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НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ
КАФЕДРА АВІАЦІЙНИХ КОМП' ЮТЕРНО-ІНТЕГРОВАНИХ КОМПЛЕКСІВ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
____________В.М. Синєглазов
«_____» ___________2020 р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»

ЗА НАПРЯМОМ ПІДГОТОВКИ
15 – АВТОМАТИЗАЦІЯ ТА ПРИЛАДОБУДУВАННЯ

Тема: «Автоматична система керування орієнтацією дзеркал сонячної електростанції»

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Київ 2020

MINISTRY OF EDUCATION AND SCIENCE UKRAINE
NATIONAL AVIATION UNIVERSITY
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DEPARTMENT OF AVIATION COMPUTER INTEGRATED SYSTEMS

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“____” _____________ 2020

DIPLOMA THESIS

(EXPLANATORY NOTE)

FOR THE DEGREE OF MASTER IN ENGINEERING
ON MAJOR 15 “Automation and Instrumentation"

Title: “Automatic control system of mirror orientation of solar electric power station.”

Submitted by: ________________ Diachyn Artem Oleksiyovich

Supervisor: PhD, associate professor ___________Sergeyev Igor Yuriyovich

Standards inspector : Tupitsyn Mykola Fedorovich

Kyiv 2020

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
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Кафедра авіаційних комп'ютерно-інтегрованих комплексів
Напрям: *15 – Автоматизація та приладобудування*

ЗАТВЕРДЖУЮ
Завідувач кафедри
_________В.М. Синєглазов
«_____»___________2020 р.

ЗАВДАННЯ
на виконання дипломної роботи
Дьячин Артем Олексійович

1. Тема роботи «Автоматична система керування орієнтацією дзеркал сонячної електростанції» затверджена наказом ректора від

2. Термін виконання роботи: з 01.09.2020 по 10.12.2020

3. Вихідні дані до роботи: розробка автоматизованої системи керування орієнтацією дзеркал сонячної електростанції та її програмного забезпечення.

14. Зміст пояснювальної записки: Розділ 1 Постановка задачі (аналіз проблеми) автоматизації системи керування сонячною електростанцією; Розділ 2: Огляд існуючих технічних рішень та аналіз стану проблем, що стосується автоматизації СЕС; Розділ 3: Постановка задачі, вибір і обґрунтування технічного рішення Розділ 4:Розробка структурної схеми Розділ 5:Розробка алгоритмічного забезпечення Розділ 6: Розробка програмного забезпечення; Список використаної літератури.

5. Перелік обов’язкового ілюстративного матеріалу: блок-схема керування зв'язками в автоматизованій системі керування орієнтацією сонячних дзеркал

6. Календарний план-графік

/п	Завдання	Термін виконання	Відмітка про виконання
	Пошук матеріалів для дипломної роботи	01.09.2020-11.09.2020	
	Вивчення літератури за темою дипломної роботи	11.09.2020-22.09.2020	
	Написання розділів 1-6 дипломної роботи.	22.09.2020-03.10.2020	
	Написання програмного коду.	03.10.2020-27.11.2020	
	Оформлення пояснювальної записки. Висновки	27.11.2020-10.12.2020	

7. Консультанти зі спеціальних розділів

Розділ	Консультант (посада, П. І. Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Коновалова О.В,		
Охорона навколишнього середовища	Фролов В.Ф.		

8. Дата видачі завдання:

Керівник дипломної роботи ________________ І.Ю.Сергеєв

Завдання прийняв до виконання ____________________ А.О. Дьячин

NATIONAL AVIATION UNIVERSITY

Faculty Of Air Navigation, Electronics And Telecommunications

Department Of Aviation Computer Integrated Systems

Major: 6.050202 “Automation and computer-integrated technologies”

APPROVED BY

Head of the Department

_____________V. Sineglazov

“_____”______________2020

Diploma Thesis Assignment for Graduate Student

Diachyn Artem Oleksiyovich

1. The thesis title “Automated control system for orientation of mirrors of solar power station” was approved by the Rector’s order of “

2. The thesis to be completed between: 01.09.2020-10.12.2020

3. Initial data for the thesis: development of automated control system for orientation of mirrors of solar power station

4. The content of the explanatory note: Chapter 1 analytical survey of automated mirrors control systems on sun power plant ; Chapter 2 choice and justification of ways to solve technical problems; Chapter 3 development of automated security systems smart home; List of used literature. Chapter 4 development of structural scheme.

5. List of mandatory illustrations: block diagram of communications management in an automated security system.

6. Timetable

	Assignment	Dates of completion	Execution marks
	Introduction.	01.09.2020-11.09.2020	
	Investigation of security systems. Task setting.	11.09.2020-22.09.2020	
	Preparing 1st and 6th chapters of diploma work.	22.09.2020-03.10.2020	
	Writing code.	03.10.2020-27.11.2020	
	Preparing the explanatory work, conclusions.	27.11.2020-10.12.2020	

7. Special chapters' advisors

Chapter	Advisor (position, name)	Date, signature	
		Assignment issue date	Assignment accepted
Labor protection	Associate Professor, Konovalova O. V.		
Environmental protection	Associate Professor, Frolov V.F.		

8. Assignment issue date:

Diploma thesis supervisor ____________________ I.Sergeyev

(the supervisor's signature) (Name)

Issued task accepted ____________________ A.Diachyn

РЕФЕРАТ

Пояснювальна записка до дипломної роботиє "Автоматична система керування орієнтацією дзеркал сонячної електростанції", що містить: 97 сторінок, 18 рисунків і 20 посилань.

Ключові слова: Сонячна Електростанція, автоматизована система, сервер, мережеве обладнання

Метою диплома є створення відмовостійкої автоматичної системи керування орієнтацією дзеркал сонячної електростанції, сервер

Об'єктом дослідження є автоматизована система керування орієнтацією дзеркал сонячної електростанції з високою відмовостійкістю та резервуванням

Предметом дослідження є визначення взаємозв'язку між сервером і мікропроцесорами, налаштуванні відмовостійкої мережі, резервування та серверної конфігурації

Методологічні засади базуються на сучасних методах моделювання та програмування мікропроцесорів, мережевому та системному адмініструванні.

ABSTRACT

The explanatory note to the diploma on “ Automated control system for orientation of mirrors of solar power plant ” contains: 97 pages, 18 figures and 20 references.

Keywords: AUTOMATED SYSTEM, , CONTROL SYSTEM, SUN POWER STATION, SERVER, DEBIAN, ARDUINO, ETHERNET,POE.

The purpose of the diploma is to create an automated control system for orientation of mirrors of solar power plant.

The investigation object is an automated control system of mirrors on sun power plant. Configuration of fault tolerance network and server configuration.

The subject of investigation is attitude determination the relationship between the server and the microprocessors

The methodological fundamental is based on modern methods of modeling and programming of microprocessors, network configuration, Linux server configuration.

CONTENTS

INTRODUCTION

The solar battery is the generator of alternative types of energy turning solar radiation into electricity.

Solar energy is inexhaustible and that is very important, - is ecologically safe. In fact, the only essential lack of receiving energy from the Sun is the low efficiency of such installations. For example, now the efficiency of the solar battery on the basis of single-crystal silicon about 15%.

What does the efficiency of a solar power plant depend on? It is natural that from many more or less significant factors, but the basic from them is orientation of battery cells concerning a radiation source (Sun). Such fact is absolutely obvious: rigidly fixed solar battery configured to the midday sun develops the maximum quantity of energy at noon when sunshine fall perpendicularly to its surface. And what occurs in other time? The incidence angle of beams on the battery is small, and the amount of the developed energy sharply decreases. And each user wants that its solar power plant developed equally high amount of energy throughout the day. And it can be reached!

Illumination of solar batteries should be supported at optimum level. The various systems of tracking — from protozoa analog to analog and digital are developed for maintenance of this level.

The system of tracking the sun is a device for orientation of the photovoltaic solar array or for deduction of the solar reflector turned to the Sun.

CHAPTER 1

1 PROBLEM STATEMENT OF AUTOMATION OF MIRROR CONTROL ON THE SUN POWER PLANT

1.1 Consideration of automation of elements (mirrors) of SPP as an object of control

Nowadays, the question of searching for new energy sources, including electric ones, is becoming more and more actual, as there is a problem of the limitations of the currently used minerals, which are used to obtain heat and electricians. Also, their use, which also includes burning, leads to environmental pollution, which cause SPP the serious illnes SPP of both power plant workers and simple people who are not connected with these proces SPP and the rapid catastrophic change in the climate system of the planet. Therefore, more and more attention is paid to self-restraining forces of nature, whose "work" can be transformed into necessary heat with electric energy (wind forces, tides and flows, falling water, all that the sun gives us) without any harm to the environment and humanity.

Despite the costly construction and operation of alternative energy stations, solar panels and power plants are increasingly being used for use. This is due to the fact that the energy of sunlight can be used to generate electricity. Also, solar power is the most popular because it is available at almost every point on the planet.

Relevance of the use of solar power plants

Solar energy is a fairly young branch of energy that is rapidly developing. Solar power plants are objects with very long service life, which, if properly selected equipment, can generate a large amount of electricity. Automated ones can do all this without any human intervention.

Here are some aspects of the relevance of the development and use of solar power plants (SPP):

• ecological, which was mentioned earlier. For example, the use of only one large SPP will reduce carbon dioxide emissions by 3 thousand tons per year;

• political, since the use of alternative energy deprives the need for fuel materials that can be used by other countries for the purpose of blackmail and all sorts of influences on the life of another state;

• economic - transition to alternative energy technologies will allow preserving the country's fuel resources for processing in the chemical and other industries. In addition, the cost of energy produced by many alternative sources is already lower than the cost of energy from traditional sources, and the payback period for the construction of alternative power plants is significantly shorter. Prices for alternative energy are declining, and traditional prices are constantly increasing.

At the same time, solar energy is used in various fields of human activity:

• industrial heat and power plants;

• stations for supplying heat and electricity to various types of buildings and premiSPP;

• cost-effective installation for private homes;

• the use of flexible solar cells as a building material;

• backup power sources in consumer goods: calculators, watches, laptops, flashlights, batteries, etc .;

• backup power sources for vehicles;

• lighting in the dark road signs and other things due to the accumulated energy of the sun.

1.2 The task of automating the management of SPP components

Often, the source of clean electricity will consist of the following devices: directly, solar panels (DC generator), batteries with a charge controller and an inverter that converts direct current into AC. Basically, automatic control is applicable to solar panels and / or batteries, whose task is to "absorb" the maximum amount of sunlight during a sunny day.

Since our planet is moving around the Sun and around its axis, installed statically solar panels and / or batteries receive a lot of indirect sunlight, which significantly reduces the efficiency of these panels and / or batteries. Often solar panels or panels are installed statically, facing south. This technical solution simplifies the entire installation as a whole, but leads to an incomplete use of solar energy, since during the time interval between the spring and autumn equinoxes there are time intervals when the sun is already in the sky but does not yet illuminate the solar panels. In this regard, there is the problem of ensuring the process of tracking SPP for the Sun.

The most effective choice will be the automated control system for solar panels, since this will allow you to get the most out of using a solar battery, regardless of the Earth's position relative to the Sun by orienting the panel in space and then placing it at the most optimal angle relative to the Sun.

Automation of the control system of solar panels can be carried out in many ways, the most common of which is automation based on data obtained using photosensors installed on the panel or work on a program that is designed taking into account calculated position of the Sun in the sky at each point of operation of the SPP.

1.3 Tasks of automation of control system SPP

The best result of the SPP will be obtained when the sun's rays fall on the panel perpendicularly - at an angle of 90 °.

The maximum energy that can be obtained will be generated in the case of perpendicular direction of the sun's rays on the plane of the panels. Otherwise, their efficiency is extremely low - about 10-15%. If you use the system of automatically guiding the batteries in the sun, you can increase the result.

The main task of automation of control of SPP is to provide autonomous operation of the power plant under all possible conditions without direct control by the operator of this station.

One of the tasks of the automation of the SPP control system is the use of a controller with a high-performance DSP core that combines switching key management with the task of tracking the point of maximum power of the solar module and the current of the battery of the autonomous SPP, however, the efficient control of the solar cell inverter in real time requires the coordination of a number of independent parameters both from the side of the solar module and from the side of the electrical network. Considering the last parameters in the controller of the inverter conveniently addresSPP the task of efficient control of the power system.

One of the tasks is to develop a platform control system with solar modules located on it, which would increase the efficiency of the solar system by maintaining the solar disk with the given accuracy, regardless of the various weather conditions (haze, cloudiness), and would minimize the search time and accurate targeting of the solar disk throughout the life of the installation. The solution of such a task is provided by programs of the control device, predefined and written to the control server that provides the entire system.

An important task of the automated control system of SPP is to ensure the functioning of power plants in local electrical systems (LES). It also helps to improve the quality of production and distribution of electricity.

One of the important tasks of the ASC SPP is to ensure the stability of its operation under different conditions. Since these stations are located directly outdoors, an important role is to ensure their operation in all weather conditions. In some areas of our planet we must also take into account the possibility of earthquakes, which will affect the accuracy of the location of panels and their orientation on the Sun. It is also necessary to take into account the air humidity, atmospheric pressure, which undoubtedly affect the details of all components of the power plants, and, of course, the level of cloudiness that affects the level of illumination of the SPP panels and the amount of energy they receive.

The undeniable task of automation is to eliminate the influence of the human factor on the uninterrupted operation of the SPP system. Insufficiently skilled workers of any power plant can by their actions lead to the smallest losSPP of energy due to improper adjustment of the system to the most terrible disasters of anthropogenic nature, which will result in injury and death of people. The best example of such disasters is the accident at the

Chernobyl nuclear power plant. Therefore, the introduction of automation is very important in all spheres of human activity; In addition, automation of various process SPP of production leads to an increase in the efficiency of these industries, reducing the risks of employees, creating jobs for specialists in the field of automation and the development of science.

1.4 Requirements for systems of automatic control of technological parameters of SPP

In many respects, the efficiency of SPP depends on its location.

The SPP automatic control system itself and its management depend on the same.

The main equipment of the SPP must comply with the general technical requirements of the existing regulatory documents on this issue and enable the use of the SPP to regulate active power / frequency and reactive power / voltage at the point of general connection to the grid of the grid, in order to maintain the proper level of reliability of the grid operation.

To the central substation (CSS) of the SPP are connected only power lines, lines of the internal electric network and lines of backup power for own needs of power plants. The addition of lines of another purpose requires a separate substantiation and agreement with the operator of the distribution system (transmission).

If the voltage of the internal network of the power plant and the voltage of the connection are the same, a switch on the power supply line is installed on the switchgear of the DPS. [5]

In order to maintain the efficiency and integrity of SPP systems, power stations must be able to automatically activate / deactivate all control functions.

The SPP must automatically connect to the general purpose electrical network, after shutting down due to emergency situations in the network, not earlier than 3 minutes, if the voltage and frequency returned to the range of normal operating conditions.

Requirements for the management and monitoring of the SPP operating modes, including the requirements for the algorithm and the provisions for automatic operation of the power plant branch for autonomous operation (for which it is possible) to meet their own needs in case of regime violations, and the ability to manually and / or automatically synchronize power plants with the network, should be coordinated by the operator of the transmission system and / or distribution system of electricity in the electrical grids at the stages of issuing the TU and the connection of the SPP to the general purpose electric network.

SPP must issue power to the general-purpose network in a priority order. The intervention of dispatchers in power delivery from the SPP is only permitted if there is a real or predictable threat of reliability of the electricity grids. However, even in these caSPP, this tool can be used only when all other possibilities are exhausted.

The settings for the automatic control system of active power SPP are determined by the owner of the networks and the system operator in the technical conditions for the connection of power plants to the electrical grid.

In the case of a technical necessity, systems for automated control of the technological processes of the SPP, it is necessary to provide a function of the implementation of automatic change of settings of relay protection devices and emergency automatics at both ends of transmission lines departing from power plants, depending on the power of power plants.

The amount of information from the devices for the registration of emergency events must be agreed with the system operator during the commissioning of the power plant.

If necessary, the SPP must be equipped with appropriate high-speed reactive power compensation devices with filters of higher harmonics.

The SPP must be equipped with an automatic active power control system that would allow the power station to be remotely controlled by the Central Control Station and has a limitation of generating functions that are used to balance the grid in case of an emergency excess of active power (frequency increase), to avoid violations of conditions parallel operation of the neighboring countries' energy systems (ENTSO-E) or overload in a general purpose electrical network due to changes in the network topology under the accidents. To such functions limitation of generation of SPP include:

• absolute limitation of generation - limitation of active power of power plants to a predetermined capacity limit (setpoint) in the TPP for the protection of the general purpose network from overloads;

• delta generating limitation - reserve of active power of power plants, which is created for frequency regulation and set by setting in % of the possible generation of power plants;

• limiting the power gradient - limiting the maximum speed at which the active power may change in the event of a change:

• - wind speed for wind power plants;

• - intensity of solar radiation for SPP;

• - settings for power control of WES and SPP.

Limit of the power gradient is used for system-wide purposes to prevent the emergence of power-system unbalances that are hazardous to the grid.

The SPP must be equipped with reactive power control functions capable of regulating the reactive power of the power plant at the point of general connection, as well as voltage regulation functions capable of regulating the voltage at the point of general connection using the settings and gradients. The reactive power control and the voltage regulation function are mutually exclusive, which means that only one function can be active at a certain time.

The current parameter settings for reactive power and voltage regulation of SPP should be determined before they are put into operation by the operator of the distribution system or the system of transmission of electric energy in the general-purpose network to which the power plant is connected.

Voltage regulation in the TPP SPP should be in the range of given minimum and maximum voltage values, at the expense of generation modules of power plants or at the expense of additional compensating devices. The adequacy of the ability to regulate the reactive power of WEU and SPP in the TPP to the electrical network requires confirmation by simulation and / or experimentally.

SPP should be able to automatically regulate the voltage in the TPP to a general purpose electrical network. Since it is impossible to simultaneously control the voltage and cos φ, the deviation of both settings is weighed against each other, using a coefficient called "static coefficient", or simply "static". Voltage regulation taking into account "static" and "zone of insensitivity" when the station controller within the "zone of insensitivity" acts as a reactive power regulator with a setpoint for reactive power, and when the voltage on the monitored tires leaves the "zone of insensitivity", the station controller regulates the voltage according to the given "Staticism". If the voltage control function reaches the design limitations of the SPP (Qmax, Qmin and / or Umax, Umin), the control function should expect the operation of the regulation system under the voltage of the transformers or the actions of other voltage regulation functions. SPPs must be included in the U / Q regulation of the grid in the same way as traditional power plants. Coordination of voltage regulation is carried out by operators of distribution systems and transmission of electric energy in a general purpose network. At the same time, it should be taken into account that the meteorological factors affect the power generation of the SPP, taking into account that it is only appropriate to regulate the reactive power of power plants in the full range only when the output of active power exceeds 10% of rated power.

The SPP must be equipped with system protection, which represents the functions of automatic descending regulation of the active power of the power plant, which acts to reduce the power of power plants, using one or more of the settings defined by the system operator when the SPP is commissioned. It should be possible to set at least 5 different settings for the power plant.

Other protection settings for power plants can only be used if they are agreed with the respective CPR of the distribution or transmission system of the network to which they are connected. All settings are set to true. The power plant must be switched off or stopped if the measured values are beyond the limits of the permissible values. At the same time, the power failure time in the event of emergencies should be clearly defined by the security functions. Delay of shutdown time is not allowed.

CHAPTER 2

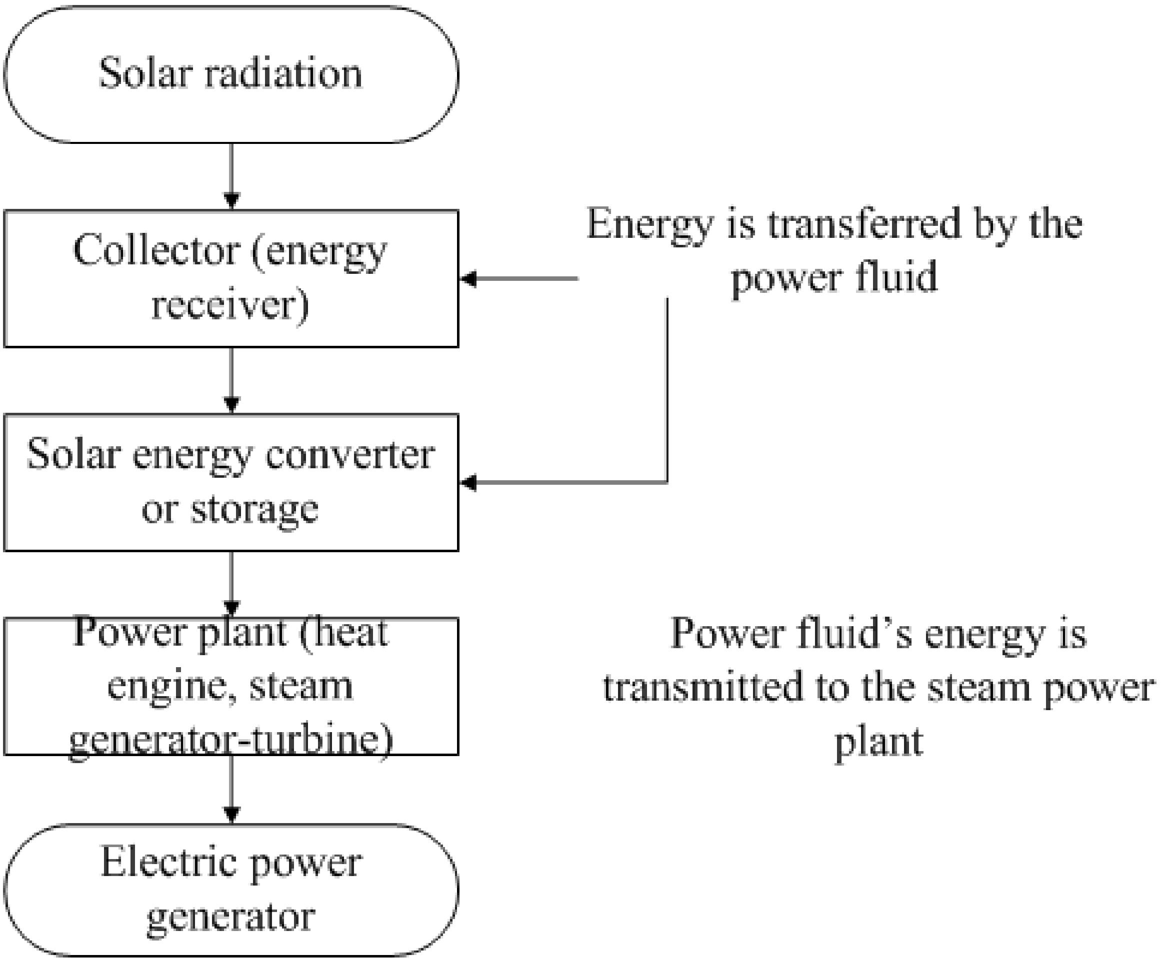
2. Review of existing technical solutions and analysis of the state of problems relating to automation of mirror control on SPP

2.1. An overview of existing solutions

Today, practically every person has the opportunity to assemble his own independent source of electricity based on clean energy sources - solar panels. Recently, the cost of photovoltaic panels has decreased tenfold, and this trend continues, which allows us to talk about the incredible prospects for the use of photovoltaic panels (photoelectric panels).

There are two main ways of converting solar energy into electrical: thermodynamic and photovoltaic.

In the thermodynamic method, electric energy can be obtained by using solar energy using traditional circuits in thermal electrical installations, in which the heat from combustion of fuel is replaced by the flow of concentrated solar radiation. The basic scheme of obtaining electric energy in a solar thermal power station:



The basic block diagram of the conversion of solar energy into electrical

here are solar power plants of these types:

• tower type;

• disc type;

• with parabolic capacitors;

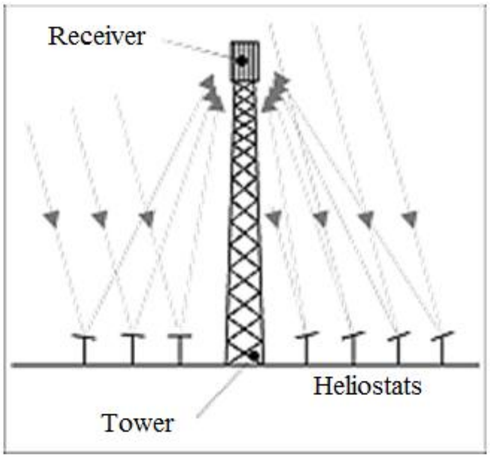
• based on photovoltaic modules and solar cells;

• balloon;

• solar-vacuum;

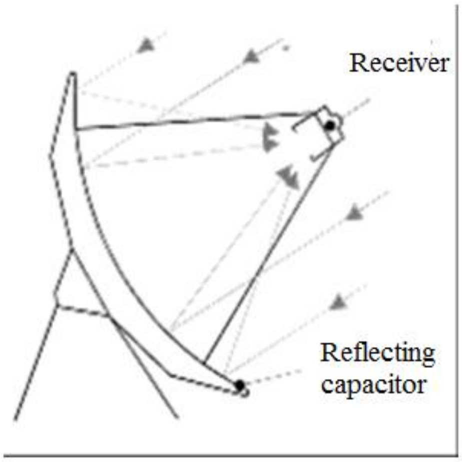
• combined.

The basis of the tower-type power plant is the principle of obtaining water vapor through the use of solar radiation. [2] In the center of the station stands a tower with a height of 18 to 24 meters (sometimes this characteristic can be more or less, depending on the power and some other parameters), at the top of which is a black water tank to absorb thermal radiation. In the tower itself there is a pump group, which delivers steam to a turbogenerator located outside the tower. In a circle from the tower at some distance there are heliostats - mirrors with an area of several square meters, mounted on supports and connected to a common positioning system. This provides a change in the orientation of the mirror in space, depending on the position of the sun. The main and most labor-intensive task is to position all the station mirrors so that at any time all the reflected rays from them fall on the reservoir. In clear sunny weather, the temperature in the tank can reach 700 degrees. Such temperature parameters are used at most traditional thermal power plants, so standard turbines are used to generate energy. In fact, at stations of this type it is possible to obtain a relatively high efficiency (about 20%) and high power. Water is not the only thing that can be heated by solar radiation in the tower. For example, in Spain, in 2011, a Gemasolar tower-type solar power plant was commissioned, in which a salt-based heat transfer fluid is heated. This solution allowed to keep warm even at night. Heated to 565 ° C salt enters a special tank, then transfers heat to the steam generator, which rotates the turbine. The entire system has a rated capacity of 19.9 MW and is capable of supplying 110 GWh of electrical energy (on average per year) to power a network of 27,500 households, working around the clock in full force for 9 months.



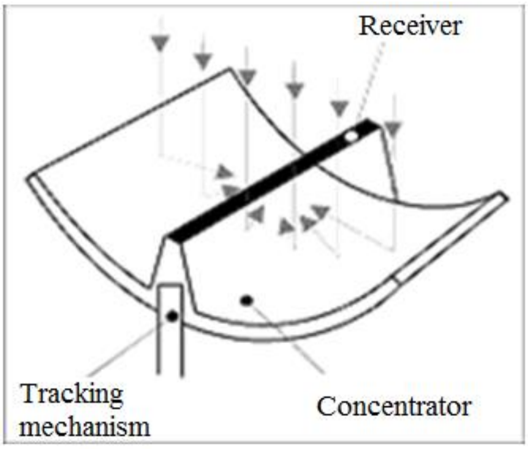
Pic. 2.1 Tower SPP

Power stations of the plate type are fundamentally similar to tower towers, however they differ structurally. They use separate modules, each of which generates electricity. The module includes a reflector and receiver. A parabolic assembly of mirrors forming a reflector is installed on the support. The receiver is located approximately in the concentration of reflected sunlight. [2] The reflector consists of mirrors in the shape of a plate (hence the name), radially located on the farm. The diameters of these mirrors reach 2 meters, and the number of mirrors - several dozen (depending on the module power). Such stations can consist of one module (autonomous) or several dozen (working in parallel with the network).



Pic 2.2 Plate type SPP

The principle of operation of SPP with parabolic capacitors is to heat the coolant to the parameters suitable for use in the turbogenerator. [1] Here the coolant is also heated by concentrated reflected radiation. The mirror has the shape of a parabolic cylinder up to 50 meters in length and is located in the north-south direction, rotates following the movement of the sun. In the focus of the mirror, a tube is fixed along which the heat transfer fluid moves. After the coolant has warmed up sufficiently, heat is transferred to the heat exchanger in water, where steam rotates the generator.

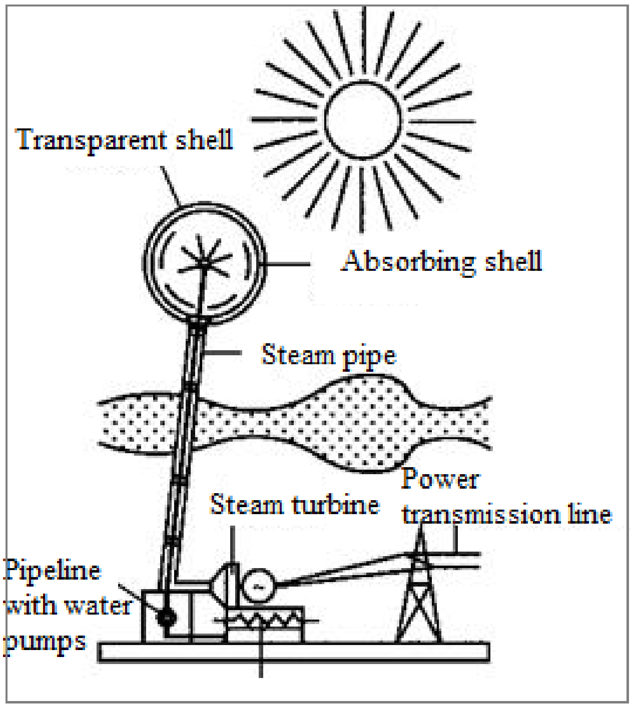


Pic 2.3 SPP With parabolic capacitors

Stations based on photovoltaic modules and solar cells are very popular and common in the modern world. Such SPP consist of a large number of individual modules (photo batteries) of different power and output parameters. The principle of operation of such stations is simple. The energy of photons of light is converted into current in a silicon wafer, the internal photoelectric effect in this semiconductor has long been studied and adopted by manufacturers of solar cells. But crystalline silicon, giving an efficiency of 24% is not the only option. The technology is continuously improving. So, back in 2013, Sharp engineers achieved an efficiency of 44.4% from an indium-gallium-arsenide element, and the use of focusing length SPP makes it possible to achieve all 46%. These SPP are widely used for energy supply of both small and large objects (private cottages, boarding house SPP, motels, industrial buildings, etc.). Photo batteries can be installed almost everywhere, from the roof and the facade of the building to the designated areas. Installed capacity also fluctuates in a wide range, ranging from the supply of individual pumps, ending with the power supply of a small village.

Pic 2.4 SPP based on photovoltaic modules and solar panels

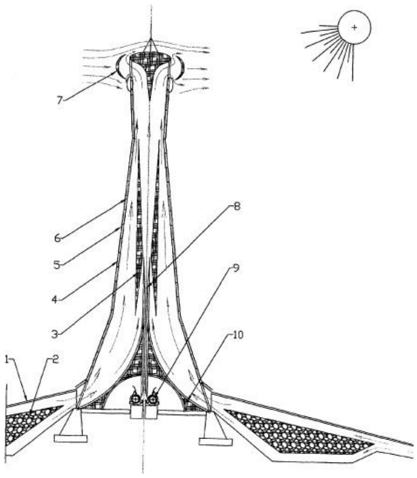
Balloon solar stations (SPP) are of 2 types: the first - solar cells are located on the surface of the balloon. In this case, the efficiency does not exceed the efficiency of solar cells and is about 15% (up to 40%). In the construction of the second type, a parabolic, concave gas pressure, metallized film is used as a reflector, which serves to concentrate solar energy. The cost per square meter is small in comparison with solar panels and any reflective surfaces. Located at an altitude of more than 20 km, the balloon is not afraid of shading under cloudy weather, and does not experience wind loads while moving with air currents. The upper part is made of a transparent film with a reinforcement, in the middle of a parabola of a film concentrator made of a reinforced metallized film, and at the focus is a thermal transducer cooled by a light gas, hydrogen, for a system with decomposition of water, or helium in case of a system of remote energy transfer — for example, radio or microwave radiation. The ball is oriented to the sun by pumping the ballast fluid (water for the hydrogen cycle), and the exact orientation is carried out by gyros. If necessary, there may be several floating spherical modules in one airship.



Pic 2.5 Balloon SPP

The solar-vacuum power station is made in the form of a greenhouse 1 and is filled with material 2, which accumulates solar energy, and the pipe is made in the form of a tower of venturi tubes placed one into another, each of which consists of two hollow truncated cones connected by smaller base SPP, and is installed vertically that the upper wide base of the inner tube 3 is placed with a gap in the narrow section of the outer 4, and the outer walls of the tower 4 are made in the form of glazed 5 "warm" boxes with a black heat-conducting surface 6 - for use solar energy, and in the upper part of the tower is equipped with a deflector

7 - to use wind energy, and at the bottom - a vacuum tube 8, in the form of a hollow truncated cone, the wide base of which is placed with a gap in a narrow section of the inner tube 3, and the smaller base is connected to one or more turbine generators 9, which are placed in the hall at the base of the power plant. To protect against noise, the power plant is equipped with known passive and active noise absorption systems 10 located near the noise source.

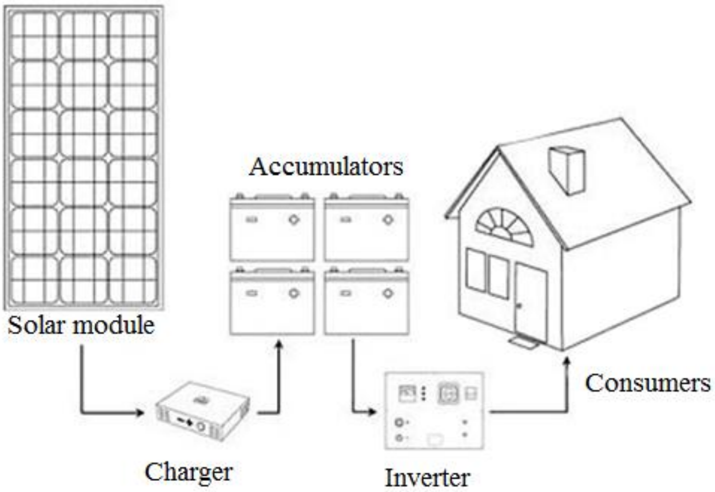


Pic 2.6 Solar-vacuum SPP

Constructed a greenhouse, which is covered with glass of land. From the center of the greenhouse stands a tower, a tall pipe in which a generator turbine is installed. The sun warms up the greenhouse, and the air rushing up through the pipe, rotates the turbine. Traction is kept constant while the sun warms the air in a volume covered with glass, and even at night, while the earth's surface retains heat. In 1982, 150 kilometers south of Madrid, in Spain, an experimental station of this type was built. The greenhouse had a diameter of 244 meters, and the pipe was 195 meters in height. The most developed power turned out only 50 kW. Despite this, the turbine worked for 8 years, until it failed due to rust and storm winds. In 2010, China completed the construction of a solar-vacuum station, which was able to produce 200 kW. It occupied an area of 277 hectares. [2]

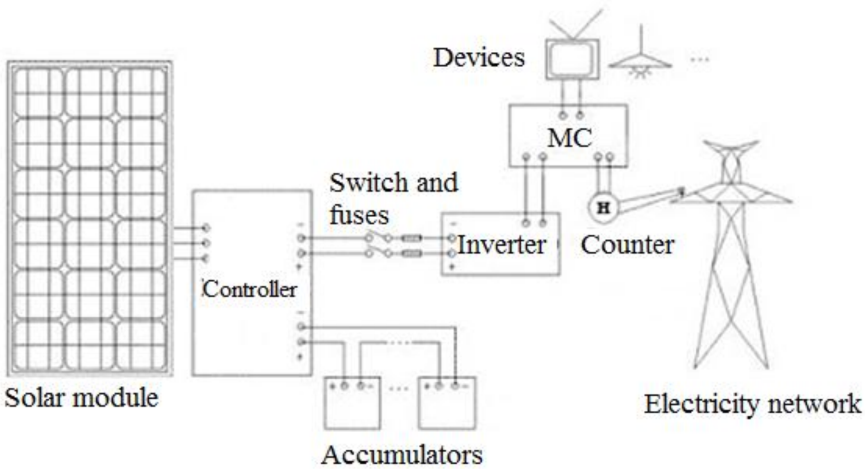
Combined SPP - these are the stations where heat exchangers are connected by communications of hot water supply, heating, in general, they heat water for various needs. Combined stations also belong to combined stations, when hubs operate parallel to solar batteries. Often combined solar power plants are the only solution for alternative power supply and heating of private house SPP. [7]

Below are a few popular schemes of solar power plants with the consumer. These are just some examples; therefore, other work patterns are possible. In each case, an individual project is compiled that is able to solve the task set before us.



Scheme 2.1

This scheme of operation of a solar power plant relates to an autonomous type of solar photovoltaic plants. The object is powered only by solar panels



Scheme 2.2

This scheme of operation of a solar power station refers to the type of solar photovoltaic plants connected to the network. AVR allows you to switch the power of the object in the absence of the sun and the batteries are completely discharged to the mains.

The same scheme can be used and vice versa - solar battery, as a backup power source. In this case, the AVR switches you to the batteries when power is lost from the mains.

2.2. Disadvantages of existing solutions

• high cost. Solar power plant is a pleasure not from budget, if we talk about one-time investment of funds. The benefits of this station will certainly be much greater, but again, in the long run. With the proper organization of such systems, taking into account all the basic costs, the acquisition of solar energy is cheaper than electricity from the network.

First of all, the high cost of SPP is due to expensive technology and materials, which consist of solar panels;

• variability. The amount of energy received directly depends on the intensity of the solar radiation, so, for example, in our latitudes, in the summer, SPP work much more efficiently than in the cold season. The same can be said about the cloudy days, and about the morning and evening time of the day. It is precisely because of this system without batteries that at the moment can not be used as the main sources of energy. All this is not such a big problem, but there may still be some difficulties;

• expensive energy storage systems. To maximize the use of electricity, we use accumulators that store their supplies and, say, smooth the scheduling of its supply. Thanks to the batteries, the system works more stable, but also have to spend on their purchase;

• SPP requires space. This may be the earth, the wall of a building, or a roof, but the place still needs to be allocated.

For the constant operation of the station, the system requires the use of storage batteries for storing electricity. Rechargeable batteries require regular replacement. The replacement period can range from 5 to 15 years (usually less than 10 years). The replacement cost is not the only drawback, there is still a cost of maintenance and time and effort spent when replacing AB. There is also some influence on the environment during the production, transportation and disposal of lead contained in accumulators;

• Low power density. The average power density is one of the important parameters of the power source. It is measured in W / m2, characterizing the amount of energy that can be obtained from unit area of energy. For solar radiation, this figure is 170 W / m2 - more than that of other self-renewable natural resources, but lower than that of oil, gas, coal and nuclear energy. Therefore, to generate 1 kW of electricity from solar heat, large areas of solar panels are required.

Due to the low power density, the energy generated by solar panels is problematic to use for devices and equipment that require high power.

For example, during heavy snowfall the solar station will not work. And although there are about 20 such days a year, the inclusion of energy-intensive equipment - an oven, a boiler and a dishwasher - will have to be abandoned. For such caSPP, you can buy a small generator (1-2 kW) - it is enough to charge the batteries.

Also in the area of your residence often hail falls, there are storms, this is certainly a serious problem, since solar photovoltaic cells are fairly easy to damage. In this case, the installation of a photovoltaic power generation system will require additional costs for its protection.

There are many advantages and disadvantages of SPP, but natural resources are not eternal and solar power stations can be a worthy replacement. Automating the operation of the elements of the station allows these to compensate for the shortcomings, which will make them a complete and attractive product.

3. Choice and justification of the technical solution

3.1 Choosing a workstation, setting the task

In the present, there is a problem of obtaining not only electric energy, but also thermal energy, which are used in various spheres of human activity. This is connected, as mentioned earlier, with the limited methods and resources for obtaining these types of energy, especially thermal energy.

Non-traditional renewable energy sources (NRES) allow to receive energy by controlling the natural process SPP occurring on the planet, as well as by recycling human waste. NIE include the planet’s subsurface, the sun, wind, small rivers, seas and oceans, combustible industrial wastes and households. The energy produced by large rivers has long been developed, and therefore belongs to a wider group of renewable energy sources (VEIs). Renewable energy sources are inexhaustible and capable of restoring energy potential for several decades. Today, the world potential of renewable energy sources amounts to about 20 billion tons of reference fuel (tfc), almost twice the amount of extracted mineral fuels.

Solar panels work best when they are directed towards the sun.

Therefore, usually solar panels are not at an optimal angle (90 degrees) throughout the day. [8]

One solution to this problem may be the use of a tower-type station, where, together with electricity, “thermal energy” is also “produced”. Which can then be used to heat water, which will heat residential houses SPP and other buildings for various purposes SPP.

SPP tower type surrounded by mirrors that reflect the light of the sun in the direction of the tower, which ensures the work of turbogenerators located in it to generate electricity. The main task of the optimal operation of such a station is to choose such a positioning of the mirrors, which will provide the maximum intensity and duration of the “lighting” of the tower for the most effective generation of both types of energy - electrical and thermal.

The solution to this problem can be the use of both solar panels and mirrors. Solar panels-batteries must be placed perpendicular to the Sun, and mirrors - at a certain angle to it and to the tower. Everything is located on a relatively flat plot of land around the tower, and the mirrors are installed on the inner and outer radius of the field, and between them are installations with solar panels. The principle of operation of such an installation is simple - the battery receives the maximum radiation of the Sun, accumulating and converting it into electricity, and the mirror reflects the rays received on it to the tower, where, besides electricity, thermal energy is also collected.

For better performance of the SPP, the battery is equipped with a sun tracking sensor, whose job is to continuously monitor the position of the star in the sky. The data received by the sensor is processed on the central computer of the entire SPP, the program of which sends a signal to the servomotor to change the tilt of the system if the angle of incidence of the light becomes different from ninety degrees. Mirrors, installed statically at a certain angle on the tower, reflect the radiation falling on them at the top of the tower, where the reservoir is located. In this case, it is necessary to calculate the possible angles of incidence and reflection of the rays, as well as the height of the tower, so that the heating of water or the electricity generating composition in the reservoir of the tower takes place continuously throughout the daylight hours.

The signal to rotate will be generated by a sun exposure sensor. The single-chip microcontroller will compare the readings of this sensor and give a signal to the drives, which will deflect the solar battery to the optimum angle. To feed the circuit at the initial moment is necessary from an autonomous source.

There is also a need to equip the sun tracking sensors as a solar battery. It makes sense to ensure the autonomous [5] operation of these sensors, because the use of two light sensors can not ensure the normal operation of the control system in cases SPP of at least short-term closure of the sun by clouds. In this situation, the illumination becomes more uniform than in the absence of cloudiness, and the control signals to rotate the solar panels may not be produced, with the result that when the Sun appears, time will be needed to ensure the rotation.

The solution of these problems can be the use of a microprocessor, which will perform the first processing of data from the solar panel, transmit them and ensure the correction of the system management program depending on the moment of time and new data on the position of the luminaries, the value of the voltage at the output of the photovoltaic panels is constantly changing due to factors such as weather conditions, time of day and temperature of the panels. In modern systems of vector control, inverters that have become used in frequency electric drives use the reduction of the three-phase system of inverter currents to the orthogonal d-q-coordinate system. In this case, the output voltage at the output of the inverter is accordingly set proportional to the longitudinal component of the current Id, and the output power is provided by the corresponding value of the transverse component of Iq. In the case of coordinating the operation of the multi-level inverter with the network for monitoring the point of the quasi-extremity of the volt-ampere characteristic (VAC) of the solar module, the longitudinal and transverse components of the current of the multi-level inverter will provide the voltage and power that will be removed from the solar module on the input side of the inverter and will be given out of the output side into the network.

The main task is to choose the best form of the mirror to reflect the sun's rays.

There are two main types of mirrors - flat and spherical, which, in turn, is divided into concave and convex. A flat mirror is a flat surface that mirrors the light; spherical mirror - a mirror, the reflecting surface of which has the form of a segment of a sphere.

The construction of images in mirrors is based on the laws of rectilinear propagation and reflection of light.

We construct an image of a point source S (Fig. 3.1, a). From the source of the light goes in all directions. A beam of SAB light falls on the mirror and the image is created by the whole beam. But to build an image, it is enough to take any two beams from this beam, for example, SO and SC. The SO beam falls perpendicular to the surface of the mirror AB (the angle of incidence is 0), so the reflected one will go in the opposite direction OS. The SC beam is reflected at an angle γ = α. The reflected rays of OS and SC diverge and do not intersect, but if they fall into the human eye, the person will see the image S1 which is the intersection point of the continuation of the reflected rays.

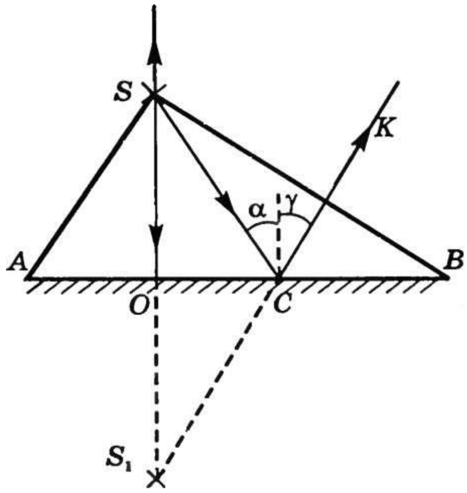


Fig 3.1 (a)

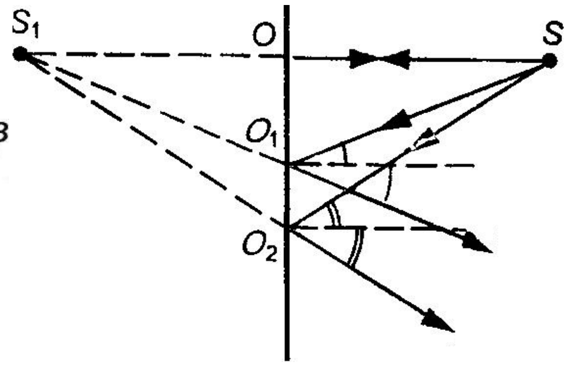


Fig 3.1 (b)

When using this type of mirror, the task of arranging them is such that the reflected light always falls on the tower reservoir. This will be possible only with an independent change in the position of the mirror relative to the tower and relative to the Sun. However, there is a difficulty in illuminating the tower at a time when the sun is close to the horizon, namely at the time of sunrise and sunset. At this time, the tower will remain unlit. Even at noon, the use of a flat mirror will not be as effective as possible.

On the field around the tower are flat mirrors. Their task is to reflect the sun's rays onto the surface of the tower reservoir, which contains a substance, the heating of which leads to the release of electricity. The task is to position these mirrors in such a way that they constantly reflect sunlight on the tank with gas / liquid.

The task of automation in this case is to control the positions of the mirrors relative to the tower and the sun at the same time. As a result of this control, the tower reservoir must be illuminated regardless of the position of the sun in the sky.

To solve the problem, we equip each of them with an engine that will change the angle of inclination relative to the horizon. The motors are connected to a common power supply system and a central server running the engine management program. Also, a microcontroller is connected to each of them to correct the program of work depending on different circumstances. In order to correct the operation of the engines and ensure maximum illumination of the tower with reflected light, it is proposed to install illumination sensors at its top, the data from which will be sent to the microcontrollers to correctly control the operation of the engines. For the same, each mirror is equipped with the same sensor measuring the illumination.

In order for the sun's rays to be accurately reflected on the tower, the perpendicular (φ) drawn from the center of the mirror must be located exactly in the middle between the incident rays of light (α1) and the reflected (α2). That is, the perpendicular is the arithmetic average between two angles: $\varphi = \frac{\alpha_1+\alpha_2}{2}$.

The initial data of the task for the calculation: the tower height is 180 m, the distance from the tower is from 100 to 200 m, the height of mirrors and panels above the ground is 2 m. Light reflected on the tank, which is located at the top of the tower, because we assume that it is at a maximum height of 180 m. The distance from the tank to the mirrors will be different, since the mirrors are at different distances from it.

Spherical mirrors are concave and convex. If a beam of rays falls on a concave spherical mirror parallel to the main optical axis, then after reflection from the mirror, the rays will intersect at a point called the main focus F of the mirror. The distance from the focus to the pole of the mirror is called the focal length and is denoted by the same letter F. For a concave spherical mirror, the main focus is real. It is located midway between the center and the pole of the mirror (Fig. 3.2, a).

The main focus of a convex mirror is imaginary. If a beam of rays parallel to the main optical axis falls on a convex mirror, then after reflection at the focus, it is not the rays that intersect themselves, but their continuations (Fig. 3.2. B).

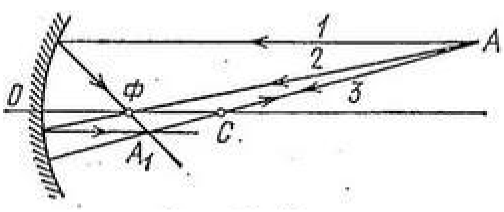


Fig 3.2A

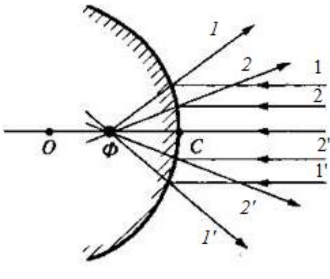


Fig 3.2B

a - reflection of light by a concave mirror. 1, 2, 3 are the rays of light, A is the source of light, A1 is its reflection, C is the spherical center of the mirror, f is the main focus of the mirror.

b - reflection of light by a curved mirror. 1, 2 - the rays of light, 1 ', 2' - the reflected rays of light, C - the spherical center of the mirror, f - the main focus of the mirror.

Obviously, the best choice of a spherical mirror is concave. It allows you to concentrate more of the reflected light in the plane of the main focus of the mirror, which is located in the same plane as the light source.

Formula of a concave spherical mirror

$\frac{1}{d} + \frac{1}{f} = \frac{1}{F}$, (1)

where d is the distance from the pole of the mirror to the light source; f is the distance from the pole of the mirror to the reflection of a point, object; F is the main focus of the mirror, the following special case is justified: when the object is at a very large distance from the mirror ($d \to \infty$) - the rays from the object are collected in the main focus of the mirror ($f = F$). [20]

Since the distance from the Sun to the Earth is in the hundreds of millions of kilometers, this particular case takes effect, which gives us reason to use concave mirrors to concentrate sunlight in the direction of the tower. However, it is worth taking into account the fact that $F = R / 2$ (2), where R is the radius of curvature of the mirror. Accordingly, the radius of curvature of the mirror will be equal to twice the distance from the pole of the mirror to the reflected point, which in our case is a tower.

For more efficient operation of the SPP, it makes sense to place mirrors on the field around the tower, which will ensure the “operation” of the electrolyte contained in the tower, and solar panels, which will produce and accumulate electricity from the light, both for powering the motor and the tracking sensors, and for supplying to the network. Mirrors are encouraged to use concave, the radius of curvature of which is calculated by the formula 1.

The distance can be calculated by the Pythagorean theorem, where the distances and height of the tower will be taken by the legs. Thus, the distance to the nearest mirrors will be ≈205.9 m, to the distant ones - ≈269 m. Thus, the radius of curvature of the mirrors will be: for the closes sets ones - ≈411.8 m, for distant ones - ≈538.1 m.

Despite the loss of light, which leads to a decrease in the efficiency of the SPP, the use of flat mirrors is preferable due to the fact that the manufacture of spherical mirrors is very complex and time consuming.

3.2. Selection of sensors for the automation system

As sensors for the current position of the apparatus, electron-optical sensors are usually used, using various celestial bodies as reference points: the Sun, the Moon, and stars. The visible or infrared spectrum is used, the second is more convenient, for example, for the Earth, since in the infrared region of the spectrum, the day and night sides are little different.

In addition to optical sensors, ion sensors, earth magnetic field sensors, and gyroscopic sensors can be used.

Since direct solar radiation is used in the selected type of power station, concentrating helios systems must have a solar observation system, with each of the heliostats individually oriented in space. [6]

It is necessary to equip the battery with a sun tracking sensor, which will increase its efficiency and allow you to get maximum radiation with minimal loss of light.

These sensors are based on photo sensors. A photo sensor is a semiconductor converter designed to measure the parameters of light radiation.

In this thesis project, it was decided to use the Sunshine Sensor BF3 sun sensor from DELTA-T-DEVICES Ltd:

Fig. 3.1. Sunshine Sensor Sunshine sensor BF3

The solar radiation sensor type F3 performs the following tasks:

• measurement of total and scattered radiation;

• measurement of the duration of solar lighting;

• without tedious adjustments and pole alignment;

• works at any geographic latitude;

• has no moving parts, shading rings or motorized tracking;

• for the output signal, energy units of measure (W × m – 2), PAR (mmol × m – 2 × s – 1) or lux can be selected.

A solar radiation sensor measures the total and diffuse radiation, as well as the duration of sunlight. It is easy to operate and does not require lengthy adjustments or adjustment of the poles.

It uses SPP a photodiode array with a unique shading pattern to measure incident solar radiation. The microprocessor calculates the components of the total and scattered radiation and determines the state of the solar radiation.

For full and for scattered radiation, two analog outputs are provided. The state of solar radiation is represented at the digital output (logic level or contact closure). The three outputs can be connected to the corresponding data logger channels, such as the Delta-T data logger of type DL2e or other data loggers commonly used for environmental monitoring.

Areas of use:

• control of solar radiation;

• control of the duration of solar lighting;

• monitoring of solar energy;

• heat balance and daylight control.

The BF3 sensor can be used as an additional sensor in conventional [...] stations. A meteorological station recorder is used to record the total and scattered radiation and the state of solar radiation (or duration), using three additional channels.

The power for the sensor comes from the internal alkaline batteries or from the battery of the recorder [...] station. Generally used are data on total and diffuse radiation, as well as the duration of solar radiation in hours per day. The magnitude of the direct radiation is calculated by subtracting the scattered radiation from the total. Energy, PAR, or luminance can be selected as output units.

The photodiode array and the computer-controlled shading system are arranged in such a way that at least one LED is illuminated by sunlight and at least one is shaded, regardless of the position of the sun in the sky. All photodiodes get the same amount of diffused sunlight.

The internal microprocessor scans the readings of the diodes to determine the values of the total and scattered radiation. From these readings, the microprocessor calculates these values. The result is cosine-corrected solar radiation values. The state of solar radiation is calculated by an empirical algorithm.

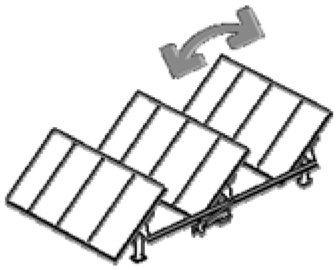
Table 3.1. Characteristics of the solar radiation sensor Sunshine sensor BF3 sensor BF3

Sunshine hours Accuracy	±10% compared to the WMO definition
Cosine correction Accuracy	±10% of incoming radiation over 0-90° Zenith angle
Azimuth angle Accuracy	±5% over 360° rotation
Temperature coefficient	±0.15% /°C typical (without thermostat)
Temperature range	-20 to +50°C with Alkaline batteries -20 to +70°C with Lithium batteries
Stability	Recalibration recommended every 2 years
Response time	<200 ms
Spectral response	400-700 nm
Latitude capability	-90° to +90°
Environmental: Sealing	IP65 (shower and dust proof)

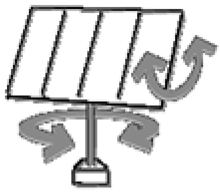
Sunshine status: contact closure (CMOS switch) mode	No sun = open circuit Sun = short circuit to ground
Sunshine status: logic state voltage (TTL) mode	No sun = 0 V Sun = 3.3 V (10K output Impedance)
Internal battery	4×1.5 V AA Alkaline batteries
Power requirement	6.5 mA (awake), <30 μA (asleep)
Battery lifetime	1 year typical
Input voltage range – powered from internal battery	3.6 to 15 V DC
Input voltage range – external power	5 to 15 V DC
Logger power supply fuse	100 mA, 24 V (self resseting)
Fuse trip point, on sunshine status signal, (when in switch-closure mode)	1 A, 24 V (not self resseting)
Max applied voltage, on sunshine status signal (when in switch-closure mode)	0 to 24 V
RS232 connector	DB9 panel mounted plug
Signal output and power-in connector	5 pin mini Triad01 panel mounted plug
Mounting options	1/4 inch whitworth camera triod socket Holes for 4×M4 bolts as corners of box
Size and weight	20 mm × 122 mm × 95 mm, 556 g

3.3. Choice of control system (controller)

There are two main types of rotary mechanisms for solar modules: single-axis and two-axis . Single-axis implements the rotation of the solar module around a single central axis, which is quite convenient for large-scale power plants. The biaxial allows you to more flexibly track the position of the sun, controlling both the azimuth and the declination of the sun above the horizon. Both types shown at Pic 3.1 (A,B)



Pick 3.1(A)



Pick 3.1(B)

The control of such mechanisms is carried out with the help of the controller.

The orientation is carried out according to the commands of the local controller [3] depending on the position of the Sun relative to the axes [3] and the position signals of the SB panels formed in the orientation system. In the process of orientation, the orientation system of the solar panels provides transit transmission of electricity generated by the SS, and transit transmission of signals from devices installed on the SS panels. [7]

The basic requirements that apply to the control units of the devices (in this case, the controller) can be formulated as:

•low cost;

• high reliability;

• high degree of miniaturization;

• low power consumption;

• performance in harsh environments;

• sufficient performance to perform all required functions.

Unlike universal computers, controllers, as a rule, do not have high requirements for performance and software compatibility.

We will use an Arduino microcontroller to control the rotation process of the stepper motor, the operation of the sensors and the determination of the highest power point. [...] This line of microcontrollers has gained great fame in the world, thanks to the simplicity of its interface, hardware and software, as well as data processing speed, a set of I / O ports and almost all the features.

Arduino Ethernet POE controller is built on ATmega328 (technical description, pdf). The platform has 14 digital inputs / outputs (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connector, a power connector, an ICSP connector and a reset button. To work, you need to connect the platform to your computer using a USB cable, ethernet-connection , or supply power using an AC / DC adapter or battery.

Unlike all previous boards that used an FTDI USB microcontroller for USB communication, the new Arduino Ethernet with POE uses the ATmega8U2 microcontroller.

Pick 3.2 Arduino Ethernet with POE

Arduino Ethernet with POE can get power via USB, Internal Power Supply or Ethernet (using POE)

Ethernet is the traditional technology for connecting wired local area networks (LANs), enabling devices to communicate with each other via a protocol -- a set of rules or common network language.

As a data-link layer protocol in the TCP/IP stack, Ethernet describes how network devices can format and transmit data packets so other devices on the same local or campus area network segment can recognize, receive and process them. An Ethernet cable is the physical, encased wiring over which the data travels.

Any device accessing a geographically localized network using a cable -- i.e., with a wired rather than wireless connection -- likely uSPP Ethernet -- whether in a home, school or office setting. From businesSPP to gamers, diverse end users depend on the benefits of Ethernet connectivity, including reliability and security.

Compared to wireless LAN technology, Ethernet is typically less vulnerable to disruptions -- whether from radio wave interference, physical barriers or bandwidth hogs. It can also offer a greater degree of network security and control than wireless technology, as devices must connect using physical cabling -- making it difficult for outsiders to access network data or hijack bandwidth for unsanctioned devices.

How Ethernet works

The Institute of Electrical and Electronics Engineers Inc. (IEEE) specifies in the family of standards called IEEE 802.3 that the Ethernet protocol touches both Layer 1 -- the physical layer -- and Layer 2 -- the data link layer -- on the OSI network protocol model. Ethernet defines two units of transmission: packet and frame. The frame includes not just the payload of data being transmitted, but also:

- the physical media access control (MAC) addresSPP of both the sender and receiver;
- VLAN tagging and quality of service information; and
- error correction information to detect transmission problems.

Each frame is wrapped in a packet that contains several bytes of information to establish the connection and mark where the frame starts.

Engineers at Xerox first developed Ethernet in the 1970s. Ethernet initially ran over coaxial cables, while a typical Ethernet LAN today uSPP special grades of twisted pair cables or fiber optic cabling. Early Ethernet connected multiple devices into network segments through hubs -- Layer 1 devices responsible for transporting network data -- using either a daisy chain or star topology.

If two devices that share a hub try to transmit data at the same time, however, the packets can collide and create connectivity problems. To alleviate these digital traffic jams, the IEEE developed the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol, which allows devices to check whether a given line is in use before initiating new transmissions.

Later, Ethernet hubs largely gave way to network switches, their more sophisticated and modern counterparts. Because a hub cannot discriminate between points on a network segment, it can't send data directly from point A to point B. Instead, whenever a network device sends a transmission via an input port, the hub copies the data and distributes it to all the available output ports.

In contrast, a switch intelligently sends any given port only the traffic intended for its devices rather than copies of any and all the transmissions on the network segment -- improving security and efficiency.

The IEEE 802.3 working group approved the first Ethernet standard in 1983. Since then, the technology has continued to evolve and embrace new media, higher transmission speeds and changes in frame content -- e.g., 802.3ac to accommodate VLAN and priority tagging -- and functional requirements -- e.g., 802.3af to define Power over Ethernet (POE), which is crucial to most Wi-Fi and IP telephony deployments. Wi-Fi standards -- IEEE 802.11a, b, g, n, ac and ax -- define the equivalent of Ethernet for Wireless LANs.

Ethernet standard IEEE 802.3u ushered in 100BASE-T -- also known as Fast Ethernet -- with data transmission speeds of up to 100 megabits per second (Mbps). The term BASE-Tindicates the use of twisted-pair cabling.

Gigabit Ethernet boasts speeds of 1,000 Mbps -- 1 gigabit or 1 billion bits per second -- 10-Gigabit Ethernet (GbE), up to 10 Gbps, and so on. Network engineers use 100BASE-T largely to connect end-user computers, printers and other devices; to manage servers and storage; and to achieve higher speeds for network backbone segments. Over time, the typical speed of each connection tends to increase.

Ethernet cables connect network devices to the appropriate routers or modems, with different cables working with different standards and speeds. The Category 5 (CAT5) cable supports traditional and 100BASE-T Ethernet, for example, while Category 5e (CAT5e) can handle Gigabit Ethernet and Category 6 (CAT6) works with 10 GbE

Power over Ethernet (PoE) is a technology for wired Ethernet local area networks (LANs) that allows the electrical current necessary for the operation of each device to be carried by the data cables rather than by power cords. Doing so minimizes the number of wires that must be strung in order to install the network. PoE was originally developed in 2003 to support devices like Wi-Fi access points (APs). PoE made AP installations easier and more flexible, especially on ceilings.

For PoE to work, the electrical current must go into the data cable at the power-supply end, and come out at the device end, in such a way that the current is kept separate from the data signal so that neither interferes with the other. The current enters the cable by means of a component called an injector. If the device at the other end of the cable is PoE compatible, then that device will function properly without modification. If the device is not PoE compatible, then a component called a picker (or tap) must be installed to remove the current from the cable. This "picked-off" current is routed to the power jack.

Equipment built to the 2003 standard initially delivered enough power for most APs, but could not provide enough power for other types of mounted technology, such as video surveillance cameras. Over the years, the Institute of Electrical and Electronics Engineers (IEEE) and several vendors have attempted to address the power issue, but there have always been problems with interoperability. The IEEE will be solving the problem by releasing a new standard that supplies power through all four wire pairs in a Cat5 cable.

IEEE 802.3bt, also known as Next Generation PoE, can supply enough power to support LED lighting, kiosks, terminals and a variety of other devices, including security-card readers. It also defines a way to supply two different power levels simultaneously. Now that an industry standard is finally in place once again, it's expected that PoE usage will continue to grow and play an important role in the Internet of Things (IoT).

The platform can operate with an external power supply from 6 V to 20 V. When the supply voltage is lower than 7 V, the 5V output can produce less than 5 V, while the platform may operate unstable. When using voltages higher than 12 V, the voltage regulator may overheat and damage the board. The recommended range is from 7 V to 12 V.

Each of the 14 Uno digital pins can be configured as an input or output using the pinMode (), digitalWrite (), and digitalRead () functions,. The pins operate at a voltage of 5 V. Each pin has a load resistor (disabled by default) 20-50 kΩ and can pass up to 40 mA. [...] On the Uno platform, there are 6 analog inputs (labeled A0 .. A5), each with a resolution of 10 bits (i.e. it can take 1024 different values). Standardly, the outputs have a measurement range up to 5 V relative to the ground, however, it is possible to change the upper limit by means of the AREF output and the analogReference () function.

Uno restarts every time you connect to the Arduino program on a computer running Mac X or Linux (via USB). The next half second after rebooting the boot loader works. During programming, the first few bytes of code are delayed in order to prevent the platform from receiving incorrect data (all but the code of the new program). If you make a one-time debugging of the sketch recorded on the platform, or enter any other data when you first start, you need to make sure that the program on the computer waits for a second before transferring the data.

On Uno, it is possible to disable the automatic restart line by breaking the corresponding line. Microcircuit contacts at both ends of the line can be connected for the purpose of recovery. The line is labeled "RESET-EN". It is also possible to disable automatic restarting by connecting a 110 Ohm resistor between the 5 V source and this line.

The length and width of the Uno printed circuit board are 6.9 and 5.3 cm respectively. USB connector and power connector are beyond the limits of these sizes. Four holes in the board allow you to fix it on the surface. The distance between digital pins 7 and 8 is 0.4 cm, although between other pins it is 0.25 cm.

3.4. Choosing a network switch, system engine

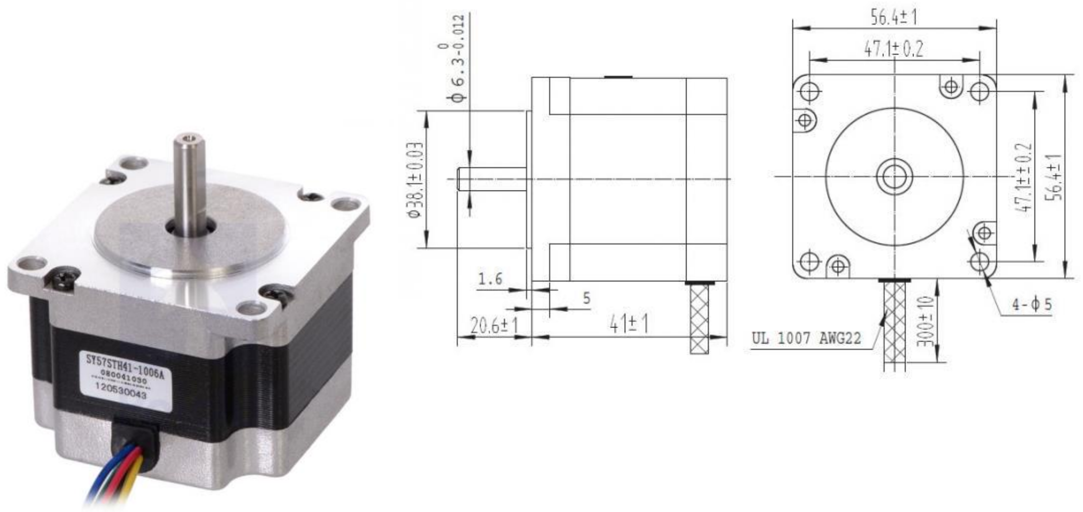
Used in the described system, microcontrollers can be considered computers due to their functionality and construction properties, the whole system - a network that connects a large number of local computers with the main, acting as the control and distribution server. Such systems are equipped with various sensors, components for operation, valves and controllers. For a proper functioning, a system is required for a variety of technical aspects. Therefore, it is necessary to use network switches in the SPP software system described.

Switchboards provide the interaction of computers on the network. Unlike the hubs that send data across the network on all connected computers, the commutators can determine the destination, so they transmit data only to the computers they are assigned to.

The choice of engine will largely depend on the owner of the SPP and his wishes.

However, to solve both versions of the task, changing the orientation of the panel and the mirror relative to the horizon, it is preferable to use a stepping motor. This is due to the fact that the engine of this type makes the movement of the installation or its parts with fixation in a given position, the movement itself can be of two types - angular or linear. Such an engine is synchronous. The main advantage of this type of drive is accuracy.

It is proposed to use a stepper motor standardized by the National Association of Electrical Equipment Manufacturers (NEMA) in terms of landing size and flange size. NEMA 23: flange size 57 mm. NEMA 23 stepper motors can generate torque up to 30 kg * cm. [15]



Pick 3.3 Two-shaft stepper motor **NEMA-23 SY57STH41-2804MB**

Technical Characteristics of two-shaft stepper motor NEMA-23 SY57STH41-2804MB

Model	NEMA-23 SY57STH41-2804MB
Rated voltage, V	2.5
Current / phase, A	2.8
Resistance / phase, Ω	0.9
Inductance / phase, mH	4.5
Holding torque, kg·cm	12.6
Leads #	4
Rotor inertia, g·cm^2	300
Weight, kg	0.7
Detent torque, kg·cm	0.4
Operating curve	h
Length, mm	56

Technical Specifications of two-shaft stepper motor NEMA-23 SY57STH41-2804MB

Item	Specification
Step angle	0.9°
Step angle accuracy	±5% (full step, no load)
Resistance accuracy	±10%
Inductance accuracy	±20%
Temperature rise	80°C max. (rated current, phase on)
Ambient temperature	-20°C~+50°C
Insulation resistance	100M Ω min., 500 V DC
Dielectric strength	500 VAC for one minute
Shaft radial play	0.02 max (450 g-load)
Shaft axial play	0.08 max. (450 g-load)
Max. radial force	75 N (20 mm for the flang)
Max. axial force	15 N
Rotation	CW (see from the front flange)

3.6 Choosing Server configuration and operation system

In this diploma work, we need server to improve reservation. We also can to control a huge quantity of mirrors with server. It will get data from our microcontroller and get data from online Sun calculator via API. Server can also determine sun position by itself with formula that was described in…

Server can also get information about the weather, season and control mirrors to get the highest efficiency

I decided to choose Debian 9 Server+ LAMP stack because of these advantages

It is maintained by its users.

If something needs to be fixed or improved, we just do it.

Unparalleled support

Mail sent to the mailing lists often gets answers within 15 minutes (or less), for free, and by the people who developed it. Compare that to typical phone support: hours spent on the phone, for money, only to get someone who doesn't know the system well enough to even understand your question.

You wouldn't be alone in your choice

A wide range of organizations and individuals use Debian. See our Who's Using Debian? page for a description of some high-profile sites which use Debian, and have chosen to submit a short description of how they use Debian and why.

The best packaging system in the world.

Tired of old files from software three versions old cluttering your system? Or installing a piece of software only to find it cauSPP your system to crash because of software conflicts? Dpkg, Debian's endured packaging system, takes care of these issues for you.

Easy installation

If you have heard that Debian is difficult to install, then you haven't tried Debian lately. We are constantly improving the installation process. You can do the installation directly from CD, DVD, Blu-ray, USB stick or even over the network.

Incredible amounts of software

Debian comes with over 51000 different pieces of software. Every bit of it is free. If you have proprietary software that runs under GNU/Linux or GNU/kFreeBSD, you can still use it - in fact, there may even be an installer in Debian that will automatically install and set up everything for you.

Packages well integrated

Debian surpasses all other distributions in how well its packages are integrated. Since all software is packaged by a coherent group, not only can all packages be found at a single site, but you can be assured that we have already worked out all issues regarding complicated dependencies. While we feel that the deb format has some advantages over the rpm format, it is the integration between the packages that makes a Debian system more robust.

Source code

If you are a software developer, you will appreciate the fact that there are hundreds of development tools and languages, plus millions of lines of source code in the base system. All of the software in the main distribution meets the criteria of the Debian Free Software Guidelines (DFSG). This means that you can freely use this code to study from, or to incorporate into new free software projects. There are also plenty of tools and code suitable for use in proprietary projects.

Easy upgrades

Due to our packaging system, upgrading to a new version of Debian is a snap. Just run apt-get update ; apt-get dist-upgrade (or aptitude update; aptitude dist-upgrade in newer releases SPP) and you can upgrade from a CD in a matter of minutes or point apt at one of the over 300 Debian mirrors and upgrade over the net.

Multiple architectures and kernels

Currently Debian supports an impressive number of CPU architectures: alpha, amd64, armel, hppa, i386, ia64, mips, mipsel, powerpc, s390, and sparc. It also runs on GNU Hurd and FreeBSD kernels besides Linux, and with the debootstrap utility you will be hard-pressed to find a device that can't run Debian.

Bug tracking system

Debian's bug tracking system is publicly available. We don't try to hide the fact that software doesn't always work the way users want. Users are encouraged to submit bug reports and are notified when and why the bug was closed. This system allows Debian to respond to problems quickly and honestly.

If you are not already a Debian user, you may also enjoy the following benefits:

Stability

There are many cases of machines that run for over a year without rebooting. Even then, they are only rebooted due to a power failure or a hardware upgrade. Compare that to other systems that crash multiple times a day.

Fast and easy on memory

Other operating systems may be as fast in one or two areas, but being based on GNU/Linux or GNU/kFreeBSD, Debian is lean and mean. Windows software run from GNU/Linux using an emulator sometimes runs faster than when run in the native environment.

Drivers for most hardware is written by GNU/Linux / GNU/kFreeBSD users, not the manufacturer.

While this can mean delays before new hardware is supported and no support for some hardware, it enables support for hardware long after the manufacturer has stopped producing it or gone out of business. Experience has shown that Open Source drivers are usually much better than proprietary ones.

Good system security

Debian and the free software community are very responsive to make sure that fixes of security problems get into the distribution quickly. Usually, fixed packages are uploaded within a few days. The availability of source code allows the security in Debian to be evaluated in an open setting which prevents poor security models from being implemented. Also, most free software projects have peer-review systems, which prevents potential security problems from being introduced in essential systems in the first place.

Security software

Unknown to many, anything sent over the net can be read by any machine between you and the receiver. Debian has packages of the famous GPG (and PGP) software which allows mail to be sent privately between users. In addition, ssh allows you to create secure connections to other machines which have ssh installed.

Of course, Debian is not perfect. There are three areas that are common causes of complaints:

Lack of popular commercial software.

It is quite true that some popular software is not available for Debian. There are, however, replacement programs for most of those, designed to mimic the best features of the proprietary programs, with the added value of being free software.
Lack of office programs such as Word or Excel should no longer be a problem, because Debian includes three office suites composed entirely of free software, LibreOffice, Calligra, and GNOME office applications.

Various proprietary office suites are also available: Applixware (Anyware), Hancom Office and others.

For those interested in databases, Debian ships with two popular database programs: MySQL and PostgreSQL. SAP DB, Informix, IBM DB2 and others are also available for GNU/Linux.

Various other proprietary software is coming out in greater numbers, too, as more companies discover the power of GNU/Linux / GNU/kFreeBSD and its largely untapped market with a rapidly growing user base (since GNU/Linux and GNU/kFreeBSD are freely distributable, sales figures can't be used for user estimates. Best estimates are that GNU/Linux has 5% of the market, giving 15 million users as of early 2001).

Debian is hard to configure.

Note that this says configure, not install, as some people find the initial installation of Debian easier than Windows. A lot of hardware (printers for example) could be made easier to set up, though. Also, some software could have a script that would walk the user through the configuration (at least for the most common setups). This is an area that is being worked on.

Not all hardware is supported

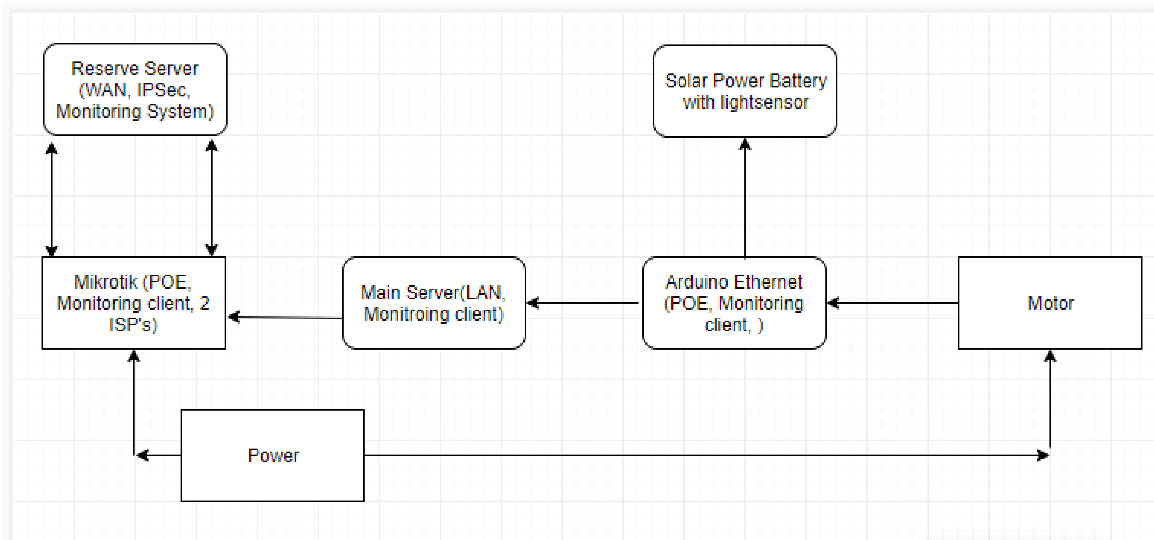
Particularly, really new, really old, or really rare hardware. Also hardware that is dependent on complex driver software that the manufacturer only supplies for Windows platforms (software modems or some laptop wifi devices for example). However, in most causes, equivalent hardware is available that does work with Debian. Some hardware is not supported because the vendor chooses not to make the hardware specifications available. This is also an area that is being worked on.

CHAPTER 4

4. Development of the structural scheme

Naturally, for the correct operation of the SPP it is necessary to connect all its elements. This can be accomplished by developing or selecting the most efficient station scheme in which communications and the location of all SPP elements relative to each other will be “shown”.

The main condition for the development of high-performance autonomous photovoltaic power plants (AFEU) is the implementation of the automatic tracking of solar cells behind the sun. When aiming solar panels on the Sun, it is necessary to minimize the energy consumption of electric drives. This is realized by continuous-discrete movement, which is carried out by stepper electric drives operating in the tracking-positional mode.



Scheme 4.1 Structural scheme

In fig. 4.1 shows a functional diagram of a photovoltaic power plant, where SAT is a solar battery; AB1, AB2 - rechargeable batteries; KZAB - AB charge controller; And - the inverter; M1, M2 - stepper motors; P1, P2 - reducers; DShD1, DShD2 - stepper motors control drivers; DPS1, DPS2 - sun position sensors; KNS - controller pointing to the sun; КВ1 – КВ4 - limit switches, GPRS module; The CONVERTER is a communication center with an external computer via RS 485. The Sun pointing controller consists of a STM32-F103 microcontroller, a DC-DC converter, five operational amplifiers, a communication node with a manual guidance unit, a communication node with limit switches, and an external computer communication center. The software of the pointing controller on the Sun allows working in the following modes: automatic pointing to the Sun, manual pointing from the control panel, pointing mode from an external computer with changing the settings of the pointing mode, control via GPRS.

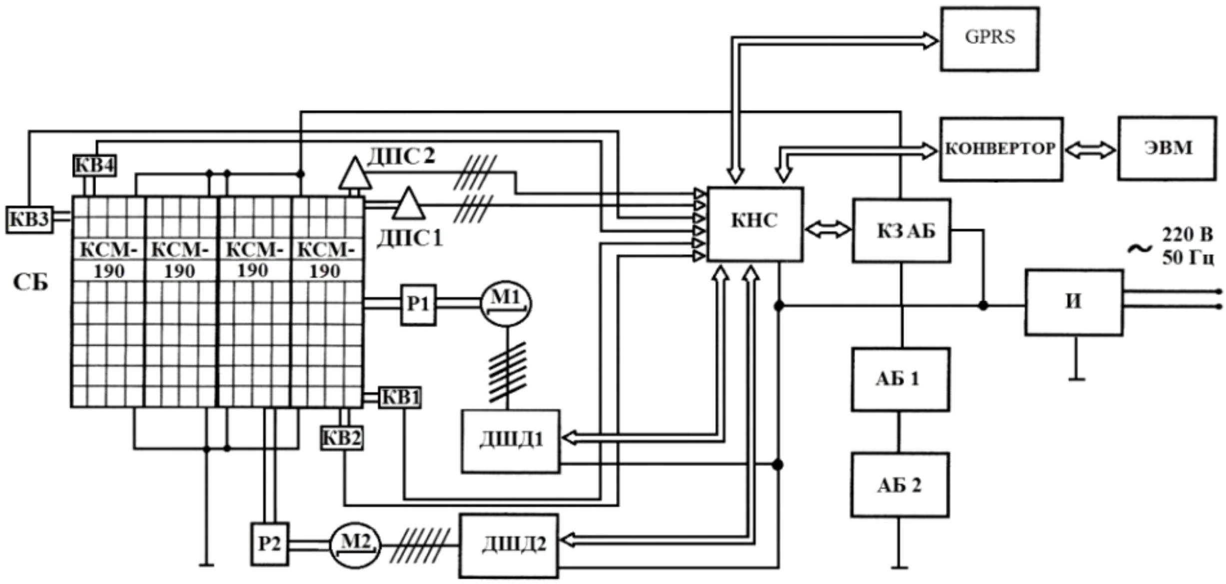


Fig 4.1 Functional diagram of a photovoltaic power plant

The use of GPRS modules is not always justified in terms of efficiency; moreover, it increases the cost of installation and complicates the software solution for controlling the station. Therefore, it is possible to do without them when designing and developing a system for tracking the Sun.

In fig. 4.2 shows a functional diagram of a photovoltaic power plant, where SAT is a solar battery; AB1, AB2 - rechargeable batteries; KZAB - AB charge controller; And - the inverter; M1, M2 - stepper motors; P1, P2 - reducers; DShD1, DShD2 - stepper motors control drivers; BSPS - block sensors of the position of the Sun; KNS - controller pointing to the sun; BKVX, BKVY - blocks of limit switches.

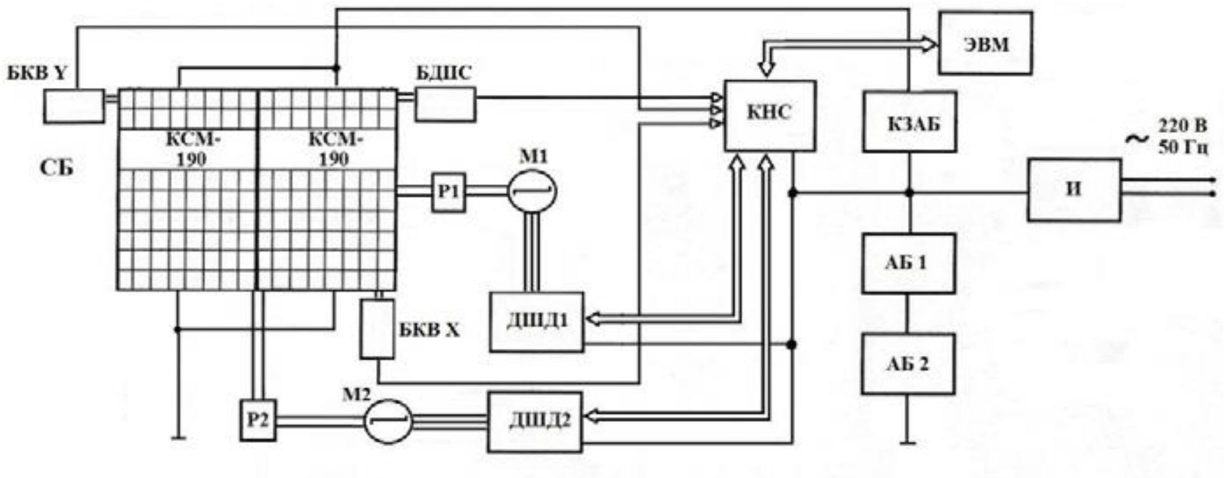


Fig. 4.2 Functional diagram of a photovoltaic power plant, SAT is a solar battery

The solar pointing controller consists of a microcontroller, a constant voltage converter, five operational amplifiers, and a microcircuit that provides communication with an external computer through a converter. The microcontroller provides the following signals to the input of a stepper motor driver: the direction of rotation of the stepper motors in azimuth (signal DR1) and in elevation (signal DR2), the number of pulses that need to be worked out by drivers (stepper motors) in azimuth (signal UP1) and in elevation (U2 signal, driver azimuth (MF1) and elevation angle (MF2) turn on signals, stepper motor current amplitude reference signals (SD) for azimuth and elevation. The controller pointing to the Sun receives signals from two blocks of the limit switches: X1, Y1 and X2, Y2 - the initial and final frame positions in the X coordinate (azimuth) and Y (in elevation) and driver readiness signals (RYD1 and RYD2).

Frame guidance on the sun is carried out using stepper drives. The need to move the frame is estimated using a photoelectric sun position sensor. If the right and left photocell sensors produce the same current, then moving the frame with SS is not required, and if there is a difference, then it is necessary to move in such a direction in order to compensate for this difference in current. If the three photocells of the sensor show the same current, then the photo sensor (and, accordingly, SB) is in the shade, and the movement of the frame is not required. If the rear photocell produces the highest current, then the Sun shines from the back of the frame, and the frame must be turned in the direction of the Sun. [18]

Driver DPR1 (DPR2) generates sine signals (U1) and cosine (U2) angle of rotation, which are fed to the controller of the electric drive. The calculation of the speed of rotation of the engine is carried out programmatically, using sine and cosine signals of the angle of rotation. In the controller of the electric drive control, the sine (U1) and cosine (U2) angle signals are multiplied by the output of the speed controller (Upc) and the received signals are fed to the transistor converter inputs TP1.1 and TP1.2. The transistor converter consists of two single-phase inverters with symmetrical PWM modulation with field-effect transistors and drivers and contains a control microcontroller. The microcontroller provides testing of a given sine wave and cosine control signals with high accuracy. The switching frequency of transistors up to 20 kHz. The current limit in the transistor converter is made at the level of six times the rated motor current. Current protection with off transistor converter is at the level of eight times the rated motor current.

The electric drive with the DBM 120 valve motor, with the transistor converter and the electric drive control controller is closed through the DPR. The current loop with the electromechanical part under a certain assumption can be represented as a link of the second order with variable time constants. It is advisable to optimize the speed control loop of the electric speed controller to perform as a PI controller that compensates for the electromechanical time constant. The transfer function of the speed controller in this case is as follows:

$$W_{pc} = \frac{T_M p + 1}{T_M p} K_k,$$

where Kk is the coefficient of transmission of the regulator; TM - Electromechanical time constant of the engine; p is the Laplace operator.

The transmission coefficient Kk in the speed controller is determined by the expression:

$$K_k = \frac{T_M}{K_m T_u K_{vs} K_{tr}},$$

where Km is the transmission coefficient of the engine; Tu is the equivalent uncompensated time constant; Kvc is the transmission coefficient of the speed sensor; Ktr is the transmission coefficient of the converter.

Equivalent uncompensated time constant in the drive is determined by the expression:

$T_u = T_e + T_f + T_ш$,

where Tf is the time constant of the filters in the forward channel; Ts is the time constant equal to the PWM period; Te is the electromagnetic time constant of the phase of the valve engine.

In the electric drive, there is no exact compensation of the electromechanical time constant of the engine, and also in the mechanical guidance system of the solar power station the moment of inertia of the movement mechanism itself changes due to the spatial change (in azimuth and elevation) of the frame position in the photovoltaic power station itself. To stabilize the dynamic characteristics of the electric drive, an adaptive control loop with a reference model and signal self-tuning is introduced. The reference model of the electric drive system is presented as a link of the second order. The time constants of the reference model determine the specified frequency band in the rotational speed control loop and the overshoot of the rotational speed when the engine starts to a maximum speed of no more than 10%. Self-tuning in the electric drive system is carried out by introducing an error signal (the error between the output signal of the reference model and the speed sensor signal –Δω), its first derivative to the input of the electric speed controller. The second derivative is not introduced, since it is an order of magnitude smaller than the first derivative.

The transmission coefficients by error and its derivative are optimized based on the system stability with large input signals (in large), as well as the quality of transients in the drive.

The gains of the first and second amplifiers are optimized based on the quality of transients in the electric drive and the avoidance of large overcompensation in speed, expressed in an increase in overshoot and oscillation in the transient.

Chapter 5

Development of algorithm

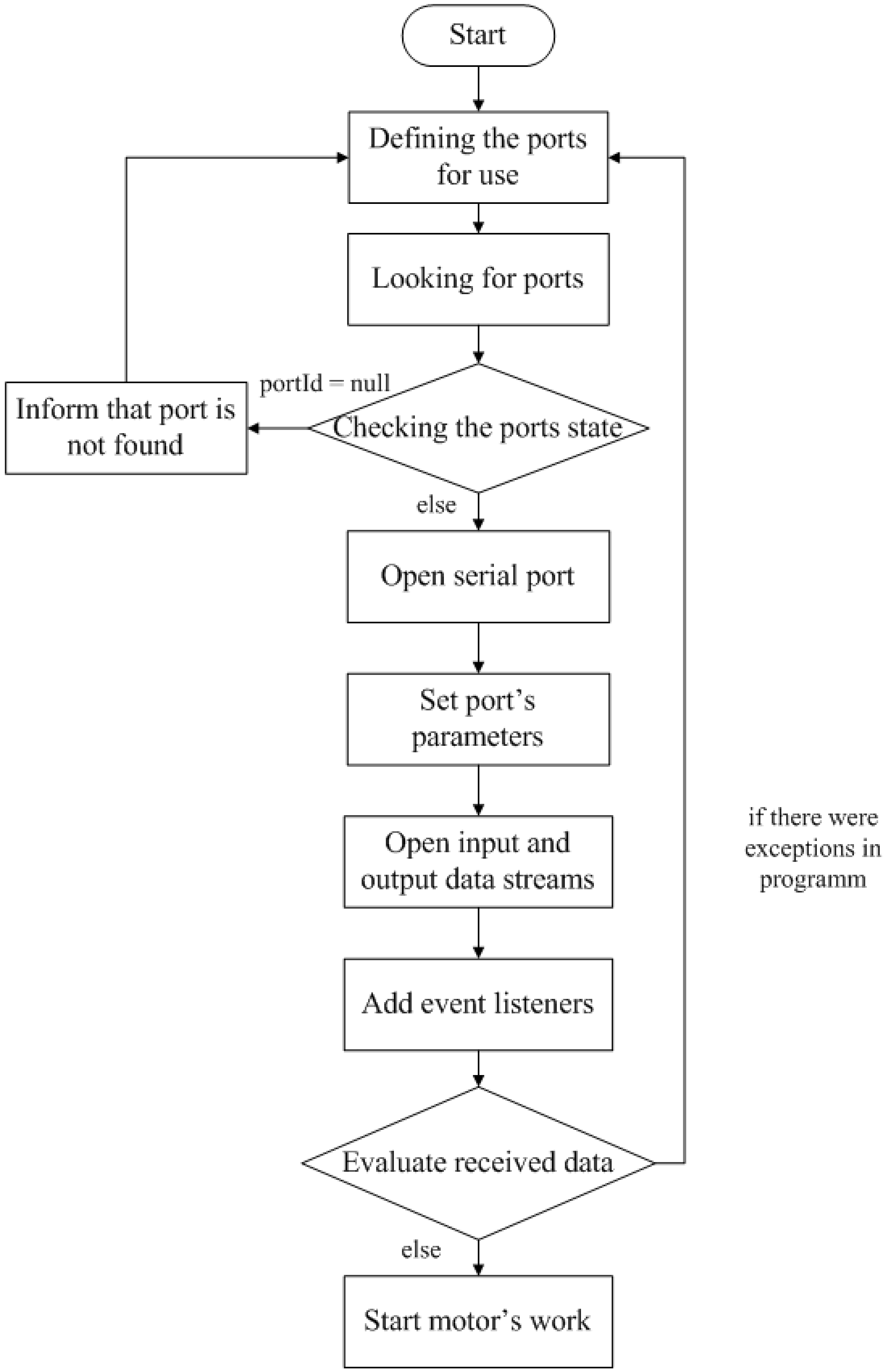
In order to write the code “correctly” and achieve the desired result, it is necessary to create an algorithm for the robots program. This will allow you to think out and write the commands of the engine control program correctly, help you avoid mistakes in writing or correct those that have already been made.

Algorithm is a strictly defined procedure that takes one or several values to the input, returning also one or several values as a result. The algorithm is defined in different computation models - the operations necessary for the execution of a computer / machine. In fact, any code that performs a particular action is an implementation of a specific algorithm. To write the program code, you should first develop an algorithm for the program.

The main server server program will ensure the operation of the engines in the SPP system. For this, it is necessary to ensure the connection of the system's engines directly to the server itself.

To connect the engine uses the COM port of the server computer. A COM port is a serial bidirectional interface whose purpose is to exchange bit information. Also, this port is called serial, as it provides a serial transmission of information, bit by bit. COM ports can be used to connect a computer to external devices — satellite receivers, uninterruptible power supplies, security devices.

The task is to use the port and transfer through it the necessary bits of information that will “set” the command engine for its operation. Since our system is also equipped with microcontrollers, the main task of the application of the control of the operation of the mora lies in the simple maintenance of the engine.



Scheme 5.1 The algorithm of the server program to ensure the health of the engine

The Arduino Ethernet microcontroller board will implement the engine operation control based on the readings transmitted by the Sunshine sensor BF3 solar sensors.

The program must ensure that the Arduino Ethernet microprocessor board reads the light readings received from the light sensor located on the platform with a solar battery, recognizes their values and then assigns commands to the motor to change the position of the platform.

The main task of the program will be the recognition of the data transmitted to it by the light sensor, with subsequent oh evaluation. It is necessary to take into account two possible options - the “presence” of light and its “absence”, in other words, it is necessary to teach the microprocessor to recognize day and night.

This is easy to do, since the light sensor detects rays in the 180 degree range. It is necessary to specify in the program a mechanism for evaluating the incoming data on their value and subsequent corresponding actions. From these estimates directly depends on the work of the motor and the rotation of the panel in one direction or another and one degree or another relative to the horizon.

At the same time, it is necessary to specify the condition that the rotation will take place until the light sensor detects the perpendicular position of itself and the panel, respectively, relative to the Sun.

There is also a need for the motor to return the position of the panel to its primary state relative to the tower when the sun disappears behind the horizon.

Chapter 6

6. Software development

6.1 Choice of programming language

Programming for microcontrollers as well as programming for universal computers has undergone a great path of development from programming in machine codes to the application of modern integrated systems for writing programs, debugging and programming microcontrollers. At present, the text of the program is written in one of the programming languages.

The very programming languages in turn are divided into two groups:

1. "high" programming language

2. "low" programming languages

In the programming language of the "low" level are programming languages in which each operator is responsible for no more than one machine command. A set of machine commands for each particular processor is necessarily part of such a programming language. Low-level programming languages are called assemblers. For each processor there is a group of assemblers. Assemblers for the same processor are distinguished by additional features that facilitate programming.

The programming languages of the "high" level allow you to replace one operator with several machine commands. This allows you to increase the productivity of programmers. In addition, languages of the "high" level allow you to write programs that can be executed on different microprocessors (with this it is necessary to use programs - translators for the corresponding processor). Currently, the most common is the programming language of high-level C, although others are used (Pascal, Basic, PLM). The choice of programming language depends on the hardware composition for which the program is written, as well as on the desired performance of the entire software and hardware complex as a whole. In caSPP where the volume of RAM and RPM is small (in the area of several kilobytes), there is no alternative to assembler. It is he who allows you to receive the shortest and fastest code of the program (other things being equal). [21]

The task is to ensure the operation of engines from the main SPP server. To solve it, we use a program that will be written to and performed by the server itself. The program will be created in a Java programming language environment, due to its widespread prevalence and applicability, as well as its compactness in comparison with C / C ++ and a greater focus on simple, quick code development.

This program will give the engine a team of its work. It specifies to which port the engine is connected, what information should be transmitted to the engine itself from this port. The function of the program is to "turn on" the engine, give him power and “prepare” for the control commands that will be given to him from the microcontroller.

In both tasks, Arduino boards are used to control the movement of the motor to read the solar sensor readings and use them to operate the motor and change the position of the panel.

The Arduino device programming language is based on C / C ++ and is linked to the AVR Libc library and allows you to use any of its functions. However, it is easy to learn, and at the moment Arduino is perhaps the most convenient way to program devices on microcontrollers.

The Arduino language can be divided into four sections: operators, data (variables and constants), functions and libraries.

All the features boil down to the fact that there is a set of libraries that includes some functions (like pinMode) and objects (like Serial), and when you compile your program, the development environment creates a temporary .cpp file, which, in addition to your code, includes a few more lines, and the result is fed to the compiler and then the linker with the necessary parameters.

Arduino microcontrollers are programmed in the C programming language. This language is high-level, therefore it is considered difficult and has a high threshold of entry. But for Arduino programming, a simplified version of this programming language is used. Also, to simplify the development of firmware, there are many functions, classes, methods and libraries. Thanks to this, working with these microcontrollers is very convenient and easy. [24]

Writing a program is made in the Arduino IDE. The IDE is supported by operating systems such as Windows, MacOs, and Linux. It is indicated on the company's official website that this programming language is written in Wiring, but in fact it does not exist and C ++ is used for writing with slight modifications. [25] A program written in the Arduino programming language is called a sketch. Ready made sketches are written to the board for their execution. To do this, you need to connect the board to the computer via the USB port for the compiler to work correctly and to correct the mistakes made in writing the code in a timely manner.

6.2 Input Data

Input data are received by local computer programs, various online services, operating systems, over the network, wired and wirelessly, from equipment, from each other. In general, somehow and from anything.

Input data is exactly what we send to any computing system [...] with our own hands or programmatically.

The input data of the program for controlling the operation of the engine will be data on its connection to a computer and / or network, data on its initial state.

The input data of the program for solving the problem of changing the installation position depending on the location of the Sun in the sky will be data received from the solar radiation sensor.

The illumination data will be obtained by a light sensor, which converts them into electrical impulSPP. The controller recognizes these impulses, transmits to the Arduino board that, using the program recorded on it, evaluates the received data and adjusts the operation of the motor, which will change the position of the entire installation so that the solar panel is constantly perpendicular to the Sun.

6.3 Output data

Output data - the data obtained as a result of the program.

In our case, this will be the direct operation of the engine of the sun tracking system. Since the program runs continuously, depending on the operation of the solar radiation sensor, we can observe its operation at almost any time.

The main output of the program is the operation of the platform engine, followed by a change in the location of the platform specified earlier. At the same time, constant lighting of the tower, where electricity is produced, is provided.

Also, the output of the program in this case can be called data on the effectiveness of the SPP. The program’s inoperability or its incorrect operation will lead to immobility of the panels, followed by intermittent illumination of the electrolyte reservoir and the lack of generation of electrical energy. This will lead to a significant reduction in KKD SPP and call into question the feasibility of its work with the previous construction, design, calculation and design.

6.4 Research of the code of the solution of a task of the program

Work of SES begins with operation of its server and posleduyushche1 behind it implementations of the program of control of engines. The program written in the Java language in the environment of NetBeans IDE 8.2 has such appearance:package serial;

```
import gnu.io.CommPortIdentifier;
import gnu.io.SerialPort;
import gnu.io.SerialPortEvent;
import gnu.io.SerialPortEventListener;
import java.io.InputStream;
import java.io.OutputStream;
import java.util.Enumeration;

public class Serial implements SerialPortEventListener{
        SerialPort serialPort;
       // The port we're normally going to use.
        private static final String PORT_NAMES[] = {
                "/dev/tty.usbserial-A9007UX1", // for Mac OS X
                "/dev/ttyUSB0", // for Linux OS
                "COM4", // for Windows OS
                };

        // Buffered input stream from the port
        private InputStream input;
        // The output stream to the port
        private OutputStream output;
        // Milliseconds to block while waiting for port open
        private static final int TIME_OUT = 2000;
        // Default bits per second for COM port
        private static final int DATA_RATE = 9600;
```

```
public void initialize() {
    CommPortIdentifier portId = null;
    Enumeration portEnum = CommPortIdentifier.getPortIdentifiers();

    // iterate through, looking for the port
    while (portEnum.hasMoreElements()) {
        CommPortIdentifier currPortId = (CommPortIdentifier) portEnum.nextElement();
        for (String portName : PORT_NAMES) {
            if (currPortId.getName().equals(portName)) {
                portId = currPortId;
                break;
            }
        }
    }

    if (portId == null) {
        System.out.println("Could not find COM port.");
        return;
    }else{
        System.out.println("Found your Port");
    }

    try {
        // open serial port, and use class name for the appName.
        serialPort = (SerialPort) portId.open(this.getClass().getName(),TIME_OUT);
```

```
                // set port parameters
                serialPort.setSerialPortParams(DATA_RATE,
                        SerialPort.DATABITS_8,
                        SerialPort.STOPBITS_1,
                        SerialPort.PARITY_NONE);

                // open the streams
                input = serialPort.getInputStream();
                output = serialPort.getOutputStream();

                // add event listeners
                serialPort.addEventListener(this);
                serialPort.notifyOnDataAvailable(true);
            } catch (Exception e) {
                System.err.println(e.toString());
            }
        }
        public synchronized void close() {
            if (serialPort != null) {
                serialPort.removeEventListener();
                serialPort.close();
            }
        }
        public synchronized void serialEvent (SerialPortEvent oEvent) {
            if (oEvent.getEventType() ==
SerialPortEvent.DATA_AVAILABLE) {
                try {
                    int myByte=input.read();
                    int value = myByte & 0xff;//byte to int
conversion:0...127,-127...0 -> 0...255
```

```
                    if(value>=0 && value<256){//make shure everything is ok
                        System.out.println(myByte);
                        //sendSingleByte((byte)myByte);
                    }
                } catch (Exception e) {
                    System.err.println(e.toString());
                }
            }
        public static void main(String[] args) throws Exception
            Serial main = new Serial();
            main.initialize();
        }
    }
```

Comments on the code describe the work done by the commented lines or program blocks. The program code specifies the use of the COM port for connecting and working with the engine.

It is also necessary to program microcontrollers to perform the task of obtaining data from sensors on the tower and installed on panels with mirrors, with subsequent correction of the engine to change the position of the plane with mirrors installed on it.

```
#include <Servo.h>
 Servo servo;
int pinS = A0;
int pinS1 = A1;
int pos = 0;
void setup() {
  Serial.begin(9600);
  pinMode(pinS, INPUT);
  servo.attach(pinS); }
void loop() {
```

```
11        pinS = analogRead (pinS);
12        for (pinS = 90; pinS <= 180; pinS += 1){
13          servo.write((pinS+pinS1)/2);
14          delay(20);
15          }
16        for (pinS = 180; pinS >= 180; pinS -= 1) {
17          pos = 0;
18          servo.write(pos); }
19      }
```

The first row of the program includes the Servo.h function library, which provides a set of functions for controlling servos. Standard servos allow you to rotate the drive at a certain angle from 0 to 180 degrees normally. Some servos allow you to make full turns at a given speed. The Servo library allows you to simultaneously control 12 servos on most Arduino boards.

In the next row, the used server is set. Then follow the rows in which we specify which of the ports of our board we use to read data from light sensors located on the panel with a mirror (pins) and the top of the tower (pinS1). Line number 5 sets the starting position panels with solar cells and a sunlight measurement sensor placed on it.

The next row is the beginning of the first of the two main functions of the program for all Arduino boards. The string Serial.begin (9600) is an extremely important instruction of the Arduino, it allows you to establish a controller connection to external devices. Most often such a "external device" is the computer to which we connect the Arduino. Therefore, Serial begin is most intensively used in sketches that display some information on the port monitor, for example, to debug a program. 9600 denotes the speed of interaction with an external device, calculated in bits / sec or baud. [28] In the 6th row, we assign the pinS sensor variable assignment to the signal input. Then we set pinS as servo control input.

The 10th line starts the work of the void loop () function, the place where we must place the commands that will be executed all the time while the Arduino board is on.

There is a reading of the light sensor that is installed on the mirror panel. Further, the function of analyzing the data received from this sensor is programmed. The condition of this function - the angle of incidence of sun rays that fall on the sensor must be less than or equal to 180 degrees. When such a condition is satisfied, the next line takes up the work, which sets the control of the motor to change its position. As mentioned in the problem, the angle of inclination of the panel is equal to the arithmetic average between the angle of incidence and reflection of light. It is at this angle that the engine should tilt our panel, which is set by the microcontroller. In the case when the light from the Sun falls on the sensor at an angle greater than or equal to 180 degrees, the program instructs the engine to return the panel to its original position.

The program code for solving the second problem has the following form:

```
#include <Servo.h>
servo servo;
int pinS = A0;
int pos = 0;
void setup() {
  Serial.begin(9600);
  pinMode(pinS, INPUT);
  servo.attach(pinS); }
void loop() {
  pinS = analogRead (pinS);
  for (pinS = 0; pinS <= 180; pinS += 1){
    servo.write(pinS);
    delay(20); }
  for (pinS = 180; pinS >= 180; pinS -= 1) {
    pos = 0;
    servo.write(pos); }
}
```

The beginning of this program is exactly the same as in the solution of the previous problem.

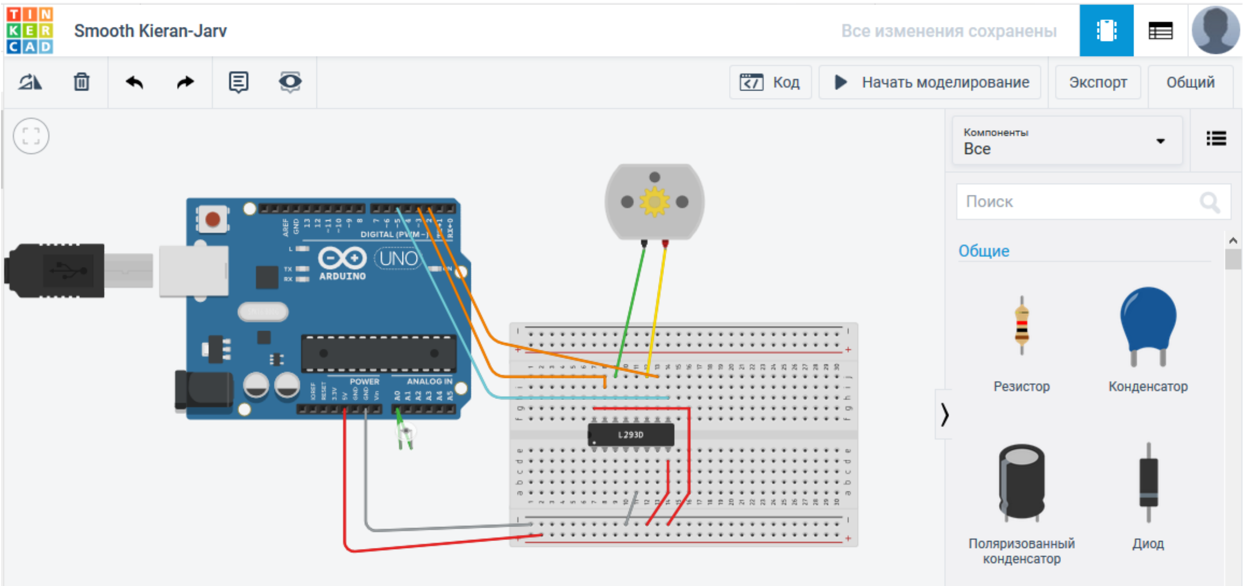
The first function of the program is the same for both tasks. Her work is described above.

In the 9th line of the program, the void loop () function begins, where the control and decision code of the problem is written. Starting from the first command, the microcontroller will go to the end and immediately jump to the beginning to repeat the same sequence. And so an infinite number of times (as long as electricity is supplied to the board). [...] At its core, the void loop is the main function, the entry point to our program. Arduino repeats the call to this function millions of times per second. [29] The string after causes the board to read the sensor value. Then begins the cycle of evaluation and setting the position of the servo, which directly depend on the readings obtained from the sensor. Motor operation is set when the angle of incidence of light on the sensor is 90 degrees, followed by a one-degree change in position and a delay of 20 milliseconds to reach the servo position. This entire cycle sets the work of the program and the board, respectively, when the data from the light sensor "indicates" the position of the Sun in the sky. After all, after entering the sensor does not receive light, it means that the angle of incidence is equal or greater in 180 degrees. And in this case, the next cycle works, which commands the motor to return to its original, original position.

6.5 Example of the program

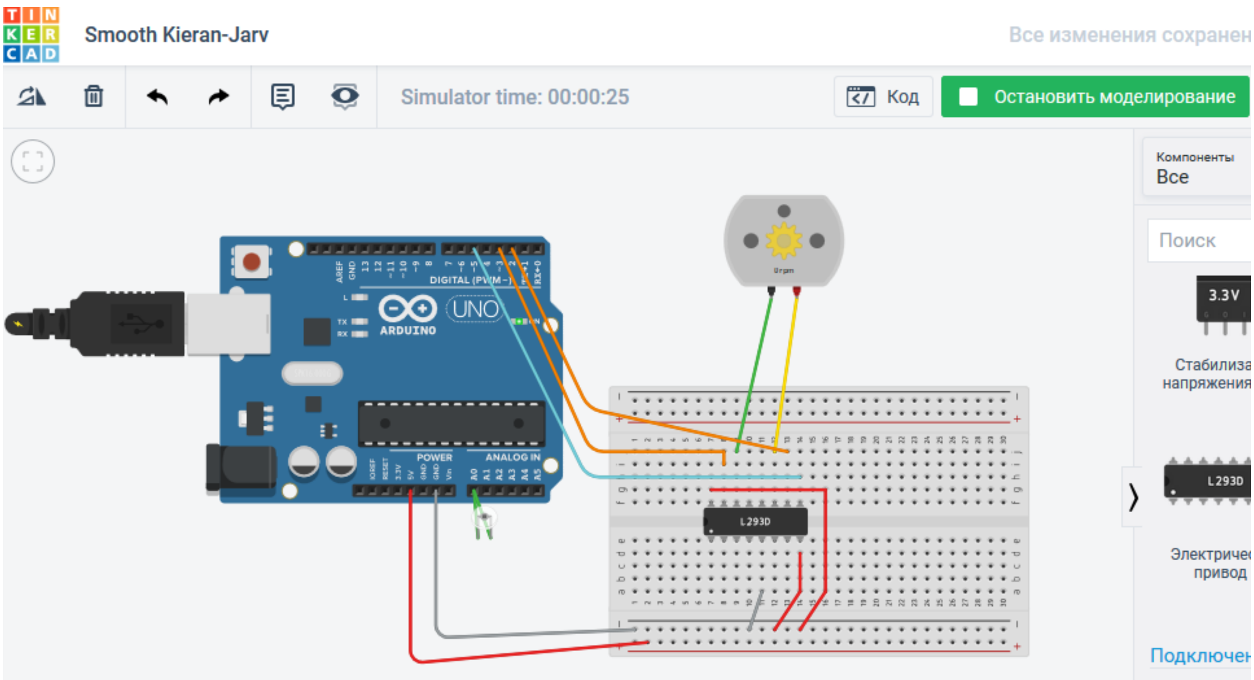
The program was tested using a microprocessor simulator, circuit boards, programs for drawing up electrical circuits - the Tinkercad platform, located at https://www.tinkercad.com. As it is written on the site itself, “create and make. We’re the ideal introduction to Autodesk, the leader in 3D design, engineering and entertainment software.

This online application allows you to collect electrical target and immediately test its performance. This platform provides an opportunity to test the work written for Arduino programs on the correctness of writing, compiling and working without the required physical connection of the board to the computer. Software simulates the mechanism of the board with components connected to it - LEDs, sonars, servomotors and the like. However, to test the operation of the programmed board, it is necessary to carry out tests with the material board (pre-programmed using the Arduino IDE application) and the light sensor and the engine connected to it.



Pic 6.1 Connected Scheme at Tinkerkad GUI

This platform is convenient for those people and times when the Arduino board was not at hand, but you need to check the correctness of the writing and operation of the program.



Pic 6.2 Simulation of work of microcontroller

With this simulation, we can verify the correctness of the writing program.

7. Analysis of the results

As a result of my master's thesis writing, I conducted:

- consideration of the SPP itself and its elements as objects of control and automation. Basically, automatic control is applicable to solar panels and / or batteries to ensure that the maximum amount of sunshine is "absorbed" during the sunny day. Management is best done automated. It can be completely by implementing a computer program for controlling the elements of SPP;

- consideration of requirements for systems of automatic control of technological parameters of SPP, which are specified in the project of the state enterprise "National energy company" Ukrenergo "," REQUIREMENTS FOR VOLTAGE AND SOLAR POWER PLANTS AT THEIR WORK

PARALLELLY WITH THE UNITED NATIONS ENERGY SYSTEM ";

- Examination of existing solutions to the problem of automation of SPP with the subsequent analysis of these decisions on the subject of existing deficiencies;

- selection of the most efficient type of SPP. The main criterion for selecting stations is the fact that all possible and existing types of SPP operate most effectively when their elements are directed to the sun and are as far as possible perpendicular to the sun's rays. The selected station type met all the criteria;

- setting the task of using solar panels and mirrors simultaneously to achieve maximum "absorption" of solar energy by SPP. The task of choosing the best form of the mirror to reflect the sun's rays was solved. After considering the types of mirrors and their possibilities to reflect the rays of light, it was reasonable to provide SPP with concave shape spherical mirrors;

- substantiation of the application together with obligatory elements of the SPP as well as light sensors and microcontrollers for reading and using the data obtained to control the operation of motors that change the positions of the panels relative to the horizon;

- Selection of the light sensor, microcontroller and motor to control the position of the platform with a solar panel or battery attached thereto;

- development of the structural scheme of the SPP, showing the connections of all elements, their work and influence on each other;

- Development of algorithmic software support, which is written on a microcontroller board and provides engine operation, which sets the position of the panel with a solar panel or battery attached thereto;

- Select a programming language to create a program for the microcontroller installation;

- task and explanation of the input data of the program. In this case, they will be indications regarding sunlight, obtained from the light sensor;

- the task and explanation of the output data of the program, which will be the commands that determine the operation of the engine;

- writing a program, checking the correctness of its writing and studying its code;

- Verification of the program's work performed on the virtual simulator of the Arduino microcontroller with an illuminated sensor and an engine connected to it.

As a result of the fulfillment of the above, I proposed to use such a type of work of the SPP that it would be able to increase its efficiency, the amount of electric power produced, and also allow to reduce the cost of its maintenance, both monetary, material and energy.

The results - we analyzed, calculated the choice of SPP model with the most optimal performance characteristics, aimed at self-sufficiency;

Chapter 8 Ecological efficiency of the mirror installation of the solar power station

Compared to other types of energy, solar energy is generally one of the most environmentally friendly types of energy. However, it is practically impossible to completely avoid the harmful effects of solar energy on humans and the environment, if we take into account the entire technological chain from obtaining required materials to generating electricity.

The most typical in this aspect are SFEUs, the operation of which causes minimal harm to the environment. At the same time, the production of semiconductor materials is highly ecological and socially hazardous. In this regard, in a number of countries of the world there are very stringent requirements for the production of semiconductors for SFEU, as well as for storage, transportation and disposal of harmful substances from the production of SFEU, limitation of personnel contacts with these substances, development of action plans in case of emergency or abnormal technological situations, as well as programs for the elimination of production wastes that have worked out or rejected by SFEU.

The most dangerous in this respect are cadmium Cd , as well as Ga , As and Te . Today, the most studied the harmful effects of cadmium on human health and even implemented e us bans on the use of living conditions of its compounds (for example, microbattery and batteries based on it). Long-term inhalation of cadmium vapors can lead to pulmonary or bronchial disease and even death. Constant exposure to low doses of cadmium leads to its accumulation in the kidneys and kidney disease. At the same time, lung diseases, softening and deformation of the bone structure of the skeleton are also observed.

Some selenium compounds are also very toxic. For example, SeH , SeO_2 - negatively affect the respiratory system. Tests of spent or discarded solar modules based on $CuInSe_2$ and CdTe showed that if the first of them meet the requirements of the American Environmental Protection Agency, then the second does not, since the level of cadmium in them turned out to be 8-10 times higher than the permissible standards ... As a consequence, the exhausted CdTe- based solar modules may now be classified as potentially toxic waste and, if possible, returned to their manufacturers.

In other words, the actual greatest social and environmental hazard for SFEM is mainly associated with the production of some SFEM, during which a significant amount of harmful substances for human health and the environment are processed. According Daubney production. Obviously, it should be fully automated and located at a significant distance from settlements. Special measures must be taken to protect the production itself. As for the operation of the SFEU, it is practically safe.

In t Power Requirements 's safe STI enterprises, industrial activities are related to hazardous substances must be:

• complexes of organizational and technical, sanitary and hygienic and medico-biological measures were carried out.

To illustrate what has been said about the harmfulness of the production of solar cells in table. 1 shows five main stages of obtaining high-purity polycrystalline silicon. In fig. 1 also presents possible methods of converting fossil silicon into single-crystal or coarse-grained polycrystalline silicon sheets for solar cells in a continuous cleaning process.

Fossil flint or silica are colorless crystals with high hardness and strength. Silicon dioxide is used in the production of glass , ceramics , abrasives , concrete products , for the production of silicon , as a filler in the production of rubber , in the production of silica refractories , in the production of solar panels , etc. Quartz crystals have piezoelectric properties and therefore are used in radio engineering , ultrasonic installations, in lighters .

Table 1 - main stages of the technological process for obtaining high-purity polycrystalline silicon

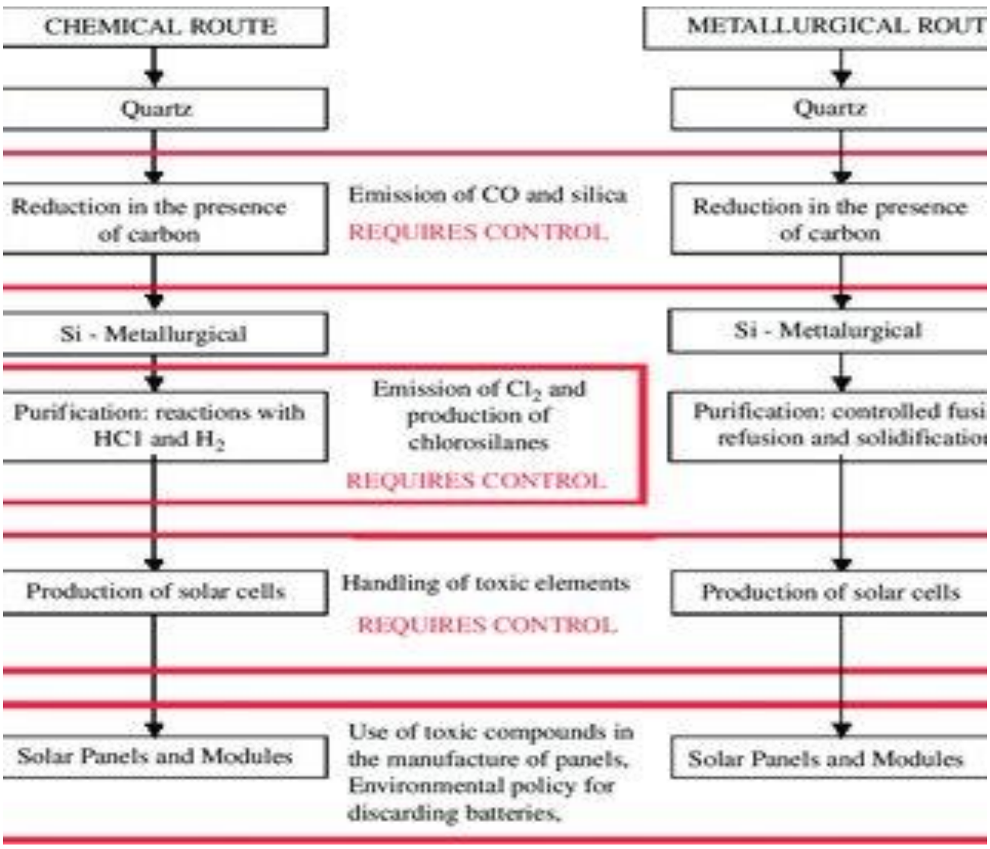
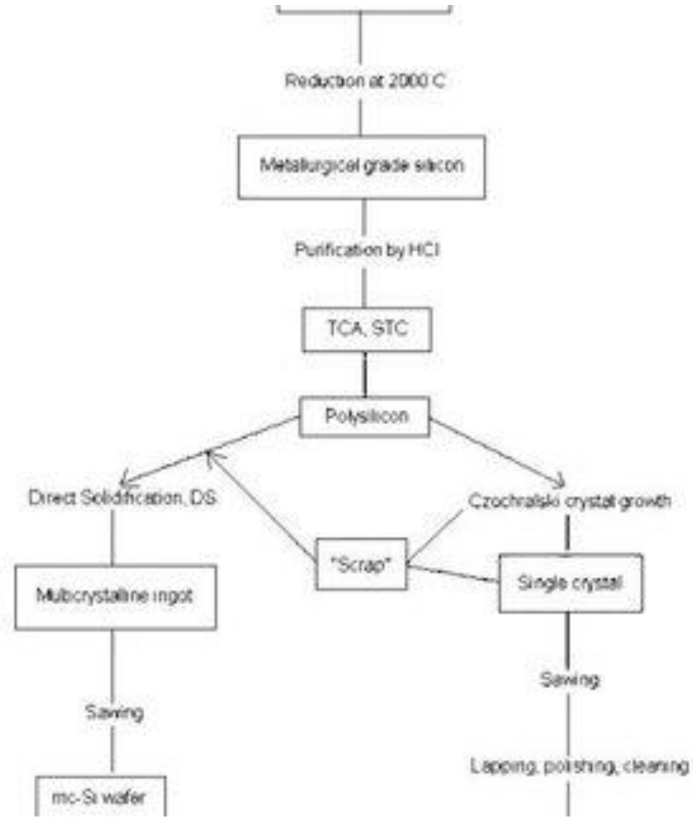


Figure 1 Possible sequence of technological operations for the purification of silicon intended for the manufacture of solar cells



The use of the chemical interaction of silicon with silicon tetrafluoride is also considered promising. In this case, the extraction of silicon from the melt, its purification and chemical deposition from the vapor phrase are realized during one stage of the technological process.

Modern methods of obtaining silicon wafers and sheets are very numerous. The main efforts here are aimed at optimizing the ways of creating polycrystalline and monocrystalline silicon with the highest efficiency.

The standard technological process, which makes it possible to obtain a monocrystalline solar cell up to 7.6 cm in diameter or pseudo-rectangular elements up to 2 × 8 cm in size, is based on growing crystals by the Czochralski method, followed by cutting the plates using diamond strips and grinding them with an abrasive powder, which is very harmful. for human health (silicon dust, cadmium and arsenide compounds).

Thus, in solar photovoltaics, the most harmful to humans and the environment is the technological process of obtaining solar cells, their storage and disposal. To improve efficiency, this production must be large-scale, which requires large capital and material costs. It is also necessary to take into account the work on exploration and extraction of silica, as well as the inevitable withdrawal of land from economic production in this case. [2]

The solar power plants themselves are noticeably material-intensive (metal, glass, concrete, etc.).

During the operation of solar photovoltaic stations, there is a noticeable change in climatic conditions in a given place, including a change in soil conditions, vegetation, air circulation as a result of surface shading, on the one hand, and air heating, on the other hand. Because of the latter, the thermal balance of air humidity, the direction and magnitude of the winds change. For a solar power plant with solar radiation concentrators, there is a great danger of overheating and fire of the systems themselves for obtaining energy from solar radiation .

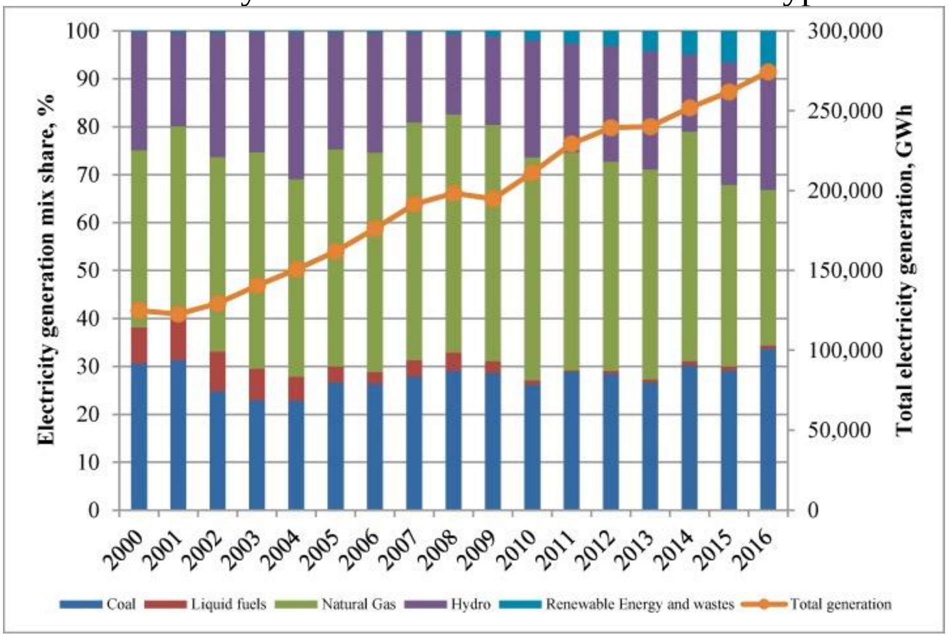
The use of low-boiling liquids and their inevitable leakage in the SES can lead to contamination of soil, underground and even drinking water in the region. Liquids containing nitrites and chromates, which are highly toxic substances, are especially dangerous.

The low conversion rate of solar radiation into electricity leads to problems associated with cooling the condensate. At the same time, thermal emissions into the atmosphere at the SPP are more than two times higher than the similar discharge from the TPP.

Table 5 .3 presents the values of the so-called penalty environmental score for various types of energy source used, which makes it possible to take some dimensionless quantitative account of their negative impact on the environment.

These scores were calculated taking into account the following environmental impacts: global warming, ozone depletion, soil acidification, eutrophication, heavy metal pollution, emissions of carcinogenic substances, the formation of winter and summer smog, industrial waste, and depletion of energy sources.

Table 2 - Penalty environmental score for different types of electricity source used

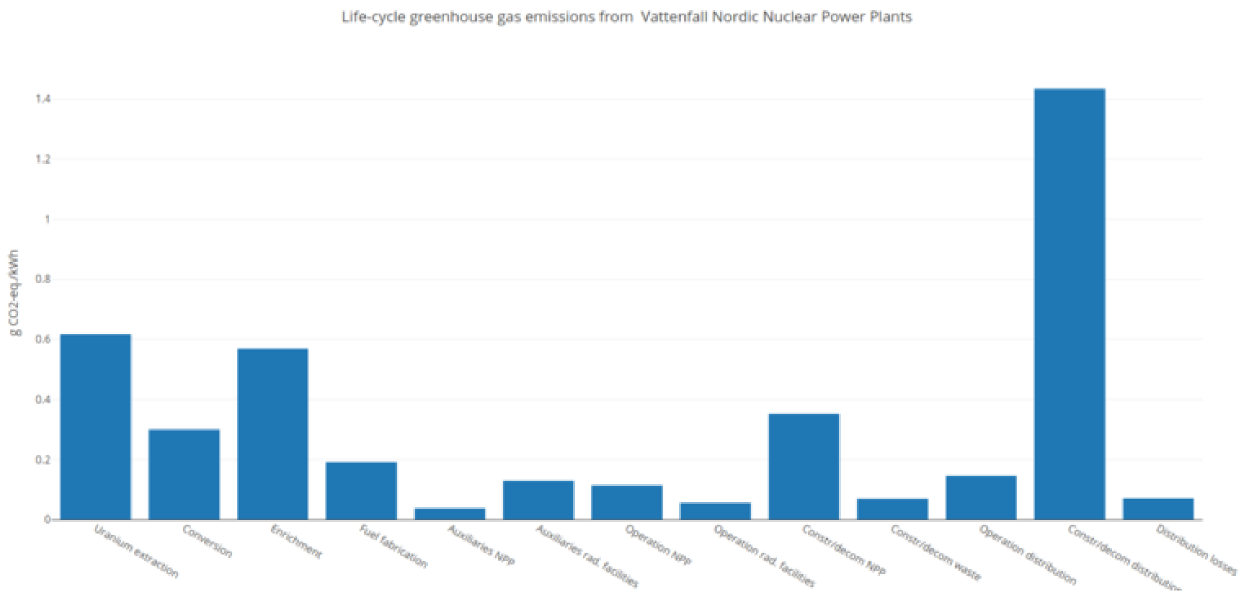


The more points each method of generating electricity gets, the more harmful it will have on the environment .

Table 3 shows the values of some key emissions for the environment, calculated for the full cycle of electricity generation, for different energy sources used to generate electricity at different types of power plants. According to the table, the least emissions are produced by hydroelectric power plants, wind farms, solar thermal stations and SFES.

The data in Tables 1 and 2 data that SFEU and solar thermal power plants have significant advantages when compared to traditional types of plant types that use non-renewable energy sources.

Table 3 - Emission of various power plants for the full cycle of electricity production (g / kWh)



However, as mentioned above, in general, the negative impact of technical devices of solar energy on humans and the environment is much less than that of other types of energy and especially traditional nuclear power plants, thermal power plants and hydroelectric power plants. [3]

Calculation of the resistance of the combined earthing

Grounding is done in order to secure the place of work and to prevent workers from receiving electrical injuries.

The total resistance of the grounding device consists of the sum of the resistance to current spreading from the ground electrodes to the ground and the resistance of the grounding conductors.

When designing a combined ground electrode system, assume that it will be made in the form of several vertical pipes installed in a row and interconnected in the upper part by a communication strip. In this case, the communication band is buried in the ground to a certain depth, which is independently adopted and can be in the range from 0.5 m to 0.8 m .

1) P aschetnoe resistivity of predelyaem by the formula:

$$\rho_{□} = \rho_{□0} \times K_P \quad (1)$$

where $\rho_{□0}$ - soil resistivity selected according to table 13;

$\rho_{□0}$ = 200Om / m , the soil - humus.

Table 4 - Specific soil resistance $\rho_{□0}$ at the site of the combined ground electrode system

Priming	Resistivity in Ohm / m	
	With a moisture content of 10-20% by weight	Limits of change
Sand	700	$4 \cdot 10^2 - 10 \cdot 10^2$
Sandy loam	300	$1.5 \cdot 10^2 - 4 \cdot 10^2$
Loam	100	$0.4 \cdot 10^2 - 1.5 \cdot 10^2$
Clay	40	$0.08 \cdot 10^2 - 0.7 \cdot 10^2$
Chernozem	200	$0.096 \cdot 10^2 - 5.8 \cdot 10^2$

K_P - the increasing coefficient K_P, which is determined according to table 14. Kp = 1.2 for climatic zone IV .

$$\rho_{□} = 200 \times 1.2 = 240 \text{ Ohm / m}$$

Table 5 - Increasing coefficient K_P

Grounding type	Values of the increasing coefficient K_P for climatic zones			
	I	II	III	IV
Combined (vertical electrodes 0.8-1.5 m long with a strip width of 0.4-0.8 m)	1.8-2	1.6-1.8	1.4-1.6	1.2-1.4

2) C oprotivlenie current spreading single vertical earthing of the limit is Busy according to the following relationship:

$$R_{TP} = 0.366\,\rho : l \times (\lg (2\,l : d) + 1/2 \lg (4\,h + l) / (4\,h - l)) \qquad (2)$$

where ρ is the calculated soil resistivity;

l is the length of the vertical ground electrode;

d is the diameter of the vertical ground electrode;

h - deepening of the communication band (take independently within the limits of 0.8 to 1 m).

l = 1 m ; d = 0.4 m ; h = 0.8 m ;

$$R_{TP} = 0.366 \cdot 240 : 1 \times (\log (2 \cdot 1 : 0.4) + 1/2 \log (4 \cdot 0.8 + 1) / (4 \cdot 0.8 - 1)) = 145 \text{ Ohm}$$

3) About the resistance of the center of grounding electrodes (approximate resistance of all vertical grounding electrodes) according to the following dependence:

$$R' = K_0 \times R_g \qquad (3)$$

where R_g is the permissible value of the resistance of grounding devices according to GOST 12.1.030-81 (10 ohms is accepted) .

K_0 - coefficient of increasing the resistance of the center of grounding electrodes (taken from 2 to 3); $K_0 = 2$

$$R' = 2 \cdot 10 = 20 \text{ Ohm}$$

4) Then the approximate number of vertical ground electrodes *n* is determined according to the following relationship:

$$n = R_{TP} : R' \qquad (4)$$

According to the calculated result, an integer number of vertical ground electrodes is taken.

$$n = 145 : 20 \approx 7$$

5) The true value of the resistance of the hearth of grounding conductors is determined according to the formula 14:

$$R_0 = R_{TP} : n \times \eta_1 \qquad (5)$$

η_1 - shielding factor between vertical earthing devices, determined according to Table 15 .

$\eta_1 = 0.56$

$$R_0 = 145 : 7 \cdot 0.56 = 11.6 \text{ Ohm}$$

Table 6 - Shielding factor between vertical earthing

Number of electrodes, *n*	The value of the utilization factor for the ratio of the distance between the electrodes to their length		
	a / l = 1	*a / l* = 2	*a / l* = 3
When placing electrodes in a row			
2	0.84-0.87	0.90-0.92	0.93-0.95
3	0.76-0.80	0.85-0.88	0.90-0.92
five	0.67-0.72	0.79-0.83	0.85-0.88
ten	0.56-0.62	0.72-0.77	0.79-0.83
fifteen	0.51-0.56	0.66-0.73	0.75-0.80
20	0.47-0.50	0.65-0.70	0.74-0.79

6) The length of the communication band l_P is determined :

$$l_П = a (n -1) \qquad (6)$$

where *a* is the distance between vertical ground electrodes;
a = 0.6m

$$l_P = 0.6 \cdot (7-1) = 1.6$$

7) The resistance of the communication band R_P is determined by the formula 16:

$$R_P = 0.366 \, \rho / l_P \times \log (2 \, l_P^2 / b \times \eta_1) \qquad (7)$$

where *ρ is the* calculated soil resistivity;

l_P is the length of the communication band;

b - strip width (taken from 40 to 80 mm);

b = 0.04 m

η_1 - shielding coefficient between vertical ground electrodes.

$$R_P = 0.366 \cdot 240 / 3.6 \times 2.81 = 68.56 \text{ Ohm}$$

8) The resistance of the combined earthing switch is determined:

$$Rz = R_0 \times R_P : (R_0 + R_P) \times \eta_2 \ (8)$$

where R_0 - resistance to current spreading of a single vertical ground electrode;

R_P - resistance of the communication band;

η_2 - the screening factor of the communication band with vertical ground electrodes, is determined according to table 1.

Table 7 - Shielding factor of the communication band with vertical grounding η_2 = 0.67

a / l	The value of the utilization factor for the number of pipes							
	4	6	eight	ten	20	thirty	50	70
When placing electrodes in a row								
1	0.77	0.72	0.67	0.62	0.42	0.31	0.21	0.19
2	0.89	0.84	0.79	0.75	0.56	0.46	0.36	0.32
3	0.92	0.88	0.85	0.82	0.68	0.58	0.49	0.42

$$Rz = 11.6 \times 68.56 : (11.6 + 68.56) \times 0.67 = 6.67 \text{ Ohm}$$

The calculated resistance R_3<10 Ohm, therefore, an increase in the number of vertical ground electrodes is not required.

Battery Safety

Battery maintenance and repair workers have to deal with lead and lead compounds, which are slow-acting poisons. The poisonous effect on the body of lead dust, lead vapors and its compounds, the irritating effect of sulfuric acid on the mucous membrane and the respiratory tract, burns caused by sulfuric acid when it comes into contact with the skin, the explosiveness of oxyhydrogen gas - all this requires strict adherence to the rules of technology from the battery workshop worker security. Workers must know safe working practices, for which, upon entering a job, they undergo induction, then on-the-job instruction and training in the basics of safety. All employees, regardless of their qualifications and length of service , are re-instructed at least once every six months .

There are many risk factors for battery exposure .
The main ones are due to:

1) explosion hazard of storage batteries;
2) corrosive sulfuric acid, which is part of the electrolyte of lead-acid batteries;
3) high toxicity of lead and sulfuric acid, which are part of most industrial and traction batteries.

Almost all modern storage batteries are explosive and fire hazardous. In order to minimize the risks when working with any battery, it is necessary to carefully observe the safety precautions and operational requirements of the manufacturer.

When batteries are charged, hydrogen and oxygen are released, the mixture of which is an explosive gas that explodes even from a small spark. Therefore, the room in which the batteries are charged must comply with fire safety requirements. The luminaires of the battery room must be explosion-proof, they are placed between the battery racks.

Supply and exhaust ventilation should be turned on before starting the battery charging and turned off after removing all gases at least 1.5 hours after the end of charging. When inspecting batteries, use a special explosion-proof lamp with a voltage not exceeding 36 V. The lamp cord must be enclosed in a rubber hose. The battery room should not contain devices that can generate a spark (switches, plug sockets, automatic devices, etc.).

Smoking near batteries is strictly prohibited.

The electrolyte of acid batteries contains sulfuric acid. Sulfuric acid causes burns on skin.

Acid that gets on the skin must be quickly and abundantly washed off with water, then its effect may be limited to a first degree burn (redness). If delayed, the acid quickly destroys the skin and tissues, resulting in a deep wound that is difficult to heal.

Batteries contain many toxic substances such as lead, arsenic, etc.

Lead and its compounds are poisonous. Getting into the stomach through the mouth and nose, C lead and its compounds dissolve and enter the bloodstream. With the systematic and prolonged ingress of lead into the blood, chronic poisoning occurs - a serious, intractable disease.

Lead can enter the body during stripping and straightening of the plates before soldering, during their soldering, during disassembly and assembly of batteries, etc. When stripping the pole branches (ears) of the plates, the smallest lead dust is released into the air before soldering with metal brushes. To prevent the ingress of this dust into the respiratory tract, and then into the stomach, the stripping of the plates is performed in respirators with replaceable cotton filters. The filter must be changed at least 2 times during the working day, while the respirator is thoroughly wiped with a clean, damp cloth.

After the end of the working day, you should shower and put on clean clothes. In case of scratches and abrasions on the joints of the fingers, do not handle the plates with bare hands. Through abrasion, lead oxides can enter the tendons, and this can cause them to die off and lose finger mobility.

Only rubber gloves should be used when handling batteries. After work, you should thoroughly wash your hands and face, brush your teeth and rinse your mouth.

Battery recommendations

When caring for batteries, it is necessary to illuminate them with a portable electric lamp. It is strictly forbidden to illuminate the battery with an open flame, as well as smoke during inspection.

It is necessary to constantly monitor the reliability of the fastening of the wire clamps, avoiding arcing.

It is necessary to carry out the following operations every shift :

- about cleaning the battery from dust. The electrolyte that has got on the surface of the battery should be wiped off with a clean cloth moistened with a 10% solution of soda ash. Lubricate non-contact metal parts with technical Vaseline or grease .
- n Checks mount batteries in the nest.
- n Checks density wiring terminals contacts on the terminals. Do not strain the wires to avoid damaging the terminals and to avoid cracks in the bridge.
- n chitchat battery vent openings.

Every 100-120 hours of operation (but at least every 10-15 days in winter and 5-6 days in summer):

- check the electrolyte level in all battery banks;
- to determine the degree of discharge of batteries by the density of the electrolyte;
- if necessary, the batteries are sent to the charging station;

protect wire ends.

Every 300-360 hours of operation (but at least once a month), you need to check the voltage of each battery with a load plug. [five]

Disposal of batteries

Lead-acid batteries are usually combined into a battery, which is placed in a monoblock made of ebonite, plastic (thermoplastic), polypropylene, asphalt, ceramic or glass. One of the most important characteristics of a battery is its service life (years) or technical resource — operating time (number of cycles). The deterioration of the battery parameters and their failure are mainly due to the corrosion of the lattice and the sliding of the active mass of the positive electrode. Battery life is primarily determined by the type of positive plates and operating conditions .

Incorrect disposal of batteries can cause enormous damage to the environment. The fact is that the acid contained in batteries penetrates the soil and enters into chemical reactions with heavy metals, which abound in landfills for storing garbage.

To prevent this from happening, batteries must be disposed of separately. In this case, it is necessary not only to detoxify the substances that make up their composition, but also to further recycle the cases and battery parts. Dispose of batteries in the same way.

Professional disposal of batteries before disposal is essential to maintain a healthy environmental situation. These works can only be carried out by specialists who have official permission for this.

Fire safety of electrical equipment and installation location

Fire safety is the state of an object in which the possibility of a fire is excluded, and in case of its occurrence, the impact on people of dangerous fire factors is prevented and the protection of material values is provided

Fire safety is ensured by a fire prevention system and a fire protection system. In all office premises and in open areas, there must be a "Plan for the evacuation of people in case of fire", which regulates the actions of personnel in the event of a fire source and indicates the location of fire fighting equipment.

Combustible components in the guidance system in open areas are : acid fumes from the battery, protective wire insulation and dry grass .

Fire protection is a complex of organizational and technical measures aimed at ensuring the safety of people, preventing a fire, limiting its spread, as well as creating conditions for the successful extinguishing of a fire.

Sources of ignition in the installation can be electronic circuits from computers, devices used for maintenance and analysis, power supplies, electrical sparks that can ignite acid fumes .

Connecting wires and cables are located in close proximity to each other. When an electric current flows through them, a significant amount of heat is released. In this case, the insulation may melt. These systems present an additional fire hazard when used continuously.

Water can be one of the main extinguishing agents . Do not extinguish live electrical installations with water.

Note: The use of water in connection with the possibility of failure of expensive equipment is possible in exceptional cases when the fire becomes alarmingly large. In this case, the amount of water should be minimal, and the devices must be protected from water ingress by covering them with a tarpaulin or canvas.

Carbon dioxide snow is also one of the means of fire extinguishing. Formed from liquid carbon dioxide, when it leaves the cylinder. Snow temperature -800C. It is used to extinguish electrical installations under voltage, fires in closed rooms and in open areas with a small size of the combustion center.

The next extinguishing agent is foam . The following types of foam are used to extinguish a fire:

- chemical foam - formed as a result of the reaction of an alkali with an acid, with the addition of a foaming agent ;
- air-mechanical foam, formed by mixing water with a foaming agent simultaneously with the addition of oxygen (air) .

Foam is mainly used for extinguishing flammable liquids.

When extinguishing a fire, sprinklers are also used . Created on the basis of inorganic salts of alkali metals, with the addition of soda, sand. Powders are the only extinguishing agents for alkali metals and compounds. They knock down the flame well, but they do not always completely extinguish, therefore they are used in conjunction with other fire extinguishing means.

The open area with the installation must be equipped with manual fire extinguishing equipment without fail. These include:

1. about the equipment of fire shields ;
2. n fire valves ;
3. p Obese extinguishers .

Fire extinguishers, depending on the substances used in them, are divided into chemical - foam, air - foam, carbon dioxide and powder.

The personnel working with the installation must know the sequence of actions in the event of a fire, as well as be able to use manual fire extinguishing equipment.

All electrical installations are protected by protection devices against short-circuit currents and overloads that can lead to fires and burns.

All current-carrying parts, switchgears, apparatus and measuring instruments, as well as safety devices of a bursting type, knife switches, and all other starting devices and devices are mounted only on non-combustible bases (marble, textolite, getinax).

Connections, terminations and branches of conductors of wires and cables in order to avoid transitional resistances that are dangerous in terms of fire are made using crimping, welding, soldering or special clamps.

The joints and branches of the conductors of wires and cables, as well as connecting and lighting clamps are insulated, equivalent to the insulation of the conductors of entire places of these wires and cables.

Connection and branching of wires and cables, with the exception of wires laid on insulating supports, are carried out in junction and lighting boxes, in insulating housings of connecting and lighting clamps, in special niches of building structures, inside the housings of wiring products, devices and machines. When laying on insulating supports, the connection or branching of the wires is carried out directly at the insulator, the clique or on them, as well as on the roller. Junction boxes and lighting boxes are provided with protective covers.

Disposal of photocells

Photovoltaic cells begin to harm nature at the production stage. During the manufacture of one ton of solar cells, up to four tons of silicon tetrachloride, which is a highly toxic colorless substance, can enter the atmosphere , the vapors of which can cause various diseases. Given the relatively short lifespan of photovoltaic cells, toxic waste disposal problems can seriously affect the air and water quality in the regions where these devices are manufactured. It should be emphasized that at the moment no technologies have been developed that fully guarantee the safe disposal of industrial waste and spent photocells. The danger of solar panels persists throughout the entire period of operation. The composition of solar panels cadmium compounds are present, which may enter the device when damaged atmosphere. These substances are carcinogens, which, accumulating in the body, lead not only to tumor diseases, but also damage to the nervous system and destruction of bones. To "rescue" cadmium, no need even of the devastating earthquake and tsunami - it's the power of any boy who threw a stone at pa nel on the roof of a neighboring house. Photocells pose no less danger during a fire. Poisonous vapors containing high concentrations of highly toxic substances can harm the health of people even hundreds of meters away from the fire. The results of the latest research have shown that the massive use of photovoltaic installations causes irreversible processes in regional ecosystems, and this threatens to reduce the diversity of species. It has been proven that more than 300 species of insects, taking solar cells for the surface of the water, lay eggs on them, which leads to a decrease in populations. This is already having a negative impact on other animal species, as insects are an important link in the food chain. According to scientists, large solar power plants can change wildlife within a radius of several kilometers, which in the long term, taking into account other features of solar cells, can lead to the transformation of huge areas into desert zones.

In the production of photovoltaic cells, the level of pollution does not exceed the permissible level for enterprises of the microelectronic industry. Modern solar cells have a service life of 30-50 years. The use of cadmium bound in compounds in the production of certain types of photovoltaic cells in order to increase the conversion efficiency raises the difficult question of their disposal , which also does not have an acceptable solution from an environmental point of view, although such elements are not widely used, and cadmium compounds in modern production already a worthy replacement has been found.

Chapter 9.OCCUPATIONAL SAFETY

Installing solar systems is a risky business. Lifting and arranging unwieldy solar panels, the potential for falls off many-storied rooftops, panels that heat up as soon as they're uncovered – these are some of the serious hazards that solar workers face. They're also subject to the risks of traditional roofing, carpentry and electrical trades – some of the most injury-prone occupations around.

The Occupational Safety requires employers to implement safety training and protection for their employees. Many solar installation companies have taken Occupational Safety requirements a step farther, creating manuals of their own that detail the specific measures they require to manage solar energy safely.

Safety issues are common for solar installations, but proactively putting preventive measures in place can help mitigate on-the-job injuries.

This chapter addresses the issue of occupational health during the development of automatic control system of mirror orientation of solar electric power station

1.2. Analysis of working conditions in the workplace

According to ГОСТ 12.0.003-74,

The following physical factors may be adversely affected by the sun power plant engineers premises:

- Falls
- Lockout/Tagout
- Crane and Hoist Safety
- Electrical
- Heat/Cold Stress
- Personal Protective Equipment
- Fatalities/Incidents

1.2. Microclimate of the working zone of the sun power plant engineer

Solar energy workers often work in very hot weather where hazards include dehydration, heat exhaustion, heat stroke, and death. Employers should monitor

employees and workers should be trained to identify and report early symptoms of any heat-related illness. Workers may also be exposed to extreme cold weather conditions and should be protected from such conditions. 89

HEAT STROKE occurs when the body's system of temperature regulation fails and body temperature becomes abnormally high. Some of the signs and symptoms of heat stroke are:

- Confusion
- Loss of consciousness
- Convulsions
- Lack of sweating (usually) hot, dry skin, and
- Very high body temperature

If a worker shows signs of possible heat stroke, medical treatment should be obtained immediately. While waiting for medical help, the worker should be:

- Placed in a shady area and the outer clothing should be removed.
- The worker's skin should be wetted and air movement around the worker should be increased
- Fluids should be replaced as soon as possible.

HEAT EXHAUSTION. The signs and symptoms of heat exhaustion are:

- Headache
- Nausea
- Vertigo
- Weakness
- Thirst and
- Giddiness.

Workers suffering from heat exhaustion should be removed from the hot environment and given fluid replacement. They should also be encouraged to get adequate rest.

1.3. Crane and Hoist Safety

Cranes can be used during the installation and maintenance of solar panels. Fatalities and serious injuries can occur if cranes are not inspected and used properly. Many fatalities can occur when the crane boom, load line or load contacts power lines and shorts electricity to ground. Other incidents happen when workers are struck by the load, are caught inside the swing radius or fail to assemble/disassemble the crane properly. There are significant safety issues to be considered, both for the operators of the diverse "lifting" devices, and for workers who work near them

Cranes are to be operated only by qualified and trained personnel.A designated competent person must inspect the crane and all crane controls before use.

Be sure that the crane is on a firm/stable surface and level.

During assembly/disassembly do not unlock or remove pins unless sections are blocked and secure (stable).

Fully extend outriggers and barricade accessible areas inside the crane's swing radius.

Watch for overhead electric power lines and maintain at least a 10-foot safe working clearance from the lines.

Inspect all rigging prior to use; do not wrap hoist lines around the load.

Be sure to use the correct load chart for the crane's current configuration and setup, the load weight and lift path.

Do not exceed the load chart capacity while making lifts.

Raise load a few inches, hold, verify capacity/balance, and test brake system before delivering load.

Do not move loads over workers.

Be sure to follow signals and manufacturer instructions while operating cranes.

Workers should watch for overhead electric power lines and maintain at least a 10-foot safe working clearance from the lines and must not move loads over workers.

1.4. Impact of chemicals on the sun power plant engineer when working with the sun power plant

To produce solar-grade silicon, semi-conductor processing typically involves hazardous chemicals.

Not every company will dump chemicals, or won't recycle their byproducts properly, but there are bad apples out there.

1.5. Development of occupational health measures

While working with a sun power plant, a sun power plant engineer spills a number of dangerous factors that can harm or negatively affect his health. Next, measures are taken to protect against these factors.

1.6. Protection from electromagnetic fields and radiation.

Occupational hazards associated with photovoltaic plant operation would be those associated with normal electricity generation, although for workers involved in the actual production of photovoltaic materials, there is some concern for the toxic effects of the materials used, including silicon, cadmium, and gallium arsenide. Using personal protective equipment is often essential, but Solar energy employers must assess their workplace to determine if hazards are present that require the use of protective equipment. Solar energy workers can be exposed to many hazards that may require the use of safety glasses, hard hats, gloves, respirators, or other personal protective equipment used to protect against injuries and illnesses. Workers exposed to potential electrical hazards must be provided with appropriate electrical protective equipment, and workers must use them. Electrical protective equipment must be maintained in a safe and reliable condition. They must be periodically inspected or tested.

1.7 Fire safety of the production premises

While solar energy is an environmentally safe form of energy generation, it still poses fire risks. It is necessary to be aware of the risks and proper fire protection solutions.

- Early fire detection - provides ample warning in structures that pose a fire risk.
- Flame-sensing radiant energy fire detectors - Ideal for flaming fires, fire detectors quickly recognize a fire ignition and alert the fire protection solutions.

- Smoke fire detectors - Sense smoldering fires in a variety of locations.
- Deluge fire sprinklers - In outdoor areas with heat transfer fluid, deluge fire sprinklers will promptly contain or extinguish fires.

1.8 Shock or electrocution from energized conductors

Just as with other electric power generation, PV systems present the risk of shock and electrocution when current takes an unintended path through a human body. Electrical shocks are typically caused by a short circuit resulting from corroded cables and connections, loose wiring, and improper grounding. Key places to look for these conditions in a PV system include the combiner box, PV source and output circuit conductors, and the equipment grounding conductor. The grounding conductor bonds all metallic components together—and eventually to ground—through the grounding electrode conductor and grounding electrode.

Measures to reduce the impact of electrocution from energized conductors

PV systems present the risk of shock and electrocution when current takes an unintended path through a human body. Current as low as **75 milliamps** (mA) across the heart is lethal. The human body has a resistance of about **600 ohms**. Per Ohm’s law, voltage (**V**) equals current (**I**) times resistance (R), so **V = IR.**

To calculate the amount of current that would course through a person’s body if exposed to 120 V, we need to use **Ohm’s law**

$$I = \frac{U}{R} = \frac{120}{600} = 0.2 amps$$

Or 200 mA That’s more than 2.5 times the lethal limit of 75 mA.

So the workers must Wear appropriate PPE, including arc-rated clothing, gloves, safety glasses or goggles, hearing protection, and leather footwear as required for the voltage they are working on.

Occupational Safety Instruction

- Make sure the installation is safe.
- Protect yourself and others from falls, do not install in strong winds.
- Prepare your work area to avoid injury.
- Observe the maximum permissible mechanical loads.
- Avoid the maximum permissible level of mechanical stress, before installation, make sure that weather conditions will not damage the solar panels.
- Remember that panels can sag under load under certain circumstances. In order to avoid damage to the panels due to unevenness and deformation, do not place fasteners or wires between the installation profile and the back of the solar panel.
- Make sure the panels are grounded. In order to reduce the risk of electrical shock or fire, solar panels must be grounded in accordance with safety regulations.
- Rooftop installations can affect the fire safety of a building. Incorrectly installed solar panels can be hazardous in the event of a fire. Therefore, roof panels must be installed above a fire-resistant surface. In addition, the panels must not be installed in close proximity to fire and flammable materials or gases.
- Solar panels are designed for use in temperate climates. Ensure that after installation the panels are not exposed to artificially concentrated solar radiation, immersed in water, or washed with pressurized water.
- If panels are exposed to salt or sulfur, corrosion can occur. Make sure panels are not exposed to abnormal 5 chemicals. In this regard, due to possible

emissions of harmful substances, installation in the immediate vicinity of production facilities is not recommended.

- Remove all electrically conductive jewelry during mechanical and electrical installation;
- Tools and work area must be dry
- Plug-in solar panels and connectors must be dry;
- Do not install solar panels in rainy weather;
- Always use insulated tools and insulated gloves when handling wires;
- Do not disassemble solar panels.
- Never remove manufacturer parts or labels;
- Use only serviceable solar panels, if there is damage or deformation of the solar battery, do not connect it;
- Do not lean against the solar panel sharp objects, do not paint or glue anything;
- Do not expose solar panels to artificially focused solar radiation; Other components in the system can also generate high voltage.

10. Conclusions

As a result of writing this thesis, the solar battery management system was developed and its management program was compiled.

During the course of the work, an analysis of the problem was made, on the basis of which the requirements for the final system were formulated. A functional scheme was proposed that reflects the relationship between the devices that are part of the system. On the basis of the functional scheme, the necessary elements were selected for the implementation of the functions of automated control of SPP elements. Further, on the basis of the selected devices, a conceptual diagram was constructed, which visually demonstrates the interconnections between them. The development was completed by drawing up a block diagram of the algorithm and writing the source code for it for the Arduino microcontroller in its corresponding programming language.

The received control system meets the established requirements. It provides reliability in automatic mode, high precision, low cost, safety at work and ease of use.

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