labor process and the production environment in which human activity is carried out, which affect health and work capacity.

The rate of growth of the number of PC users is steadily increasing. At the same time, the possible danger to the health of PC workers is becoming more and more obvious. When working with a computer, the visual, locomotor, neuropsychological systems and reproductive function in women are at the greatest risk. In addition, the video display terminal disrupts the balance between positively and negatively charged ions in the air.

Personnel working on a computer must comply with the requirements of the instructions developed on the basis of SanPiN 2.2.2.542-96 Sanitary norms and rules "Hygienic requirements for video display terminals, personal electric calculating machines and work organization."

Harmful and dangerous factors when working with a computer are: electrostatic fields; electromagnetic radiation; presence of powerful ionizing radiation; local fatigue, general fatigue; eye fatigue; danger of electric shock; fire hazard.

In emergency situations, the computer must be immediately disconnected from the network: in the event of a power outage; in case of fire; when the smell of smoke appears.

The strictest requirements in the world for computer equipment are made by the Swedes, who have conducted the most comprehensive studies of the impact of all types of radiation on human health. When creating a single EU standard, the countries of the European Union focused on the Swedish standards of TSO 92.



## CONCLUSIONS

The operation of spacecraft in the conditions of space is affected by a number of factors that make it impossible or difficult to use certain systems in its composition.

The key to the reliable operation of space vehicles is the use, development and equipping of them with a highly efficient power supply system.

How correctly the structure is chosen, the parameters of such a system are calculated and adjusted, largely depends on its effectiveness.

In the course of the diploma work there were:

- created a CAD of an extreme system for regulating the power of the spacecraft's solar batteries for which:

- the basic components and their characteristics are defined;
- the design algorithm is substantiated and developed;
- mathematical support for the design and modeling of the system was performed;
- the composition of the extreme power regulator of solar batteries is determined.

- developed methods and defined algorithms for software and methodological support of experimental research during design:

- structural modeling of control systems;
  - design based on basic application program packages;
  - software design implementation.
- the need for implementation is substantiated and experimental studies are carried out in the interests of correct design. Theoretical and experimental studies of calculation methods showed a good convergence of results.

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