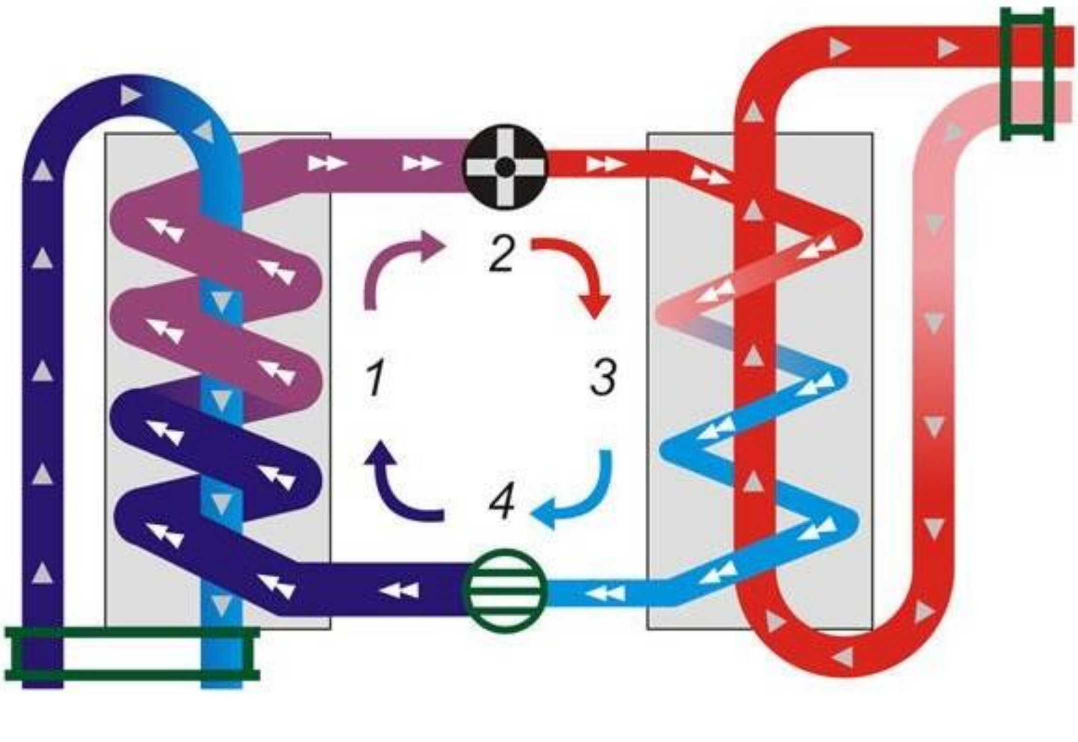
A. Zh.Sagyndykova

FUNDAMENTALS OF DIAGNOSTICS OF HEAT POWER FACILITIES AND CONTROL SYSTEMS

TEXTBOOK



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Reviewers:

Professor of the Department "Energy supply and renewable energy sources" of the Gumarbek Daukeev AUES

Aldibekov I.T.

Doc.tech.Professor,Director Of the Department of Informatization of education of Abai KazNPU

Atyhanov A.K.

kand.tech.Professor,Director Of the Department of Informatization of education of Abai KazNPU

Hasanov Kh.M.

Sagyndikova A. Zh.
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The textbook is intended for students studying in the direction of "Energy supply of agriculture" and is aimed at forming a fully developed specialist who is able to implement tasks to improve the energy efficiency of the country at various levels within the framework of the acquired competencies: from the development and adoption of laws to the direct implementation of certain technical measures.The Textbook is intended for undergraduates, doctoral students and teachers of technical universities.

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CONTENT

TERMS AND DEFINITIONS OF ELECTROTHERMIA

The following terms and definitions are used in this monograph:

Electric heating is a branch of science and technology that studies the conversion of electricity into thermal energy for useful purposes.

Electrothermal effect –the release or absorption of thermal energy due to a longitudinal temperature gradient when an electric current flows through a homogeneous conductor.

Indirect electric heating is an electric heating process in which the generated heat is transferred to the heating material.

Direct electric heating –an electric heating process in which current passes through the heated material.

Arc heating is a heating method in which heat is produced primarily by one or more electric arcs.

Induction heating – electric heating using electromagnetic induction. If you place an object made of an electrically conductive material inside a coil with an alternating current passing through its winding, eddy currents are induced in the object embedded in the coil cavity by an alternating magnetic field.

Microwave – ultra-high-frequency heating, electromagnetic radiation, including the centimeter, centimeter and millimeter ranges of radio waves (wave length from 1 m - frequency 300 MHz to 1 mm -300 GHz).

Specific energy intensity– the ratio of the lowest heat of combustion of fuel to its total volume.

Adhesion is the adhesion of surfaces of two dissimilar solid or liquid particles.

Infrared heating is a heating method based on the transfer of energy by infrared radiation.

Dielectric heating is a method of heating in which heat is mainly generated in a non-conductive body due to the movement of electric charges at the atomic or molecular level under the influence of an electric field in the frequency range from 1 MHz to 300 MHz.

Resistance heating is a heating method in which heat is generated by the Joule –Lenz effect in an electrical conductor connected directly to a power source.

Ultrahigh frequency current heating is a heating method in which heat is mainly generated by molecular motion and ionic conductivity in a non-conductive material under the action of electromagnetic waves in the frequency range between 300 MHz and 300 GHz (wavelengths from 1 m to 1 mm).

Plasma heating is a heating method that uses the thermal and/or electrical properties of an ionized gas.

Electrothermal equipment (ETO) –a device, a set of technological devices for converting electricity into heat.

Electrothermal installation (ETU) –an installation consisting of electrothermal, electrical and mechanical equipment necessary for its operation and application.

The ETU efficiency is the ratio of the energy converted to useful heat to all the electricity supplied to produce this useful heat.

An electric heater (furnace) inductor is a structural unit that includes an inductive wire.

Heating chamber –a closed heated area of the furnace where heat treatment is performed.

Heating element –a part, removable or non-removable, containing a heating conductor and devices that form an independent device.

Heating cable (wire) –a cable (wire) with high electrical resistance cores designed for heating various objects.

An electrode is a conductive part designed to make contact with a medium with a low specific conductivity.

SYMBOLS

T, t – current temperature on the Kelvin, K, and Celsius scale, °C;
T_0 – the initial temperature of the body, K;
T_c, $T_ж$ – ambient temperature, liquid, K;
$\vartheta = (T - T_0)$ – excessive temperature, K;
$\theta = T/T_0$ – the dimensionless relative temperature;
x, y, z – current coordinates;
τ – time, c;
2R – total body thickness, m;
d, D – geometric size, m;
L, A, δ – linear size, m;
F – the cross-sectional area of the body or body surface area, m^2;
q – specific heat flux, W / m^2, or heat loss, %;
q_L – linear heat flux density, W / m;
Q – total heat flow or heat output, W;
k – flat wall heat transfer coefficient, W/(m^2·K);
k_L – heat transfer coefficient of the cylindrical wall, W/(m·K);
c – specific mass heat capacity, DJ/(kg K);
ρ – material density, kg / m^3;
(cρ) – specific volume heat capacity,D J/(m^3·K);
G – flow rate of liquid, kg / s, or gas, m^3 / s;
V – volume, m^3, or volume flow, m^3 / s;
m, M, – weight of the substance, kg;
ω – speed of the substance, m / s;
a – coefficient of thermal diffusivity, m^2 / s;
λ – coefficient of thermal conductivity, W/(m·K);
α – convective heat transfer coefficient, W/(m^2·K);
E – emissive power, W/m^2;
$\varepsilon_{пр}$ – given the degree system black;
D – steam capacity, kg / s;
B_p, B_y – calculated and conditional fuel consumption, kg / s, m^3 / s.

INTRODUCTION

Energy conservation is one of the most important tasks of the XXI century, since the consumption of heat and electricity is a necessary condition for human life and the creation of favorable conditions for his life. Improving the competitiveness, financial stability, energy and environmental security of the Russian economy, as well as increasing the level and quality of life of the population is impossible without realizing the potential of energy saving and improving energy efficiency through modernization, technological development and transition to rational and environmentally responsible use of energy resources. Our society's place among the economically developed countries also depends on the results of solving this problem.

The Republic of Kazakhstan is one of the most wasteful countries in the world. The entire volume of petroleum products and oil exported by us is comparable to the energy saving potential in Kazakhstan. The prospects for energy saving in our country are huge, we only need to use energy resources efficiently. The so-called "leaks" and" costs " occur in all sectors of the economy: in housing and utilities, in industry, and even in the fuel and energy complex.

"Energy saving and energy efficiency improvement for the period up to 2020" [1] the energy intensity of Kazakhstan's gross domestic product is 2.5 times higher than the global average and 2.5 - 3.5 times higher than in developed countries. More than 90 percent of the capacity of existing power plants, 83 percent of residential buildings, 70 percent of boiler houses, 70 percent of technological equipment of electric networks and 66 percent of heating networks were built before 1990. In industry, 15 percent of fully worn-out fixed assets are used.

A long-term gap in energy efficiency levels with advanced countries is unacceptable, since maintaining the high energy intensity of the Kazakh economy will lead to a decrease in Kazakhstan's energy security and curb economic growth. The entry of the Republic of Kazakhstan to the standards of well-being of developed countries against the background of increasing global competition and the exhaustion of sources of export-raw material development requires a radical increase in the efficiency of using all types of energy resources.

In 2010 - 2018, after a long lag, Kazakhstan broke out into the world leaders in terms of reducing the energy intensity of gross domestic product. Over the years, this indicator has decreased by 35 percent, that is, on average, it has decreased by almost 5 percent per year. The main contribution to the reduction in the energy intensity of gross domestic product was made by structural shifts in the economy, since industry and the residential sector developed more slowly than the service sector, and the production of less energy-intensive products grew faster in industry [1].

The "recovery" growth in the industry allowed us to get the effect of "economies of scale" (savings on conditionally fixed energy costs as the load of old production facilities increases), but retained the high-energy-intensive raw material specialization and technological backwardness of the Kazakh economy.

Between 2000 and 2008, due to the introduction of new technologies in new construction and modernization, the energy intensity of gross domestic product decreased by an average of only 1 percent per year, or about the same as in many developed countries, which did not significantly reduce the technological gap with these countries.

The formation of an energy-efficient society in Kazakhstan is an integral part of the development of the economy of the Republic of Kazakhstan along an innovative path. The transition to an energy-efficient development option must be completed in the coming years, otherwise economic growth will be held back due to high prices and reduced availability of energy resources.

Energy saving and improving energy efficiency should be considered as one of the main sources of future economic growth. However, to date, this source has been used only to a small extent.

The solution to the problem of energy saving and increasing energy efficiency are long term, which is necessary as changes in the system of relations in energy markets and the replacement and modernization of a significant part of production, engineering and social infrastructure and its development on new technology.

One of the most important conditions is to create energy saving as a profitable business, both for companies engaged in energy saving at the professional level, and for financiers. At the same time, energy saving should be converted for energy consumers into a reasonable method of reducing costs. In a market economy, what money is willing to pay for is produced, so it is extremely important to organize the energy saving market by organizing the needs for energy-saving goods and services, and they will not be long in coming in conditions of active demand.

It is also important to provide high-quality and timely energy-saving services, establish contacts between organizations dealing with the problem, demonstrate the capabilities of industries that manufacture devices, implement technologies, provide services to the energy-saving sector, and strengthen partnerships between manufacturers and consumers of energy-saving products.

This textbook is intended for students studying the discipline "Energy supply of agriculture", which belongs to the cycle of professional disciplines. the textbook is aimed at forming a system of knowledge of scientific and technical foundations in terms of training a specialist in the operation, design and development of reliable and uninterrupted supply of rural consumers with fuel, heat, electricity, gas, warm air and water, hot water and steam.

1 CURRENT PROBLEMS OF ENERGY SAVING AND ENERGY EFFICIENCY IMPROVEMENT

1.1 Basic terms and concepts

Thermophysical properties (TFS) or thermophysical characteristics (TFS) of substances, materials and products – coefficients of thermal conductivity, thermal diffusivity, heat transfer, heat transfer, thermal resistance of heat transfer, specific volume or weight heat capacity, degree of blackness, saturation temperature.

Fuel is a substance that can be used in economic activities to produce heat energy released during its combustion[2].

Energy carrier – a substance or form of matter that is in various aggregate States (solid, liquid, gas, plasma, field, radiation). The energy of these substances, when certain conditions are created, is used for energy supply purposes.

Natural energy carrier – energy carrier formed as a result of natural processes: hydrosphere water (when using the energy of rivers, seas, oceans); hot water and steam from geothermal sources; atmospheric air (when using wind energy); organic fuel (oil, gas, coal, peat, shale), biomass.

Produced energy carrier – energy carrier obtained as a product of the production process: water vapor of various parameters of boiler plants and other steam generators; hot water; compressed air, acetylene; products of organic fuel and biomass processing, etc.

Fuel and energy resources (TER) – a set of natural and industrial energy carriers, the stored energy of which is available for use in the economic activities of enterprises, transport, housing and communal services at the current level of development of equipment and technology[3,4].

Secondary fuel and energy resources – fuel and energy resources obtained as waste or by-products (emissions) of the production process. Secondary fuel and energy resources are found in the form of heat of various parameters and fuel.

Secondary fuel and energy resources include: heated exhaust gases of technological units; gases and liquids of cooling systems; waste water vapor; waste water; ventilation emissions, the heat of which can be usefully used.

Secondary fuel and energy resources in the form of fuel include: solid and liquid waste, gaseous emissions from oil refining, oil production, chemical, pulp and paper, woodworking and other industries, urban garbage, etc.

Useful energy – energy that is theoretically necessary (under idealized conditions) for performing specified operations, technological processes, or performing work and services.

Examples of the definition of the term "useful energy»:

-in lighting systems - by the light flow of lamps;

-in power processes: for motor processes - by the working moment on the motor shaft; for direct impact processes – by the energy consumption required in accordance with the theoretical calculation of the specified forces;

- in electrochemical and electrophysical processes - by the energy consumption required for carrying out the specified conditions;

- in thermal processes - according to the theoretical energy consumption for heating, boiling, melting, evaporation of the material and conducting endothermic reactions;

-in heating, ventilation, air conditioning, hot water, and cold supply systems-by the amount of heat received by consumers or users;

-in systems of conversion, storage, and transportation of fuel and energy resources-by the amount of resources obtained from these systems.

Возобновляемые топливно-энергетические ресурсы – природные энергоносители, постоянно пополняемые в результате естественных (природных) процессов.

Renewable energy sources are based on the use of [4]:

-energy sources: solar radiation, wind energy, rivers, seas and oceans, internal heat of the Earth, water, air;

- energy of the natural movement of air, water flows and natural temperature gradients and density differences;

- biomass energy obtained as waste from crop and animal husbandry, artificial forests and algae;

- energy from the disposal of industrial waste, solid waste and sewage sludge;

- energy from the burning of plant biomass, thermal processing of waste from the forest and woodworking industries.

Power plant – a complex of interconnected equipment and structures designed for the production or conversion, transmission, storage, distribution or consumption of energy.

Rational or efficient use of fuel and energy resources is the use of fuel and energy resources that ensures maximum efficiency at the current level of technology development, taking into account their limited reserves and compliance with the requirements of reducing the anthropogenic impact on the environment and other requirements of society. The concept of "Rational use of fuel and energy resources" is General in comparison with the concept of "Economical use of fuel and energy resources" and includes:

-selection of the optimum energy mix, i.e. the optimal quantitative ratio of different used types of energy resources to install, on the site, in the shop, at the enterprise, region, industry, economy;

- integrated use of fuel, its heat, including waste products of fuel combustion as raw materials for industry (for example, the use of ash and slag in construction);

- integrated use of water resources of rivers and reservoirs;

- consideration of the possibility of using organic fuel (for example, oil) as a valuable raw material for industry;

- a comprehensive study of export-import opportunities and other structural optimizations[5].

Fuel and energy savings – a comparative reduction in fuel and energy consumption for the production of products, performance of works and provision of services of established quality without violating environmental and other restrictions in accordance with the company's requirements.

Fuel and energy savings are defined as a comparative reduction in fuel consumption, not consumption, corresponding to the expenditure part of the fuel and energy balance of a specific energy-consuming object (product, process, work and services).

Reference values of fuel and energy consumption are established in regulatory, technical, technological, and methodological documents and are approved by the authorized body in relation to the conditions and results of activities to be checked.

Non-productive consumption of fuel and energy resources – consumption of fuel and energy resources caused by non-compliance or violation of the requirements established by state standards, other regulatory acts, regulatory and methodological documents.

Energy saving – implementation of legal, organizational, scientific, industrial, technical and economic measures aimed at efficient (rational) use (and economical expenditure) Fuel and energy resources and the involvement of renewable energy sources in economic turnover.

Energy saving indicator – a qualitative and (or) quantitative characteristic of planned or implemented energy saving measures.

Energy-saving policy is a comprehensive systematic implementation at the state level of a program of measures aimed at creating the necessary organizational, material, financial and other conditions for the rational use and economical expenditure of fuel and energy resources.

Energy survey – a survey of consumers of fuel and energy resources in order to establish performance indicators for their use and develop economically sound measures to improve them[4,5].

Fuel and energy balance – a system of indicators that reflects the full quantitative correspondence between income and expenditure (including losses and balance) Fuel and energy resources in the economy as a whole or in its individual sections (industry, region, enterprise, shop, process, installation) for the selected time interval.

The term expresses a complete quantitative correspondence (equality) for a certain time interval between the consumption and arrival of energy and fuel of all types in the energy sector. The fuel and energy balance is a static characteristic of a dynamic energy management system over a certain time interval. The optimal structure of the fuel and energy balance is the result of the optimized development of the energy economy.

The fuel and energy balance can be compiled [3, 4]:

- by types of fuel and energy resources (resource balances);

-by stages of the energy flow of fuel and energy resources (extraction, processing, transformation, transportation, storage, use);

-for a single or consolidated fuel and energy balance of all types of energy and fuel and energy resources, and in General for the national economy;

-for energy facilities (power plants, boilers), individual enterprises, workshops, sites, power plants, aggregates;

-as intended (power processes, thermal, electrochemical, lighting, air conditioning, communication and control facilities);

-the level of use (with the release of useful energy and losses);

- in the territorial context and by branches of the national economy.

When compiling the fuel and energy balance, different types of fuel and energy resources lead to the same quantitative measurement. The procedure for bringing to uniformity can be performed:

-by the physical equivalent of the energy contained in the TER, i.e. in accordance with the first law of thermodynamics;

-by relative efficiency (exergy), i.e. in accordance with the second law of thermodynamics;

-by the amount of useful energy that can be obtained from the specified fuel and energy sources in the theoretical plan for the specified conditions.

Energy passport of industrial consumer of fuel and energy resources – regulatory document, reflecting the balance of consumption and indicators of efficiency of use of energy resources in the process of economic activity of object of industrial purpose and able to contain energy saving measures.

Energy passport of a civil building – a document containing the geometric, energy and heat engineering characteristics of buildings and projects of buildings, enclosing structures and establishing their compliance with the requirements of regulatory documents[5].

Energy-saving technology – a new or improved technological process characterized by a higher efficiency of fuel and energy resources.

Certification of energy-consuming products-confirmation of compliance of products with regulatory, technical, technological, methodological and other documents regarding the consumption of energy resources by fuel and energy-consuming equipment.

Energy efficiency indicator – an absolute, specific or relative parameter of consumption or loss of energy resources for products of any purpose or technological process.

Energy efficiency - the ratio of all useful energy used in the economy (site, power plant, etc.) to the total amount of energy consumed.

Efficiency-the ratio of the useful energy to the supplied; a parameter that characterizes the perfection of the process of conversion, conversion or transfer of energy.

Energy loss – the difference between the amount of supplied (primary) and consumed (useful) energy. Energy losses are classified as follows:

a) by area of origin: during extraction, storage, transportation, processing, conversion, use and disposal;

b) by physical characteristics and nature:

- heat loss to the environment with outgoing flue gases, technological products, technological waste, material entrainment, chemical, mechanical and physical underburning, cooling water;
-power losses in transformers, throttles, electrical wires, electrodes, power lines, power plants;
- loss of liquids and gases with leaks through leaks;
- hydraulic pressure losses during throttling and friction losses during the movement of liquid (steam, gas) through pipelines, taking into account local resistances;
- mechanical friction losses of moving parts of machines and mechanisms;

c) for the following reasons:

- due to design flaws,
- as a result of improper operation of the units and not optimally selected technological mode of operation;
- as a result of product defects and other reasons.

Energy intensity of production – a parameter of energy and (or) fuel consumption for the main and auxiliary technological processes of production, performance of works, provision of services on the basis of a given technological system. Practically in the production of any type of product, fuel and energy resources are consumed, and for each type of product there is a corresponding energy intensity of the technological processes of their production. At the same time, the energy intensity of technological processes for the production of the same types of products produced by different enterprises may be different.

The indicator of energy efficiency of a product is a quantitative characteristic of operational properties that reflect the technical perfection of the design, the quality of manufacture, the level or degree of energy and (or) fuel consumption when using this product for its intended purpose[6].

Energy efficiency indicators are individual for different types of products. They characterize the perfection of the design of this type of product and the quality of its manufacture. As a rule, specific indicators should be chosen as indicators of energy efficiency.

Consumer of fuel and energy resources – an individual or legal entity that uses fuel, electric energy and (or) heat energy (capacity).

1.2 Physical basics of energy saving

The fulfilment of Kazakhstan's Government objectives to improve energy efficiency, supporting energy security and competitiveness of products, seems impossible without a qualitative understanding of experts responsible for saving those physical processes and mechanisms that determine the loss of energy resources during their production, transportation and use. First of all, attention should be paid to the processes of heat energy transfer and conversion and the losses associated with these processes. To begin with, let's define the object of study – heat and the main mechanisms of its transmission.

Heat, despite the obvious nature of its manifestation, has long remained a mystery to physics. Until the mid-nineteenth century, heat was considered a kind of material substance added to a substance: it was believed that the heating of the body was associated with the addition of this substance to the body, which was called caloric. This idea was in many ways contradictory and continued to exist for a long time because no one could come up with anything better. Let us briefly consider the stages of experimental research that the modern theory of heat has gone through in its development.

The first step was taken by Benjamin Thompson, count of Rumford, who noticed that when drilling holes in metal, the temperature of the latter increased greatly. Where did the heat come from? Obviously, there were no sources of heat. Rumfoord suggested that the small metal shavings formed during drilling had a lower affinity for heat than the massive metal in which the hole was drilled. Thus, when drilling metal, heat is released, resulting in an increase in temperature. Rumfoord came up with a simple way to test this assumption.

If you take a blunt drill, he reasoned, then the chips are formed little and the temperature increase should be less. But as a result of the experiment, the temperature rose even higher. The caloric theory didn't work. And here Rumfoord took a major step forward, suggesting that heat is a property of the substance itself, and not something added to it.

Davy (1778-1829) conducted an experiment whose conditions were completely subject to the will of the experimenter. He put two pieces of ice together, placed them in a vessel from which the air was pumped out, and brought them into mutual friction. Some of the ice melted. The heat for melting could not be taken from the heat of the air.

This was the most important step: it was established that heat is a form of kinetic energy. The next necessary step was to calculate the quantitative ratio between heat and mechanical energy. Joule (1818-1889) devoted most of his life to this question. He was able to first approximate the value of the proportionality coefficient in the ratio between heat and mechanical energy from Rumford's experiments, from which it was known how much the temperature of the metal increased during drilling. But in the future, Joule designed a device on which he set quite accurately the value of the mechanical equivalent of heat (mixing water with blades, rotating the blades from weights).

So, the works of Rumford, Davy, and Joule convinced physicists that heat is a form of kinetic energy and can be transferred from one body to another. Further research has shown that heat transfer is a complex process. When studying this process, it is usually divided into three elementary methods of heat transfer: thermal conductivity, convection, and thermal radiation.

Thermal conductivity is the process of propagation of thermal energy in direct contact of individual particles of a body that have different temperatures (recall that temperature is a measure of the kinetic energy of body molecules). Thermal conductivity is caused by the movement of microparticles of the body.

Convection is the process of transferring heat energy when a liquid or gas moves in space from an area with one temperature to an area with another. Convection is only possible in a fluid medium.

Thermal radiation is the process of propagation of thermal energy using electromagnetic waves. With thermal radiation, a double transformation of energy occurs: the thermal energy of the radiating body passes into radiant energy and back-radiant energy, absorbed by the body, passes into thermal energy.

In nature and technology, the elementary processes of heat propagation – thermal conductivity, convection, and radiation – very often occur together. Thermal conductivity in its pure form mostly occurs only in solids. Convection is always accompanied by thermal conductivity, since when a liquid or gas moves, individual particles with different temperatures inevitably come into contact. The combined process of convection and heat conduction is called convective heat exchange[4,5,6].

In engineering, heat exchange processes often occur between various liquids separated by a solid wall. The process of transferring heat from a hot liquid to a cold one through a wall separating them is called heat transfer.

1.3 Current problems of energy saving and energy efficiency improvement

The problems of energy efficiency, along with improving the environmental safety of production and strengthening social responsibility, are becoming the Central object of research in the modern theory and practice of industrial enterprise management. The dynamics of implementation of energy efficiency projects in international companies increases every year, spreading to such areas as the design of energy-efficient buildings and structures, elements of industrial infrastructure.

The implementation of such projects is also a priority for Kazakhstani companies of various types of economic activity. Increasing the relevance of energy conservation and the use of alternative energy sources in connection with global and local resource crises has led to the formation of a developed system of international standardization,which is aimed at regulating and disclosing the content of the principles of building energy-efficient business processes and developing a rational policy of enterprises.

Issues of improving the universal principles of energy efficiency in individual industries and developing tools for economic analysis of the energy infrastructure of industrial enterprises based on the balance method (drawing up energy balances) using various coefficients and finding new ways to work with personnel remain relevant[4,6].

The main consumer of electric energy is industry, as it happened historically. This, in turn, determines the location of enterprises that generate electricity near its consumers. However, if a large amount of electricity is required, it is produced at generating stations located in places with large reserves of energy resources. In this case, the transmission of electricity is carried out via high-voltage lines capable of transmitting high power. With these power lines, generating stations are combined into energy systems, which allows you to create a reliable and cost-effective power supply. Industrial centers concentrate a number of enterprises in various industries, as well as cities and urban-type settlements. Existing power supply schemes meet all the requirements for providing power to the formed conglomerates.

Electricity supply to agricultural production and rural localities looks somewhat different. Here it is necessary to supply electric energy to a large number of low-power consumers located unevenly on the vast territory of the Republic of Kazakhstan. The length of electric networks per unit of power is much higher than this value in comparison with other branches of the national economy. The cost of electricity supply in agriculture is up to 75% of the total cost of electrification, including the cost of purchasing working machines [7].

Such a large cost figure becomes a problem for the electricity supply of agriculture. Its profitability can be solved only by efficient use of electric energy in agricultural production and in the everyday life of the rural population. First of all, this should be achieved by complying with all the requirements of rules and regulations aimed at ensuring the required quality of electricity and its reliable supply to the end user. Following this postulate, you can significantly reduce the cost of electricity and additionally create a reserve in its consumption. The complexity and high cost of devices for maintaining high voltage quality in rural networks allows for voltage deviation in the range (+/–7.5%). However, the voltage deviation should be the same as in industrial plants (+/-5%) at complexes for the production of agricultural products on an industrial basis.

A professionally designed power supply system that provides for optimal power flows with the right load of power lines and the right choice of places to install voltage regulators under load is a guarantee that agriculture will become more cost-effective and competitive with the release of its products to foreign markets.

The quality of electricity, determined by voltage and frequency deviations, allows the operation of electric energy receivers with nominal parameters. Deviation of frequency and voltage above acceptable parameters sometimes makes it impossible for them to work. The frequency, as a parameter, is accurately maintained on the units of power stations, where automatic speed controllers are installed, which stabilize it within the specified limits.

The situation is different with the constant voltage in the networks connected to power systems. The presence of a large number of transformations in rural electric networks, even if the correct cross-section of power lines is selected, sometimes causes large voltage losses in the networks, which leads to a significant decrease in voltage for consumers. The solution to this situation is to install voltage regulators under load, or install compensating devices in the form of capacitor banks at transformer substations. In the conditions of agricultural production, high-power asynchronous short-circuited motors are increasingly used, which reduce the voltage in the network when starting. Here you also have to introduce restrictions on the level of voltage drop. For a starting engine, it should not exceed 30%, and for other running engines, it should not decrease by more than 20%.

Also important is the asymmetry of loadings on phases in lines with a voltage of 0.38 kV. This especially affects the operation of lighting and power electrical receivers. Lighting devices, falling into different conditions in phases, lose their light output, or dramatically reduce their service life. Electric motors, falling into unbalanced phases, reduce their torque, and therefore lose power. To eliminate phase asymmetry, first of all, it is recommended to use transformers with a "star-zigzag" connection scheme.

Distortion of the voltage sinusoidal shape is determined by the presence of harmonic components in the shape of the curve. It also negatively affects the operation of electrical equipment. This creates additional power and energy losses, both in electrical equipment and in networks.

Reliability of power supply is an integral part of the performance indicator of the power supply system. Any power outage in the conditions of development of large industrial complexes, whether it is planned or emergency, causes huge damage to the consumer and the energy system itself.

1.4 Energy survey in the power supply system of an industrial enterprise

The transition to an innovative development model leads to rapid development of scientific and technological progress and modernization of the resource base of enterprises.

Energy saving is a complex, continuous process that should become the core of the enterprise. By itself, energy-saving equipment or technology without analyzing the impact on the process can lead to the opposite effect and increase the energy intensity of products. As an example, wall insulation and installation of double-glazed Windows are energy-saving measures. But not well-thought-out ventilation of the room or its absence leads to the fact that the staff is forced to open the Windows even in the cold season. This can lead to an increase in the load on the heat system and reduce the positive effect to zero. The introduction of energy-saving technologies must necessarily be accompanied by a comprehensive analysis and monitoring of the effect of implementation[8].

Positive aspects are accompanied by a number of negative aspects. They do not allow you to fully get a positive economic effect from the introduction of high-tech technologies in the production process.

The purpose of the technologies is to increase the level of energy efficiency of the enterprise and reduce the annual cost of energy resources in production. The reduction should be 45 annually by 3-5 % in relation to the reporting year.

Energy saving and improving energy efficiency should be considered as one of the main sources of future economic growth. At the same time, the effect that can be obtained through technological and organizational measures is evaluated. Also by improving the management system for energy saving and energy efficiency (Fig. 1.1.).

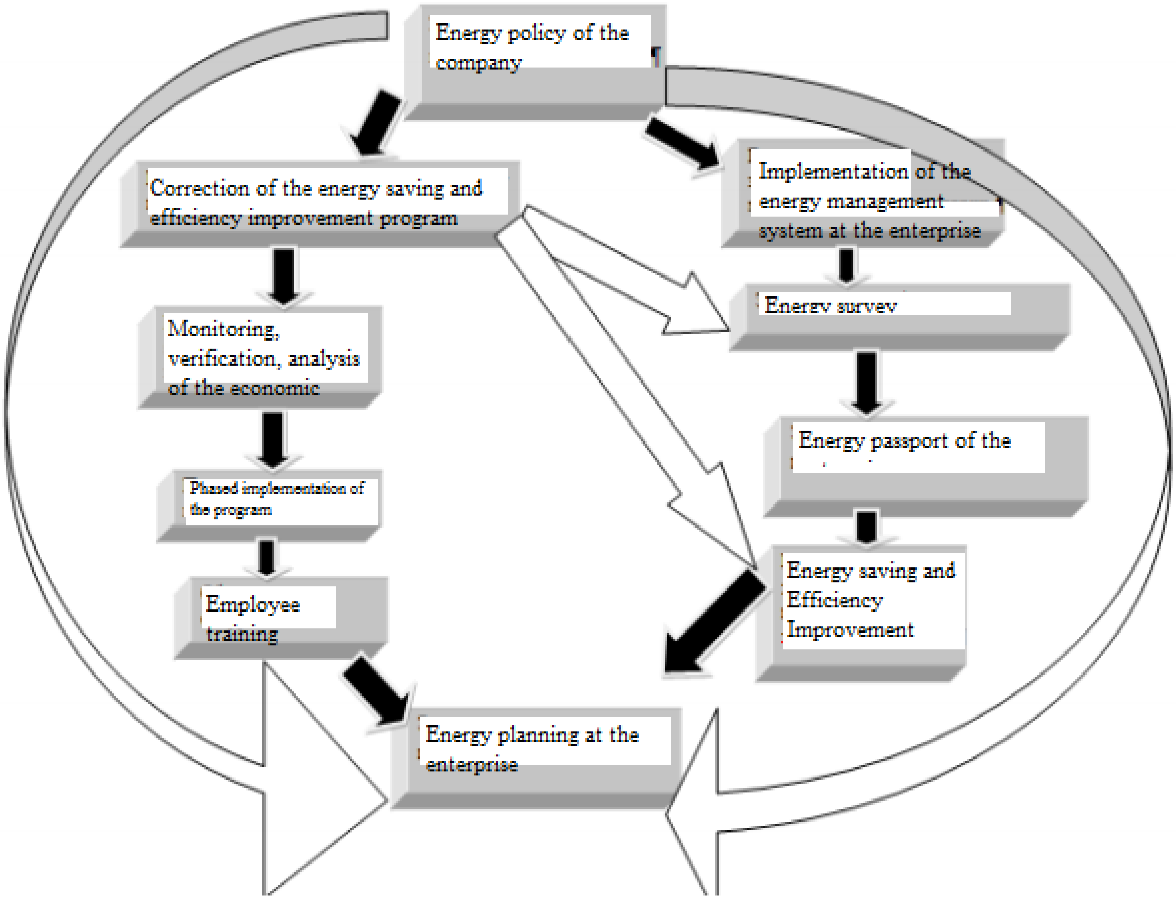


Figure 1.1-Energy saving and energy efficiency improvement systems in an industrial enterprise

The main share of expenses for industrial enterprises of heavy industry is accounted for by electricity. Accordingly, we will consider the main measures to save energy and improve energy efficiency in the field of transmission, distribution and consumption of electric energy.

Technical measures:

- introduction of an automatic control system for outdoor and street lighting;
- introduction of cost-effective ways to control the operation of fans;
- replacement of outdated transformers with modern ones;
- replacement of outdated electric motors with modern ones;
- use of frequency control systems in electric motor drives in ventilation systems, pumping stations and other objects with variable loads;
- modernization of transformer substations taking into account power

consumption;

- switching from traditional light sources to led lighting;
- reactive power compensation for consumers;
- - application of surge transformers;
- ensuring the optimal load of transformers (excluding both overloading and underloading – less than 30%), etc.
- ensuring the normative quality of the consumed electric energy.

Organizational measures:

- appointment of a person responsible for energy saving measures;
- training of personnel responsible for the provision of energy efficiency measures;
- modernization of the company's operating procedures and improvement of lighting, ventilation and water supply systems;
- introduction of schedules for switching on and off ventilation, heat curtains;
- conducting explanatory work with employees on energy saving issues;
- development and introduction of a system to reward employees of the institution for actions to save energy and improve energy efficiency;
- improvement of technical knowledge in energy saving issues for certain categories of employees of the enterprise.

The energy saving system at the enterprise must constantly monitor the process of energy consumption and make appropriate adjustments to the energy saving program. For an enterprise, energy conservation should be a continuous process. This process is subject to the company's management system. This will make both the process of improving energy efficiency and the overall operation of the company sustainable. The integrated energy saving and energy efficiency system implemented at the enterprise includes such sections as energy survey, energy monitoring and energy management. This system creates prerequisites for the implementation of energy service contracts for technical and technological modernization of the enterprise [6,7,8].

2 FEATURES OF POWER SUPPLY TO AGRICULTURAL ENTERPRISES

2.1 Improvement of agricultural enterprises in the conditions Republic of Kazakhstan. Probabilistic loads of agricultural consumers.

Electrification, i.e. the production, distribution and use of electricity, is the basis for the sustainable functioning and development of all industries and agriculture of the country and the comfortable life of the population.

Experience in the development of electrification has shown that reliable, high-quality and cheap power supply is possible only from large regional power plants United in powerful power systems. The generation of the cheapest electricity at large district-scale power plants and its transmission via long-range transmission lines is due to the high concentration of electricity production and the possibility of placing power plants directly at cheap energy sources - coal, shale, and large rivers.

On the vast territory of our country, there are areas where it is economically impractical to connect the networks of the unified energy system. There should be built modern rural power plants with an enlarged capacity of about 1000 kW or more, diesel with full automation of operation, as well as hydraulic. Small, fully automated diesel and petrol installations are only needed in sparsely populated areas [9].

In the world, there is an increased interest in the use of non-traditional, renewable energy sources (nie), which include wind power stations, solar power stations, hydraulic, bioelectric stations that work on agricultural waste, and others. The share of renewable energy sources in the world's fuel and energy balance is about 20 %, including hydroelectric power-about 26 %, solar energy-6%, wood fuel-49%, wind energy-1.8%, and waste from enterprises-15% [9,10].

In Kazakhstan, there are opportunities to obtain electricity from nvi. Research and development in this area is being intensively conducted, and it is expected that in the future the share of electricity received from nvi will be up to 10%.

Agriculture receives its electricity mainly from energy systems. Air lines cover almost all localities.

Electricity consumption for agricultural production is determined on the basis of data on specific rates of electricity consumption per unit of production. The main consumers of electricity in agricultural production are livestock and poultry farms and complexes, as well as greenhouses, greenhouses, irrigation installations and other consumers (workshops, grain dryers, etc.).

For an approximate assessment of prospective electricity consumption for the production needs of agricultural consumers, you can use generalized indicators of specific electricity consumption. Electric loads in agriculture are a constantly changing quantity: new consumers are connected, the load on entering homes is gradually increasing, as the saturation with household appliances increases, at the same time large livestock complexes cease to exist, giving way to small farms, etc. If the electric load increases, the capacity of the electric networks becomes insufficient and there is a need for their reconstruction. In this case, some of the overhead lines are replaced with underground cables or overhead lines with insulated self-supporting wires [9]. The main advantage of such networks is high reliability and long service life. Work is underway on the reconstruction of electrical networks using self-supporting wires and cables. During the reconstruction, measures are being widely implemented to improve the reliability of electricity supply to rural consumers, which is still far from sufficient.

Electric networks in rural areas usually feed a large number of different consumers of electric energy, which is understood as a receiver or a group of receivers of electric energy, united by a technological process and located in a certain territory. A receiver of electrical energy (electric receiver), in turn, is called an apparatus, unit or mechanism designed to convert electrical energy into another type of energy.

The following electricity consumers are located in rural areas:

- residential buildings of workers and employees in localities, farms;
- hospitals, schools, clubs, shops, bakeries, laundries, and other businesses that serve the public;
- production consumers of the farm (livestock farms, grain cleaning stations, greenhouses, storage of agricultural products, mills, garages, boilers, etc.);
- enterprises of the agro-industrial complex, grain receiving points, enterprises for processing agricultural products (dairies, canneries, meat processing plants, etc.);
- other consumers, including industrial enterprises.

The electric load is continuously changing, following the peculiarities of the structure of agricultural production and employment of the rural population, which are not constant in nature, associated with both seasonality and employment during the day. Some consumers are turned on, others are turned off. This is a characteristic feature of farming, which is not at all like the work of industrial production [10].

In terms of electricity supply to agriculture, it is necessary to take into account its features, which are associated with a large dispersion of electricity consumers. The housing stock in rural areas consists of small subsidiary farms, which have a rural population and cover a large area. The electricity consumption of such farms is low. However, the presence of large agricultural complexes generally changes the picture of power supply, since the capacity of these complexes can reach hundreds or thousands of kW. Therefore, both individual and group load schedules need to be compiled for accurate information about the electricity consumption of an agricultural area. The group schedule is made up of individual ones.

Thus, a thorough study of electrical loads in agriculture is a prerequisite for creating power supply schemes that meet modern requirements. We will consider a partial study of these loads, which is primarily reduced to determining the design loads, i.e. the highest values of total power for consumers or in the electrical network for a period of 0.5 hours at the end of the design period [11,12].

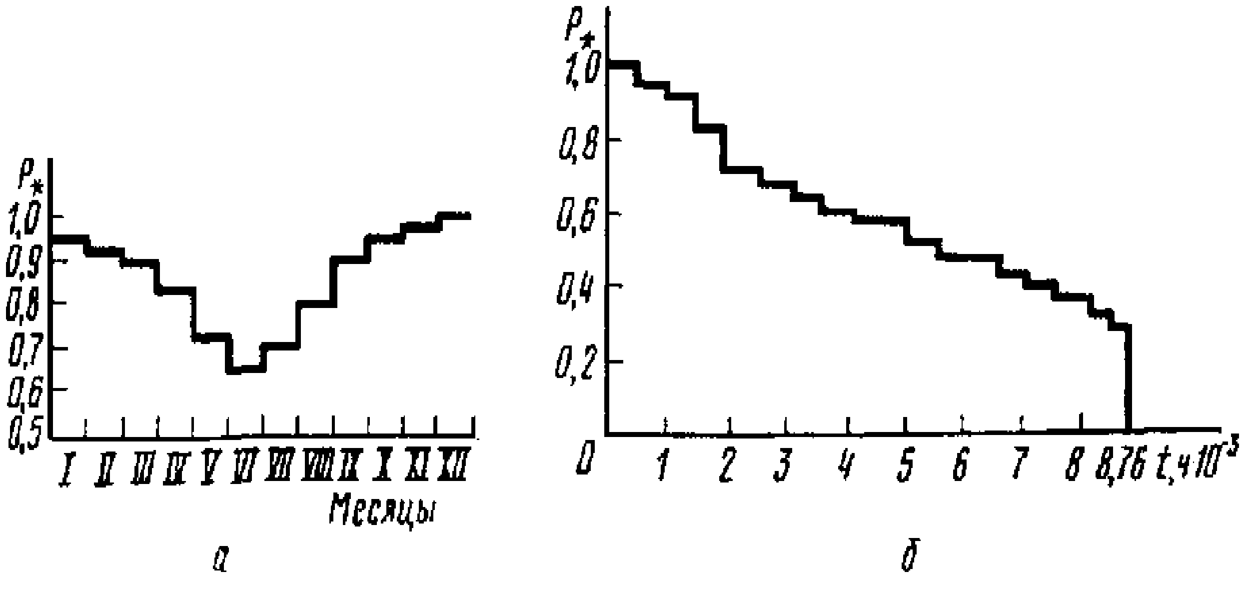
The load graph is called the dependence of the active *P*, reactive *Q*, or total *S* load power on time:

$$P(t) = \sum p_i(t); \qquad Q(t) = \sum q_i(t); \tag{2.1}$$

$$S = \sqrt{P^2 + Q^2}; \qquad I = \frac{\sqrt{P^2 + Q^2}}{\sqrt{3} \cdot U_n}. \tag{2.2}$$

Load schedules can be daily or annual.

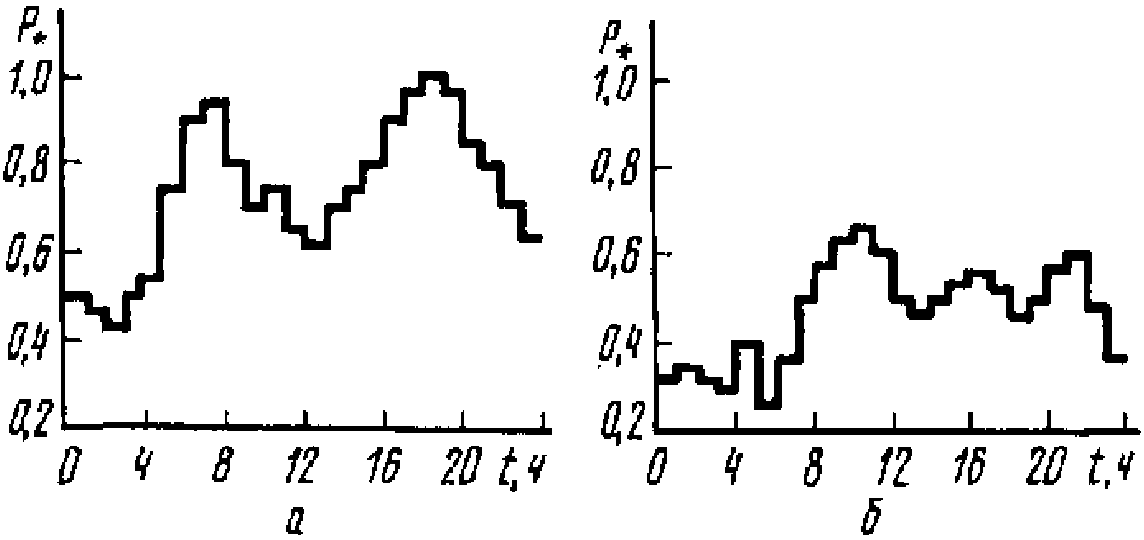
Distinguish between daytime S_D and evening S_B maximum loads of a consumer or group of consumers. The calculation period is the time elapsed from the moment the installation is put into operation until the load reaches the calculated value. In rural electrical installations, the duration of this period is assumed to be 5 to 10 years. It is also necessary to know the power factor (*cos* φ) of the calculated loads, which is determined by the active and reactive power metering devices.



а - by month of the year; *б* - by duration.

Figure 2.1 - The annual load curve

For practical purposes, the annual load schedule by duration is convenient (figure 2.1. b). In this graph, the abscissa axis is used to set the time (8760 hours per year), and the ordinate axis is used to set the minimum load that corresponds to this time. The annual duration schedule is based on daily schedules (figure 2.2) for all days of the year.



P* — power in relative units (relative to the maximum).
Figure 2.2 - Daily load schedules for winter (a) and summer (b) days

These changes are usually random, but they are subject to probabilistic laws that can be established with great accuracy if there is a large amount of experimental data used in determining them[12].

2.2 Sources of power supply for agricultural production. Various power supply schemes

Improving the efficiency of agricultural production is inextricably linked with the development of energy-saving energy supply systems. They significantly affect the reduction of the cost and energy intensity of agricultural products.

In perspective, due to the necessary growth of agricultural products, the scale of consumption of fuel and energy resources (FER) for these purposes will also grow. Thus, 1% of the increase in gross agricultural output accounts for up to 2 % of the increase in energy consumption.

The agricultural sector and especially its production is a major consumer of fuel and energy resources in stationary processes in the amount of about 10 million tons of conventional fuel. Of these, more than 60% of fuel and energy resources are used in heat supply systems for production facilities. For example, fuel and energy consumption is expected to grow by 20-25% by 2020 [12,13].

There is a direct link between production and energy consumption, the share of which in its cost increased from 3-8 % to 15-30 %, and for some types of agricultural facilities (greenhouses, poultry farms, etc.) - up to 30-50% or more. Of course, this is caused, among other things, by the faster growth of tariffs and prices for electricity and fuel in comparison with prices for agricultural products.

Therefore, there is an urgent need for economical use of electric and thermal energy. And here the priority and most effective use of systems and technical means of energy supply of a decentralized type.

Providing a microclimate is one of the most energy-intensive processes in the energy supply systems of livestock farms. This is used for up to 60% of the total energy costs of the facility as a whole. Reserves for reducing energy consumption – precise automatic control of temperature and humidity conditions, as well as the use of heat from the removed air. The use of heat exchangers of the recuperative type allows you to save energy consumption in microclimate systems up to 50%.

Currently an important priority of the strategy of industrial-innovative development of Kazakhstan for the period till 2020 is the reduction of costs of production and use of energy by introducing energy saving technologies and equipment, allowing the use of renewable energy sources (RES), especially because 2019 was announced by the President of the Republic of Kazakhstan N. Nazarbayev year of saving. The use of new environmentally friendly alternative energy technologies is particularly relevant in the run-up to Kazakhstan's upcoming ratification of the Kyoto Protocol to the UN framework Convention on climate change and our country's accession to the WTO.

Here are just a few figures describing the intensity of innovation processes in the world in relation to alternative energy sources: in the US, 275 million dollars were allocated from the Federal budget for such developments in 2018, in Japan - about 273 million dollars annually, and the European research budget exceeds 500 million.

The main direction of investment in the Republic of Kazakhstan should be aimed at:

1) development and implementation of wind power plants (wind turbines) in the energy supply systems of various facilities in the Republic of Kazakhstan.

All over the world, much attention is paid to wind power. They develop international programs for the use of wind energy in industry and agriculture. Wind power stations are widely used in Denmark, the USA, Holland, Germany, England, etc. There are more than 100 thousand people in the world. Wind farms, including 30 thousand wind farms in the USA.

Wind power can be a source of electricity supply for areas that are remote from high-power grid networks. Wind is one of the unconventional sources of energy. It is established that modern wind power plants can be effectively used in areas with an average annual wind speed exceeding 3...5 m / s.

2) use of water resources energy - construction of mini-hydroelectric power stations for Autonomous power supply of remote settlements and farms in the Republic of Kazakhstan [14].

Hydraulic power plants (HPP) have a number of advantages over thermal power plants. The cost of electricity generated at them is lower, and the consumption of electricity for their own needs is many times less than at thermal power plants. The start-up and loading of the hydrogenerator take place within a few minutes, in addition, hydroelectric power plants use renewable natural resources. The disadvantages of hydroelectric power plants include: the high cost and long terms of their construction, additional costs for possible relocation of residents from flooded land, preparation of the reservoir bed, irrigation facilities, as well as damage caused by flooding of agricultural land.

3) development and implementation of energy-saving technologies using solar energy in the energy supply systems of various facilities in the Republic of Kazakhstan.

The earth's surface receives solar energy (SE) during the year, equivalent to the energy contained in 1.22 * 1014 t. t., which is hundreds of times (5·102) higher than the reserves of organic fuel (6·1012 t.t.). Annually, the Earth receives about 4.2·1014 kW·h., and the entire population of the Earth in 2007 was spent (for the year) 94·1012 kW·h. Thus, the solar energy received by us is many times higher than the energy needs of mankind [14].

The use of SE is associated with certain difficulties, which include: the low density of the solar flux; the variability and discontinuity of the receipt of SE over time; the dependence of this flow on the geographical location of the radiation receiver, etc. Conversion of solar energy into electrical energy can be carried out according to two basic schemes: thermodynamic method and photo elements. Photoelectric (direct) conversion of SE to electrical energy is based on the features of the electronic conductivity of dielectrics. Currently, it is one of the priority areas for its use.

Development and implementation of energy-saving technologies using heat pump units (HPU) in heat supply systems of facilities in various climatic zones of the Republic of Kazakhstan. Heat pump installations are the only installations that produce 3 to 7 times more heat energy than they consume electric energy per compressor drive and are therefore considered the most efficient sources of high-potential heat [15].

Especially in the last two decades at the turn of the 20th and 21st centuries, the scale of introduction of heat pumps in the world is literally staggering.

For comparison, in Russia there are about 350 heat pumps-less than 0.1% used in the world, and in the Republic of Kazakhstan-only about a dozen units that are used practically in agriculture for processing food (milk, cheese, canned food, etc.), as an alternative source of heat in the heating and hot water supply system of residential, civil and industrial buildings. Potential consumers of the offered products are numerous farms in various regions of the country, cottages in rural areas, remote from the main lines of district heating, where as autonomous sources of heat are applied boilers for liquid and gaseous fuels, electric boilers, etc. Here we can see how much you can save electricity, therefore, incur lower costs for energy resources, reduce the environmental burden on the environment, reduce electricity tariffs, and increase the welfare of the agricultural population.

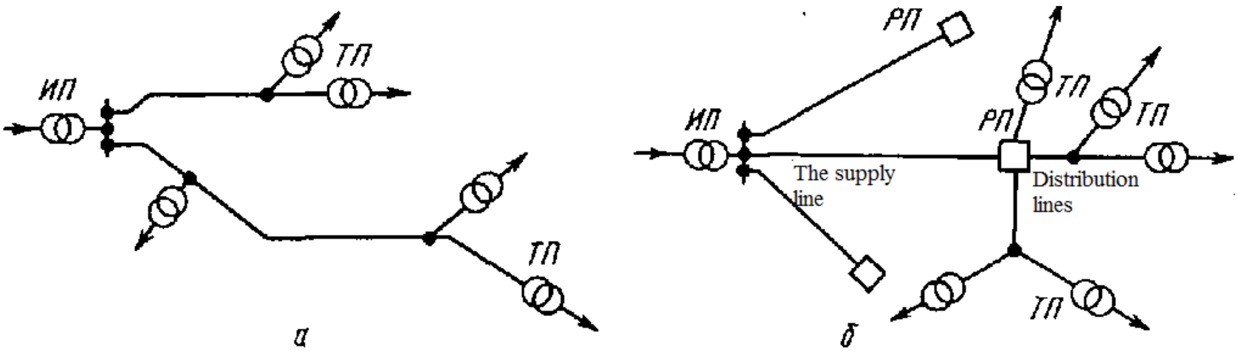
Over the past 50 years, there has been a growing relationship between the fuel and energy complex (FEC) and the agro-industrial complex. The agri-food complex is becoming more energy-intensive. The consumption of various types of energy resources in agriculture increases under the influence of the growth of mechanization of crop production and animal husbandry, increasing electricity consumption in rural housing and utilities.

Energy consumption is also increasing in industries that produce agricultural and food products. We can assume that the inevitable strengthening of the technological, economic and organizational relations of agriculture and energy will lead to a deepening of the crisis in the agro-food complex in the reduction of volume of production or cost of energy. Due to the fact that the structure of agricultural production will shift towards developing countries, which still have a lower level of energy consumption, it can be expected that the growth of agricultural mechanization will lead to a significant increase in energy demand. It will increase the need to enter new capacities at generating stations, the need to build distribution networks, both high and low voltage [14,15].

The traditional scheme of electricity generation and consumption is a complex process that is regulated according to all the laws of the economy.

Electric power is generated mainly by large power stations that are integrated into energy systems.

The part of the power system that consists of generators, switchgears, step-up and step-down transformer substations, electrical networks, and power receivers is called an *electrical system*.



а - distribution; *б* - supply.
Figure 2.3 - Electrical network diagrams

Electrical networks are parts of an electrical system consisting of substations and power lines of various voltages.

Depending on the purpose of the electric network is divided into distribution and supply.

A distribution network is an electrical network that supplies electricity from a power source (IP) to consumer TP or to consumers themselves (figure 2.3 a), if it is a low-voltage line.

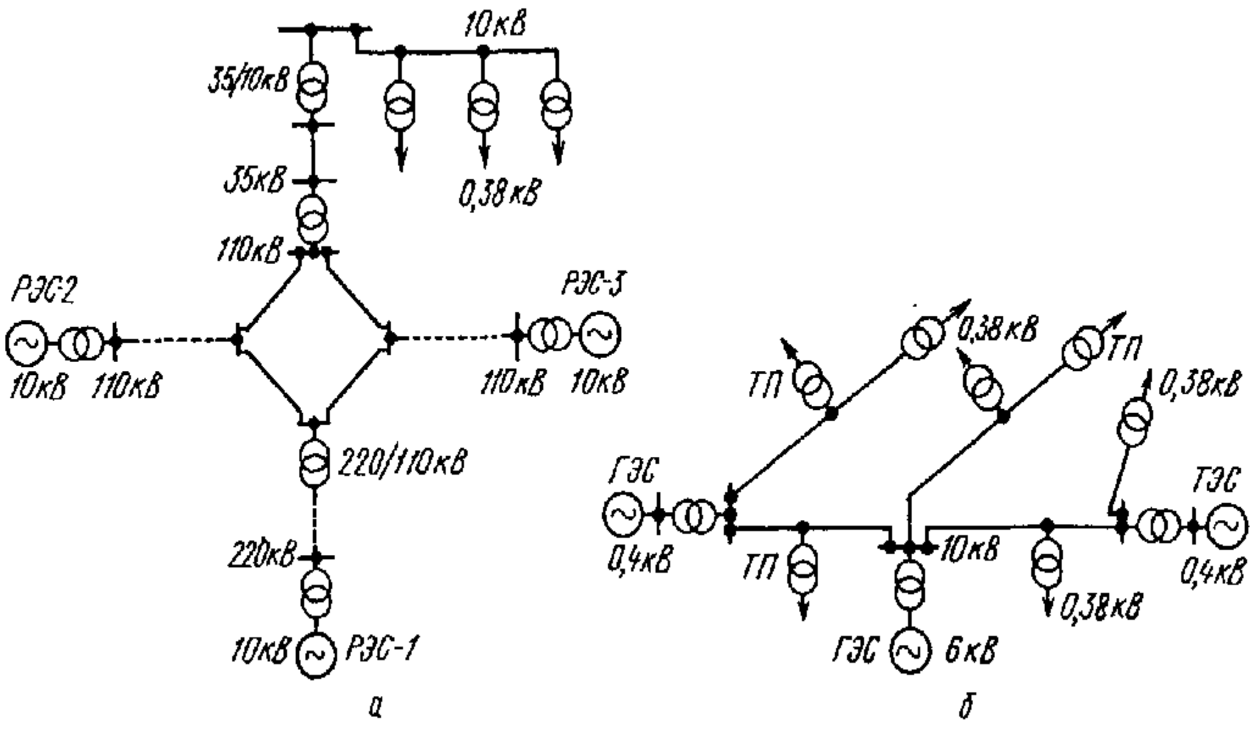
The power supply network is called (figure 2.3, b), which supplies electricity to the distribution points of the RP or substations. Figure 2.3, *a* shows a schematic diagram of a small electrical system consisting of three district power stations. [15].

The generator voltage of power plants is 10 kV (can be up to 24 kV). It is increased at the most remote station to 220 kV, and at the closest station to 110 kV (figure 2.3, a), and then the energy is transferred to the common ring with a voltage of 110 kV. At the same time, a 220/110 kV substation was built at the end of the line from the remote station. In addition, the system usually has communication lines with other systems (not shown in the figure).

Lines with a voltage of 35 kV are fed from the 110 kV common ring through 110/35 kV step-down substations. One of these lines is shown in the drawing above. These lines supply power to smaller substations at 35/10 kV. 10 kV distribution networks with step-down transformer points diverge from substations.

At transformer points, the voltage is lowered from 10 K to the working-380 V. Thus, electrical energy is transformed several times before it reaches the consumer, which necessitates the construction of a large number of transformer substations. The connected systems form the systems of separate zones of the country, and then the Unified energy system of Kazakhstan.

Figure 2.4 b shows a diagram of the rural electrical system. It consists of two hydroelectric power stations and a thermal power plant (TPP) operating on a common network of 10 kV.



a - small; *б* - rural.

Figure 2.4 - Diagrams of small electrical systems

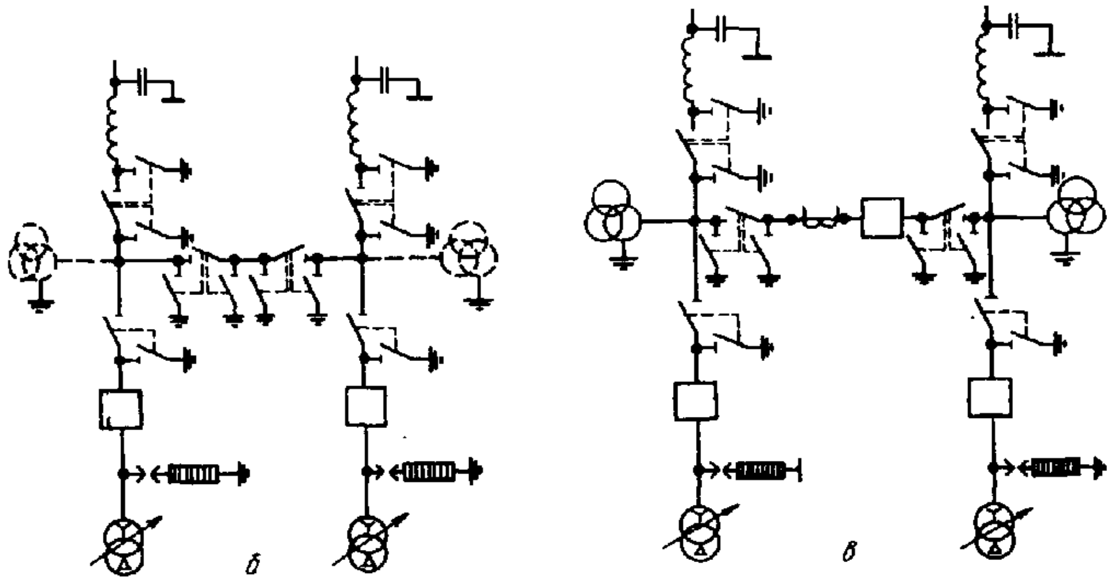
Low - voltage generators (400 V) are usually installed at small stations, and high-voltage generators (10 kV) are installed at larger ones. In this and in the other case, electric power stations connected to the network through step-up transformer substation. Consumers receive electrical energy either directly from the buses of power plants, or from a line connecting individual stations. Rural systems are connected to powerful electrical systems. In some remote rural areas, there are still single rural power plants that are not connected to others. At such stations, generators are usually installed at a voltage of 400 V, which is increased to 10 kV. At the same time, electricity is distributed throughout the district[15].

2.3 Basic schemes of centralized power supply. Nodal and district substations and their connection schemes

For economical transmission and distribution of electricity, it is necessary to convert it (increase or decrease the voltage).

An electrical installation designed for converting and distributing electricity, consisting of transformers, switchgears, control devices, and other auxiliary structures, is called a transformer substation. In agricultural areas mainly use regional transformer substation (RTS), which provides a decrease in voltage from 35...220 kV, in which electricity is transmitted from the main

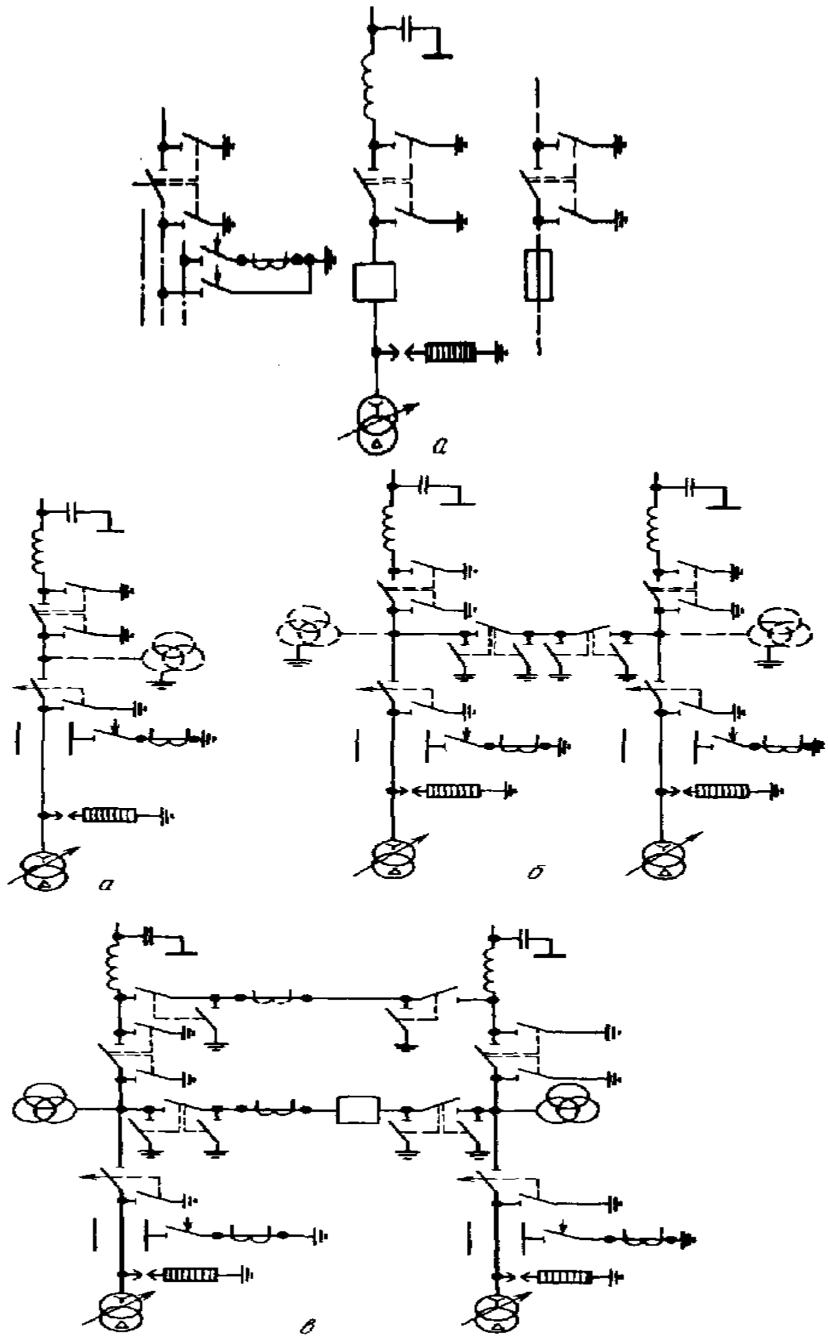
Central source of power supply of the power system, up to 6...35 kV (first to 10 kV) for distribution in the area, and consumer substations (CS) provides a voltage with 6...35 kV to 0.38 kV power distribution between consumers and passing it on to the current collectors. A part of a substation intended directly for receiving and distributing electricity and containing switching devices, busbars, protection devices, automation and measuring devices, as well as other auxiliary equipment, is called a switchgear (SG) [13,15].



a - block "line-transformer" with a switch (fuse-dotted line, separator-dashpoint); б - two blocks with switches and a non-automatic jumper on the side of the lines; *в* - bridge with switches on the jumper and in the transformer circuits, but more reliable and flexible in operation (it is allowed to turn off and on the loaded transformer, as well as turn it off in case of damage without additional operation of the head switch of the supply line).

Figure 2.5 - Main connection diagrams for 35 kV voltage SG

Figures 2.5 and 2.6 show the main typical circuits of the RC for voltage 35...110 kV (main circuits of electrical connections, i.e. the set of main equipment of the primary circuit with all connections made between them). Block diagrams (figure 2.5, a, b and figure 2.6, a, b) are used at dead-end or branch substations connected to lines with one-way or two-way power supply. The circuit of the "line-transformer" block with fuses (figure 2.5, a) was previously used for a voltage of 35 kV.



a – "line-transformer" unit with separator; *б* - two blocks with separators and a non-automatic jumper on the side of the lines; *в* – bridge with a switch in the jumper and separators in the transformer circuits.

Figure 2.6 - Main wiring diagrams for 110 kV RC

The circuit of the "line - transformer" block with a separator (figure 2.5, a and figure 2.6, a) is used to automatically disconnect the damaged transformer from the line feeding several substations, and for a voltage of 35 kV it was also used when it was impossible to use fuses.

When using short-circuit breakers with separators, you can use relay protection and eliminate the disadvantages inherent in fuses. When they are installed instead of switches on the high-voltage side of the substation, its cost is reduced, although at the same time protection becomes more complicated and the operation of the switch on the head section of the supply line becomes heavier. Therefore, at 35/10 kV substations, it is recommended to use a switch on the higher voltage side. This circuit is more expensive than with a fuse or separator. At 110 kV substations, given the high cost of 110 kV circuit breakers, circuits with short-circuit breakers and separators are widely used.

The diagrams shown in figures 2.5, b and 2.6, b are two "line-transformer" blocks with a non-automatic jumper on the side of the supply line.

With one line and two transformers, disconnectors in the jumper and lines can be omitted. These schemes are usually used if substations with a voltage of 35 ... 110 kV are connected to parallel lines on branches or serve as end lines. In the scheme with a repair jumper from disconnectors, you can connect both transformers to one line when repairing the second one. Voltage transformers are installed if there are appropriate justifications[16].

Schemes of substations of all voltages should be carried out based on the following main provisions: the use of the simplest schemes with a minimum number of switches; the desirable use of a single busbar system with its division into sections; separate operation of lines and transformers; the use of block schemes and silent deep-entry substations; the use of automation within reasonable limits.

At the inputs of 6 - 10 kV substations and at the secondary voltage outputs of GPP and PGV transformers, switches should be installed to protect the transformers and automatically turn on the reserve.

When partitioning using disconnectors, two disconnectors should be installed in series, thereby creating conditions for personnel to work on the disconnected section when the other section is working.

The substation circuit must be executed in such a way that when one of the transformers is disconnected, the power supply to the electrical receivers of the associated technological process connected to the busbars of this transformer is turned off together with it. At the same time, the operation of parallel technological processes will not be disrupted.

To reduce short-circuit currents in 6-10 kV networks, transformers with a split secondary winding should be used, which is more appropriate than using reactors. In the case of using reactors, you should not get carried away with excessive editing, as this leads to an increase in voltage deviation, especially in the case of electric receivers with sharply alternating shock loads.

The capacity of all electrical devices in the current transmission circuit must ensure the passage of maximum power in the post-accident mode, i.e. when one supply line or one transformer is disconnected[14,16].

At present, when designing and constructing substations, it should be borne in mind that in order to reduce the area occupied by substation equipment, based on significant material costs for the purchase of land plots, modern types of electrical equipment should be used to the maximum. Dry transformers are widely used, which eliminates the use of transformer oil and, in turn, the lack of oil economy at substations. However, the operation of such transformers imposes increased requirements for their protection from environmental influences and compliance with the thermal regime in a more stringent framework. Oil switches have long been replaced by modern small-sized vacuum and gas switches with improved technical characteristics. All this together makes it possible to make electrical substations several times smaller in terms of occupied area. The modern electrical industry has almost completely switched to the manufacture of the above equipment.

Attention should be paid to distribution networks with a voltage of 0.4-20 kV, based on the following considerations. Recently, there has been a steady increase in electricity consumption in the municipal sector of the village. This is due to the fact that production from the public sector of the village is transferred to the sphere of personal subsidiary farming and to peasant farmsteads. Electric loads are expected to increase 2-4 times in this regard. Under these conditions, electricity supply will be decentralized and the distribution network will need to be expanded. To this end, it is necessary to create a cost-effective, in all respects, scheme that would meet the minimum costs during the design period of operation, provide the necessary throughput taking into account the growth of loads with proper quality and reliability of power supply, have high mechanical and electrical strength over a wide temperature range, high resistance to adverse weather conditions and ensure environmental safety.

More than 30 years ago, scientists were tasked with developing a new type of overhead power lines. As a result, a system using wires with a protective cover appeared. The championship belonged to Scandinavian scientists. Since 1997, Kazakhstan has introduced a wire of the type SIP-1 and SIP-2 for a voltage of 0.4 kV and SIP-3 for a voltage of 20 kV., similar in characteristics to the Scandinavian one. The attractiveness of these wires consisted of the following conditions: the wires are protected from splashing; they practically do not form ice; they are not recyclable, which eliminates their theft; they significantly reduce the size of the lines; they create simplicity of installation work and reduce their time [16,19].

2.4 Rural power stations. Types of electric power sources and their application in different climatic zones

Autonomous permanent power plants are being built in sparsely populated areas that are not covered by power grids. They are considered rural if more than

50% of the load is made up of agricultural consumers. Primary engines at rural stations can be internal combustion engines or hydraulic turbines.

Power plants with internal combustion engines are built as the main source of power when consumers are far away from power systems, and local conditions do not allow the construction of a hydroelectric power station. Diesel engines are most often used as primary engines at such stations [17].

In addition to diesel power stations, stations with internal combustion engines that use gas are being built. It is produced in gas-generating plants that use local solid fuel, including organic waste from agricultural, woodworking and other industries. However, such stations require high costs for fuel preparation and gas production.

In places where there is hydroelectric power, it is advisable to build small-capacity hydraulic power plants. Using the potential of small rivers is beneficial even in areas where there are networks of power systems. The hydropower resources of small rivers in our country amount to tens of billions of kilowatt-hours. However, the initial cost of construction of hydroelectric power plants is much higher than the cost of construction of thermal power plants due to the large volume of earthworks and construction work. The best use of water flow is provided by the parallel operation of hydraulic power plants with thermal power plants or the power system[17,18].

Diesel power stations (DPP) are used as the main source of power supply to consumers in areas remote from the power grid networks. DES are stationary installations. Their location and capacity are determined taking into account the development schemes of electric networks and power systems of the construction area [20].

Stationary DES includes the following main elements and systems: diesel-electric unit, fuel economy, lubricating oil economy, start-up system, air cleaning system, control panel, battery economy and low-voltage switchgear.

In DES for agricultural purposes predominantly use four-stroke diesel engines. The number of cylinders varies from 2 to 12 depending on the type and design of the diesel engine.

With increasing speed, the mass of the diesel engine decreases, but at the same time the inertia and friction forces increase, which leads to faster wear of parts. Diesel engines of units and stations are performed with various cooling systems: air, water-air (radiator), water-water (two-circuit).

Diesels are equipped with synchronous generators of three-phase alternating current with a horizontal shaft arrangement. Generators are manufactured for a nominal voltage of 0.22; 0.4; 6.3 and 10.5 kV. The stator windings of generators with a voltage of 0.23 and 0.4 kV have a zero point connected to the zero wire of the electric network.

Usually, several units are installed at a power plant, since the load is constantly changing. When several generators are switched on at the same time, their parallel operation is provided, which ensures greater reliability of power supply, increases operational performance and the quality of the released electricity.

For parallel operation, generators are usually enabled by self-synchronization.

The power of the DES is selected according to the maximum load of the $P_{мах}$ station. The total capacity of the selected units must be greater than the $P_э$. Overloading the units of an Autonomous power plant by capacity is unacceptable, as it leads to a decrease in the frequency of alternating current [18].

The rated power of the $P_э$ generators must be greater than or equal to the maximum load of the $P_{мак}$ power plant generators:

$$P_э \geq P_{max} . \tag{2.3}$$

Power at generator terminals:

$$P_э = \sum_{i=1}^{n} P_c \cdot \eta_{ген} \cdot \eta_{пер}, \tag{2.4}$$

where n – the number of units station; P_c – эффективная мощность двигателя по паспорту; $\eta_{ген}$ – the efficiency of the generator; $\eta_{пер}$ – Transmission efficiency (for belt transmission from the engine shaft to the generator).

Technical operation rules recommend that when the diesel engine is running continuously for more than 24 hours, reduce the load for a four – stroke diesel engine by up to 90%, and for a two-stroke engine-up to 85 %.

In accordance with this, the power at the generator terminals:

$$P_э^{'} = 0{,}9 \cdot P_c \cdot \eta_{ген} \cdot \eta_{пер}. \tag{2.5}$$

The choice of the number of units of a diesel power plant is based on economic considerations. The power of the unit must not exceed the minimum load of the daily schedule by more than 2 times. The number of aggregates (rounded to an integer) is determined by the formula:

$$n = \frac{P_{\max}}{(0{,}9 \cdot P_э)}. \tag{2.6}$$

To the number of aggregates defined by this formula, reserve aggregates must be added, the number of which is:

$$n_p = \frac{B_p \cdot n}{(0{,}8 \cdot M_p)}, \quad (2.7),$$

where B_p – duration of all types of diesel repairs, including major repairs, during the period of engine life, ч; M_p – the lifespan of a diesel engine according to the manufacturer, h.

The electrical diagrams of diesel power stations differ in the power of the units and the purpose of the stations.

It is recommended to use simplified main wiring diagrams with a minimum number of switches. If there are electricity consumers located from power plants within 1 km, they are powered at a voltage of 380 V and 400 V generators are used at the stations.

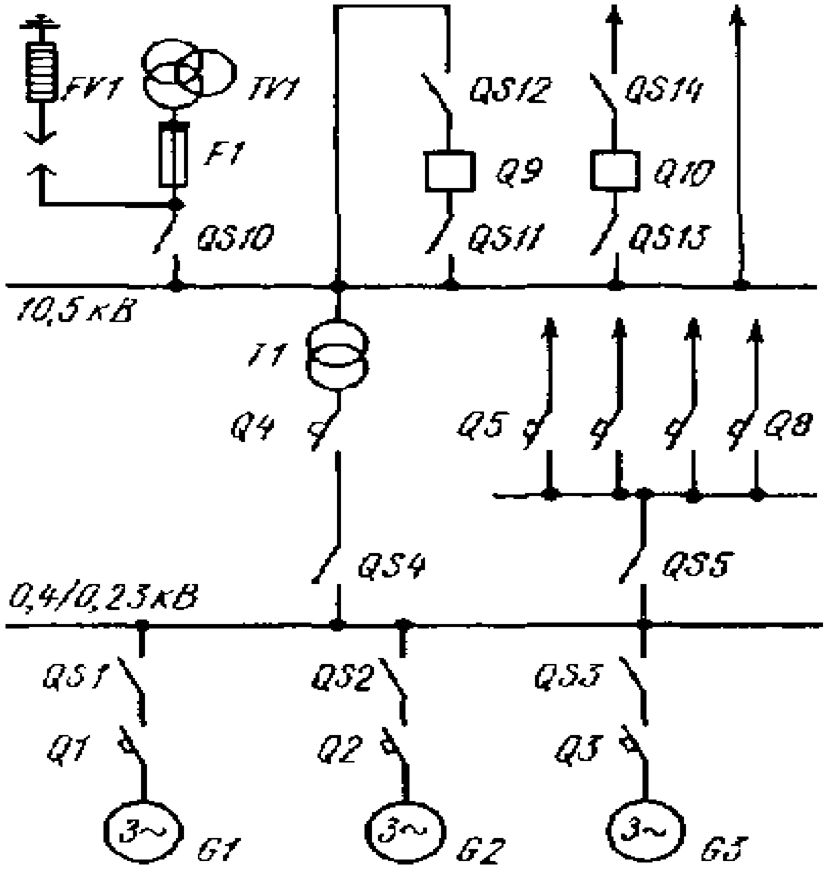


Figure 2.7 – Electrical diagram of a diesel power plant with a capacity of 400…1200 kW

For power plants located at considerable distances (up to 20 km) from the consumer and having a capacity of 4…5 thousand kW, choose generators with a voltage of 6.3 or 10.5 kV.

For more economical operation of the power plant and increase the reliability of power supply to consumers, communication with other substations is used. As a rule, the communication line is carried out at a voltage of 35 kV, for which power plants install transformers with a voltage of 6 … 10/35 kV. The station’s generators are connected to the buses via high-voltage switches and disconnectors, and the outgoing lines with a voltage of 6 … 10 kV are protected with fuses. The step-up transformer is connected to the buses with a voltage of 6.3 … 10.5 and 35 kV by switches of the corresponding voltages. The 35 kV switch is necessary in case of accidents on the communication line and during inspections and repairs of the transformer with a voltage of 6.3… 10.5/35 kV.

Diesel units used in agriculture as the main energy sources have the first or second degree of automation[21].

The problem of air pollution from emissions from thermal and diesel power plants leads to the search for non-traditional renewable energy sources (sun, wind, heat from the earth, seas and oceans, small water flows, and biomass).

Small capacities are typical for rural hydroelectric power plants. At the initial stage of development of rural electric power in the country, many rural power plants were built on small rivers. With the transfer of agriculture to electricity from state-owned energy systems, the number of rural hydroelectric power stations has decreased many times. The use of low-power hydroelectric power plants becomes necessary.

The construction of rural hydropower contributes to the fact that the much improved technology of mass production of concrete products of complex shapes and solved the problem of transportation. The HPP consists of a hydraulic turbine, a three-phase synchronous generator, and a step-up transformer if the energy is distributed at an increased voltage. For rural hydroelectric power plants with a capacity of up to 60 kW that supply consumers within a radius of 0.5 … 1 km, it is advisable to distribute energy at a generator voltage (usually 400 V).

Sometimes the hydraulic turbines of rural hydroelectric power plants have a nominal speed significantly lower than that of a synchronous generator. At the same time, at a HPP with a capacity of up to 120 kW, the turbine is connected to the generator via an intermediate connection (for example, a gearbox). At a hydroelectric power station with a capacity of more than 120 kW, the turbine and generator are placed on one shaft.

Rural hydroelectric power plants are mostly low-pressure. The exception is hydroelectric power stations built on mountain rivers. Low-pressure rural hydroelectric power plants use axial, radial-axial and rotary-blade turbines, which are characterized by higher efficiency over a large load range. Power, kW, developed by the turbine:

$$N = 9{,}81 \cdot \eta \cdot Q \cdot H, \tag{2.8}$$

where η – the efficiency of the turbine; Q – water flow through the turbine, m^3/s; H – pressure, m. The operating characteristic of the turbine is the dependence of its η on the load $\eta = f\,(P)$ at a constant head and constant speed.

Using the above expression, you can get the flow characteristic of the turbine using the existing working one. The flow characteristic gives the dependence of the water flow through the turbine on the load $Q = f(P)$ for $H = const$ and $n = const.$, where n is the speed of the turbine shaft.

The potential of electricity generated from wind farms is several times higher than the electricity generated by existing power plants in the country.

For wind farms, special devices are used that accumulate wind energy to some extent, as well as voltage and speed regulators. This makes it possible to supply consumers with electricity for lighting and electric drive. Wind turbines use various storage devices that smooth out the ripples received from wind energy and in some cases limit the power developed by the wind engine, as well as store energy for the period of calm days[20].

According to the principle of operation of storage devices used in wind power, there are mechanical, electrical, hydraulic, thermal, pneumatic and hydrogen devices.

Mechanical accumulators store excess energy and give it away when there is a shortage using a flywheel, spring, lift, etc. Through these mechanisms, the accumulated energy can be given to the working machine immediately, or at certain points in time. This type of battery is not widely used, since a significant part of the energy is not used at all when the wind speed drops, and some of the energy is lost in the flywheel itself.

Electric accumulators are devices for storing and storing electrical energy in the form of chemical energy. The efficiency of batteries reaches 70 … 85 %. These batteries operate only on direct current. Therefore, in AC networks, it is necessary to convert DC to AC. This reduces the efficiency of batteries and increases the capital investment in the installation. For large capacities, the use of electric batteries is limited due to their large size and high cost. In addition, they require careful care – timely charging, replacing the electrolyte, measuring its density, and so on. Therefore, they have found application only in circuits with low power consumers.

Hydraulic accumulators are a power plant in which wind energy is converted into the potential energy of water raised to a certain height: when the water falls back, it can drive the generator. If there is enough water, it can be used for irrigation.

The efficiency of the hydraulic accumulator unit exceeds 50 %. For its construction, it is better to look for natural reservoirs located at the required height. When constructing artificial pressure pools, large capacities are required. It is considered optimal to use reservoirs of hydroelectric power stations, where water is accumulated at the expense of wind farms operating in parallel with the hydroelectric power station[18,20].

Heat accumulators are devices in which wind energy is converted into heat stored either as hot water for heating rooms, or as steam used by a turbine or for heating. During periods when the power of the wind turbine exceeds the load, the excess electricity is sent to electric boilers, in which the water is heated to vaporization, and then used in heating systems.

Pneumatic accumulators are devices in which the kinetic energy of the wind can be converted into the potential energy of compressed air using a wind compressor unit, which can be used to operate air turbines.

Hydrogen batteries are installations where water is electrolytically decomposed into oxygen and hydrogen. Oxygen is used for industrial purposes, and hydrogen is used for combustion in an internal combustion engine. Hydrogen can be stored in cylinders, and then, as necessary, spent on the operation of the heat engine. This method of accumulation is difficult for agricultural conditions and unsafe.

2.5 Costs of production and transmission of electric energy. Selection of parameters of power supply systems for agricultural enterprises and rural localities

Costs of electricity generation and transmission.

Unit costs per 1 kWh in the production and transmission of electricity is a converted form of the cost of electricity released to the consumer. According to this indicator, the price of 1 kWh generated and transmitted over the network is set [21].

Given the costs for production and transmission of electric power to agricultural consumers depend on the cost structure of the energy system: the cost of the network that transports electricity from the grid rural supply and distribution networks with a voltage of 110, 35, 10 kV, including substations with voltage 35(110)/10 kV, and transmission costs of electricity on lines with voltage 0,38 kV and substations with voltage of 10/0,38 kV.

$$З = E_H \cdot К + И, \tag{2.9}$$

where К – capital expenditure; $E_н$ - standard coefficient equal to 0,12; И – annual production costs equal to the cost of production.

$$И = И_{рен} + И_{кап.рем.} + И_{з.п.} + И_{проч} + И_{пот.эл.эн.}; \tag{2.10}$$

$$И = И_{ам} + C;$$

where

$$И_{ам} = И_{ренов} + И_{кап.рем.}; \tag{2.11}$$

$$C = И_{зар.} + И_{проч.} + И_{пот.эл.эн}. \tag{2.12}$$

This indicator takes into account the cost of own needs of power plants, loss of power and energy in the electric networks, as well as the availability of reserves in the power system.

Average unit costs for transmission of electricity through rural networks of 110, 35 and 10 kW, tenge/(kW•h):

$$З_в = \frac{E_H \cdot К + И}{P_{35/10} \cdot T_{10}}, \tag{2.13}$$

$$З_в = \frac{М_в}{T_{10}}.$$

Average unit costs for transmission of electricity over networks with a voltage of 0.38 kV, tenge/(kW•h):

$$З_Н = \frac{Е_Н \cdot К + И}{P_{10/0,4} \cdot T_{0,38}}, \qquad (2.14)$$

$$З_Н = \frac{М_Н}{T_{10}},$$

where $P_{10/0,4}$ – maximum TP power; $T_{0,38}$ – the number of hours of maximum power.

For a consumer connected directly to the 10 kV network, the given costs, tenge/(kWh·are equal to:

$$c_{10} = З_с + \frac{М_В}{T_{10}}, \qquad (2.15)$$

where $З_с$ - the criterion of efficiency.

$$З_с = \sum_{t=1}^{T_c} З_t \cdot \beta^{t-1}, \qquad (2.16)$$

where T_c - calculation period. [1].

$$\beta = \frac{1}{1} + E_{НП}, \qquad (2.17)$$

where $E_{НП}$ – the standard coefficient of reduction of multi-time costs, equal to 0.08 [21,22].

Electricity costs for consumers who are powered by networks with a voltage of 0.38 kV are determined in accordance with the expression:

$$c_{0,38} = З_с + З_в + \frac{М_Н}{T}. \qquad (2.18)$$

The value of T in determining the Zn, as well as for high-voltage networks, is assumed to be equal to the number of hours of use of the maximum power of the consumers under consideration.

To increase the efficiency of rural electric networks, we should strive to increase the number of hours of maximum load, which will lead to an increase in electricity consumption at the same capacity and more complete use of electrical equipment. Figure 2.8 shows the dependences of the specific costs of SV and SN for electricity transmission over high and low voltage networks on the number of hours of maximum power use T for a network that includes a 35 kV supply line, a 35/10 kV substation, and 10 and 0.38 kV lines.

When calculating the annual reduced costs for electricity received from a local diesel power plant, the same formulas are used, but they must take into account the cost of the DES itself and the cost of fuel for it.

$$З_д = p \cdot К + В + к \cdot в \cdot P \cdot T, \tag{2.19}$$

where $К$ - capital investments (tenge); p - rate of renovation of deductions (tenge / year); $в$ - double fuel consumption (kg / kWh); $к$ - the cost of fuel (m/kg); P – maximum power on tires, kW; T – the number of hours of maximum power use (h/year); B - salary and other expenses (tenge / year).

The specific costs shown in (t / kWh·will be equal to:

$$З_д = \frac{З_д}{P \cdot T} = \frac{p \cdot К}{P \cdot T} + \frac{B}{P \cdot T} + к \cdot в.$$

The above costs for electricity generated at backup power plants are significantly higher than the costs for DES used as the main source.

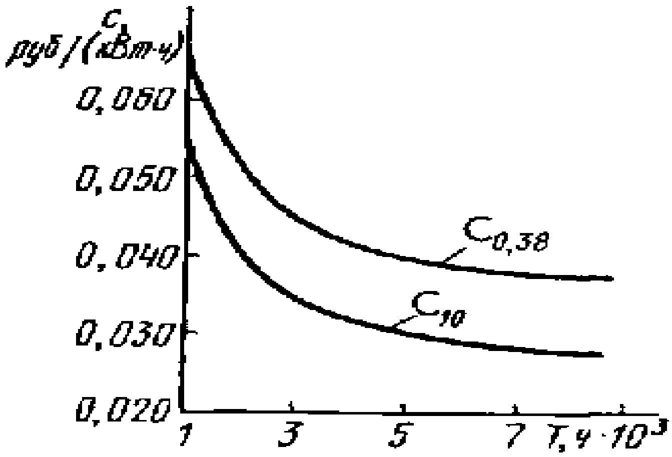


Figure 2.8 - Dependences of specific reduced electricity costs on the number of hours of maximum power usage

Figure 2.9 shows the structure of specific reduced costs % for diesel power plants with a total capacity of 2000 kW and with units of unit power up to 800 kW inclusive. These data were obtained by Academician of Sciences of Kazakhstan SH. CH. Chokin and his staff, who also developed a methodology for a feasibility study of the choice of power supply source for agricultural areas [26,29].

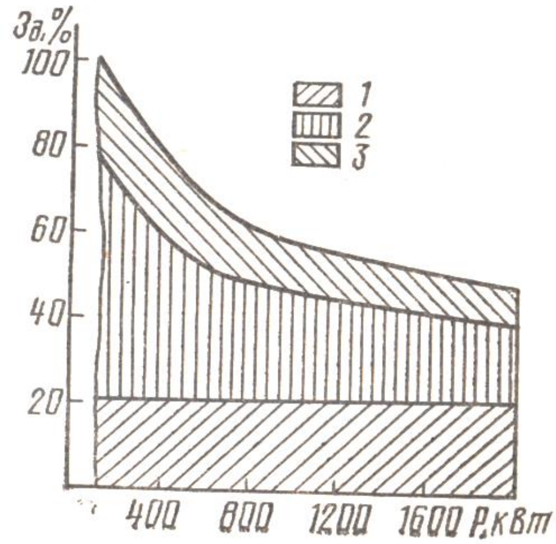


Figure 2.9 - The specific structure of the above costs as % of DES

To increase the efficiency of backup power supply, it is proposed to use synchronous generators of backup stations to generate reactive power. Backup power station generators are disconnected from the primary engines, and they operate in engine mode as synchronous compensators. When the main power supply fails, the generator is automatically connected to the primary engine, and the unit operates as a backup power plant.

This design of the backup DES allowed us to get rid of additional costs due to capital investments in capacitor banks, or energy losses when transmitting reactive power over networks without compensation. Evaluation of the efficiency of the reserve DES when it is used in a complex for local redundancy and reactive power compensation showed that the cost of generating reactive power of the reserve DES is about 2 times less than in a typical power supply scheme.

The choice of parameters of power supply circuits.

The choice of power supply schemes includes the choice of rated network voltages, its configuration, selection and placement of transformer substations of various voltages, and their connection to power sources [23].

The centralized power supply system for agriculture includes: supply networks consisting of 35 and 110 kV transmission lines and 110/35, 110/20, 110/10, 35/10 or 35/6 kV transformer substations; distribution networks with a voltage higher than 1 kV, including 35, 20, 10 and 6 kV lines and transformer substations 35/0,38, 20/0,38, 10/0,38 and 6/0. 38 kV; distribution networks with a voltage below 1 kV, consisting of lines with a voltage of 0.38/0.22 kV. Mainly used power supply system 110/35/10/0. 38 kV with three stages of transformation.

A two-stage power distribution system of 110/10/0. 38 kV is common, and a 110/35/0. 38 kV system is also possible. With a two-stage power distribution system, the need for transformer power (by about 30 %) and energy losses are reduced, and the quality of the consumer's voltage is improved.

The peculiarity of distribution networks with a voltage of 110 kV is determined by the large dispersion of consumers across the territory with a low load density. This is due to the use of branched (with blind branches) radial networks. Due to the increased requirements for the reliability of power supply, a lot of work is being done to reduce the length and branching of electric lines, ringing (with operation in a conditionally closed mode) networks with a voltage of 10 kV and the use of two-way power supply to substations with a voltage of 35, 110 kV.

Two-way power supply for these substations is recommended if two transformers must be installed on them due to the reliability of power supply, or at least one of the outgoing lines with a voltage of 10 kV is not provided by redundancy over the network with a voltage of 10 kV from a neighboring power center.

The configuration of electric grid schemes depends on a number of factors: the number of consumers, their placement and categorization in terms of reliability of power supply to consumers, the number and location of power system support substations. The variety of these factors can lead to a large number of options for building schemes and configurations of networks with different technical and economic indicators[22].

The absolute majority of agricultural consumers receive electricity from a centralized source - state power systems (National companies). Under these conditions, the basis of the rural power supply system is electric networks. These include those for which more than 50% of the design load is transferred and distributed between industrial agricultural consumers, as well as non-industrial and household consumers in rural areas. There is a powerful energy complex that provides agricultural consumers with electricity - a system of rural electric networks with a voltage of 0.38 ... 110 kV.

However, the continuous increase in the load when new consumers appear in areas already covered by centralized power supply, and when new agricultural areas are developed, the need to improve the reliability of power supply and the quality of electricity, changes in the layout of settlements, and so on require further development of electric networks. It includes both new construction and expansion and reconstruction of networks. The need to build new facilities, expand and reconstruct these networks is determined by the loads that are expected at the end of the billing period, and the requirements for the reliability of power supply.

For choice of power supply circuits of new livestock farms and existing customers with an increase in their workloads, conduct a technical and economic comparison of options with power from existing substations of 35/10, 110/10 kV and 110/35/10 on networks of 10 kV with consideration of development options for the construction razgromnoy of substations of 35/10 kV or 110/10. Schemes for the development of 10 kV networks are developed for the billing period, not counting the year of their compilation.

Schemes of 10 kV networks are performed in conjunction with schemes of 35... 110 kV networks. At the same time, they take into account promising schemes of district planning, prospects for the development of localities, and the possibility of implementing complex automation of networks. The peculiarity of distribution networks with a voltage of 10 kV is determined by the large dispersion of consumers across the territory with a low load density. This is due to the use of branched (with blind branches) radial networks.

The selected networks must be adapted to different operating modes when the load changes, as well as in post-accident situations. It is advisable to ensure that the configuration and parameters of the networks allow for further development without major changes.

Schemes of 35..110 kV electrical networks should be constructed in such a way that the buses (bus sections) of 110 kV substations of 35.. 110 kV, from which the mutually redundant 10 kV lines are powered, are independent power sources. Two 110 kV bus sections of a 35...110 kV two-transformer substation are considered independent power sources if this substation is powered by at least two 35..110 kV lines[24].

If two substations 35..110/10 kV receive power from mutually redundant lines 35...110 kV, they are connected to one line 35...110 kV off which causes the de-energization of the two substations, one of them must have two-way power with automatic supply backup power when you disconnect the common line section 35 to 110 kV. If the capacity of the new 35 kV lines is close to the limit by the end of the period under review, the technical and economic feasibility of constructing 110 kV lines with temporary operation at a voltage of 35 kV should be considered. This is allowed in cases when the duration of their operation at a voltage of 35 kV will not exceed 5 years.

Rated capacity of district transformer substations (RTP) 35...110/10 and 110/35/10 kV depend on the value, nature and placement of the load. In agricultural areas, RTP usually uses transformers with a capacity of 35/10 kV - 630...6300 kVA, 110/10 kV - 250O...10,000 kVA, for 110/35/10 kV-6300... 16,000 kVA.

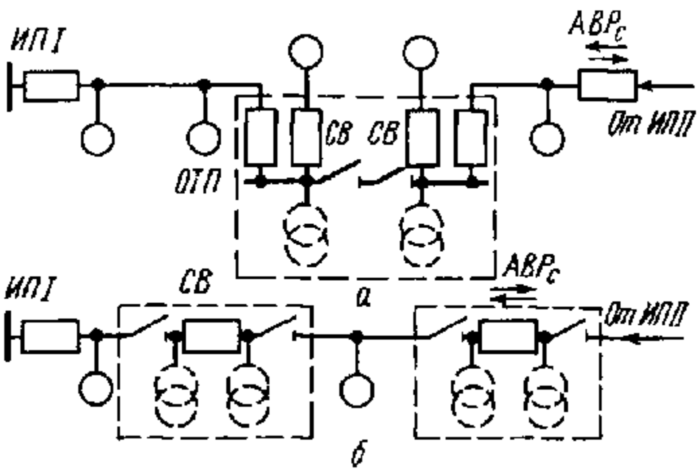
It is recommended to install transformers with automatic voltage regulation under load (RPN). Installation of two transformers on RTP should be provided in the following cases: with a design load on 10 kV tires that requires the installation of a transformer with a capacity higher than 6300 kVA; with the number of outgoing lines of 10 kV six or more; with a distance to the nearest neighboring substation 35...110 kV, exceeding 45 km; if it is impossible to reserve at least one of the 10 kV lines that supply consumers of the first and second reliability categories from the neighboring substation 35...110 kV (for example, due to obstacles in the area); when the replacement of wire sections on the main line of the 10 kV line does not provide normalized voltage deviations for consumers in the post-accident mode.

Two-transformer substation should be connected to the line on a "call - out", i.e. in the line by installing appropriate switching equipment, or two different lines. It is allowed to attach a two-transformer RTP 35 with a special justification...110/10 kV branches to the double-chain line 35 ... 110 kV. However, in this case, consumers of the first category in terms of reliability of power supply must be provided with backup power from an independent source with a voltage of 10 kV or a backup power plant. RTP 110/35/10 kV should be placed in network nodes where it is possible to distribute the load on the voltage of both 10 kV and 35 kV.

The number of 10 kV lines departing from the RTP does not exceed 5...6. Schemes of electric networks of 10 kV should be based on the use of overhead mutually redundant partitioned lines. The schemes of these networks should be built according to the main principle: in addition to the usual type of TP, support transformer substations of 10/0.38 kV (OTP) should be connected to the highways that provide mutual line redundancy. They are a 10/0. 38 kV TP, usually in a closed version, with a developed 10 kV RC designed for connecting 10 kV radial lines, automatic partitioning and redundancy of the main line, placement of automation and telemechanics devices. OTP is installed at consumers of the first category or in the courtyards of Central farmsteads, if the line requires the installation of a partitioning switch.

Figure 2.10, a shows one of the possible OTP schemes, and figure 2.10, b shows a variant of the connection scheme for 10/0. 38 kV TP feeding consumers of the first category. 10 kV distribution points can be installed in the network nodes where 35... 110/10 kV substations will be constructed.

Mutually redundant 10 kV lines should have, if possible, and if there are consumers of the first category without local redundancy, then it is mandatory to have a network reserve from an independent power source and be equipped with partitioning devices - switches and disconnectors. It is recommended to carry out the main part of these newly constructed or reconstructed lines with a steel-aluminum wire of one section of at least 70 mm2. A 10 kV line is usually provided with only one network reserve from an independent power source. TP 10/0. 38 kV connected to the main line by branches should, if possible, be switched to power from 10 kV OTP (RP) buses.

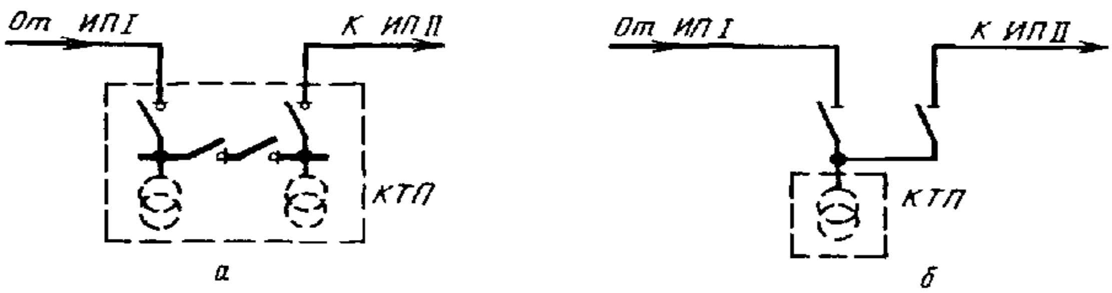


a and b are possible options; *MP-power supply* (35... 110/10 кВ);
SV - partitioning switch; LVRS-network AVR; OTP-reference TP.

Figure 2.10 - Connection schemes for 10/0. 38 kV TP supplying consumers of the first category

In most cases, transformer substations with a voltage of 10/0. 38 kV are equipped with transformers with a capacity of 25...630 kVA. If there are consumers of the first category, they provide two-transformer TP. It is advisable to connect them to the 10 kV line according to the "input - output" scheme» (Figure 2.10).

At a lower load, single-transformer substations are usually used. For power supply of consumers of the second category with a design load of 120 kW or more,a scheme with two-way power supply of TP 10/0. 38 kV is used (Figure 2.11).



a and b are possible options.

Figure 2.11 - Connection schemes for TP 10/0, 38 kV with a design load of 120 kW or more, feeding consumers of the second category

It is allowed to connect a TP with a load of less than 120 kW to the 10 kV line by a branch if the length of the non-reserved section of the 10 kV line (damage to which leads to a break in power supply during the repair of the line) is not more than 0.5 km. To supply consumers of the second category with a load of 250 kW or more,two-transformer TP 10/0. 38 kV should be used. TP 10/0. 38 kV should be designed using complete transformer substations (CTP) of factory-made outdoor installation.

It is recommended to use more reliable but expensive closed-type TP in the following cases: for power supply to consumers of the first category with a total transformer capacity of 250 kVA or more; with complex switchgear schemes that connect more than two 10 kV lines; in conditions of cramped development of urban-type settlements, Central farmsteads; in areas with a cold climate (up to -40°C), or with a polluted atmosphere (grade III or more), or with significant snow cover (more than 2 m).

10/0. 4 kV transformers are used with switching branches without excitation. With appropriate justification and the availability of equipment, it is possible to use transformers with RPN on large livestock complexes.

The power of transformers at single-transformer substations is selected according to the economic load intervals when operating in normal mode, taking into account the permissible systematic overloads.

In case of possible additional loads in the post-accident mode, the selected transformer should be checked for load capacity in the same way as in the presence of short — circuited asynchronous electric motors of comparable power-under the conditions of their start-up.

When choosing the power of transformers at two-transformer substations, the conditions of their operation in normal and emergency modes are taken into account.

TP 10/0. 38 kV, from which three or four lines usually depart, are located in the" center of gravity " of loads or, if there are larger consumers, near them.

In the schemes of electric networks of 0.38 kV, radial non-redundant lines with a voltage of 0.38/ 0.22 kV are used, extending from the TP 10/0. 38 kV. In most cases, the lines are four-wire, with a dead-earth neutral.

The first category of electric receivers must be supplied via two separate 0.38 kV lines connected to independent power sources.

Selected by economic load (kVA) [22,24] wires and cables of 0.38 kV lines should be checked for permissible voltage losses in the network, permissible long-term current loads under the heating condition in normal and post-accident modes (mainly for insulated wires and cables), ensuring reliable operation of protection devices (fuses, circuit breakers), starting asynchronous motors with a short-circuited rotor.

The conductivity of the zero wire of 0.38 kV lines that supply mainly (more than 50% of the power) single-phase electric receivers, as well as livestock and poultry farms, must be at least the conductivity of the phase wire.

2.6 Influence of the quality of electric energy on the operation of electric receivers in agricultural production and ways to improve it

Ensuring the required quality of electricity, reliability and efficiency are the main tasks of rural electricity supply.

The quality of electric energy when powering electric receivers from three-phase General-purpose electric networks, i.e. for the main version of rural power supply, is determined by the stability and frequency levels of current and voltage for consumers, as well as the degree of asymmetry and non-sinusoidality [22,25].

Changing the frequency within a few percent of the rated frequency mainly affects only the operation of asynchronous motors. When the current frequency decreases, the speed of electric motors decreases accordingly, the current, maximum torque, and engine heating increase slightly, and when the frequency increases, the opposite is true. However, with small frequency changes, the normal operation of electric motors and most other electric receivers is practically not disrupted.

In accordance with the requirements of regulatory documents, current frequency deviations in normal mode, i.e. at least 95 % of the time of day, should not exceed ±0.1 Hz (a temporary increase in frequency deviation to ±0.2 Hz is allowed). These standards do not apply to electric receivers connected to the networks of independently operating power plants with a capacity of up to 1000 kW. They are considered acceptable frequency deviations in the range of ±0.5 Hz, and for power up to 250 kW - ±2 Hz. However, this does not apply to the main tasks of rural electricity supply, since its system primarily provides distribution, not production of electricity. An important task of rural power supply is to maintain the required voltage levels for consumers. Changes in voltage, especially in excess of the permissible value, have a significant impact on the operation of consumers. Lighting devices are very sensitive to this [23].

When the voltage increases above the nominal value, the service life of incandescent lamps decreases sharply, and when the voltage decreases, their luminous flux decreases noticeably. For fluorescent lamps, which are increasingly used in agricultural lighting systems, the service life is shortened both when the voltage is increased and when the voltage is lowered.

The change in voltage has a serious impact on the operation of the most common short-circuited asynchronous motors in agricultural production. By reducing the voltage decreases the motor torque, which is almost proportional to the square of the voltage, and starting torque; reduced frequency of rotation; increase in current and motor heating; due to the accelerated wear of isolation decreases lifespan. With a significant decrease in voltage due to a decrease in torque, a full stop ("rollover") of the loaded engine may occur and, accordingly, a violation of the technological process. If the engine is not disconnected from the mains, it will be damaged.

As a result of reducing the voltage, the power decreases and, consequently, the heating of electric heating devices, the operation of televisions, radios, refrigerators and other household appliances deteriorates. Increasing the voltage also adversely affects the operation of the latter, reducing in most cases their service life.

At the terminals of electric receivers, normal voltage deviations within ±5% of the nominal value are allowed for at least 95% of the time of day. Maximum voltage deviation of ±10%. They apply to all consumers, and in particular to consumers powered by rural electric networks.

To maintain the required voltage levels for consumers in the rural power supply system, special devices are used for voltage regulation (network regulators of various types, capacitors connected in series and in parallel to the network, as well as voltage regulators for generators of rural power plants). The work of consumers is also affected by the asymmetry of the voltage and the non-sinusoidal shape of its curve [29].

Voltage asymmetry is observed primarily in rural electric networks with a voltage of 0.38 / 0.22 kV, where single-phase load prevails. In these networks, even normal modes are often asymmetric. As a result of the asymmetry, the voltage deviations for single-phase receivers connected to different phases will be different, and for some they may go beyond the permissible limits. The asymmetry of a three-phase voltage system is characterized by the appearance of components of the zero and reverse sequences in it. At the same time, reverse sequence currents in three-phase asynchronous electric motors can reach large values even with a small value of the reverse sequence voltage (due to the small resistance of the reverse sequence of motors). This leads to additional heating of the engines and shortening their service life. Stress asymmetry can also cause vibration of the motors, which reduces their durability. The normal value of the reverse sequence voltage coefficient (the ratio of the reverse sequence voltage of the main frequency to the nominal voltage) at the terminals of three-phase electric receivers is allowed for a long time in the range of up to 2 % and up to 4% maximum.

The value of another asymmetry indicator-the zero sequence voltage coefficient (the ratio of the zero sequence voltage of the main frequency to the nominal phase voltage) for three-phase distribution networks that supply single-phase lighting and household loads, should not exceed the same values.

To reduce the effect of load asymmetry on the voltage quality, it is necessary to ensure that the single-phase receivers are distributed as symmetrically as possible and that the more powerful of these receivers are switched on to the line voltage. This is also facilitated by an increase in the cross-section of the wires, and first of all the zero wire. As a result, the resistance and current of the zero sequence are reduced.

For the same purpose, it is advisable to install transformers with the "star – zig-zag – zero" scheme instead of the common 10/0.4 kV transformers with the "star - zig-zag-zero"connection scheme.

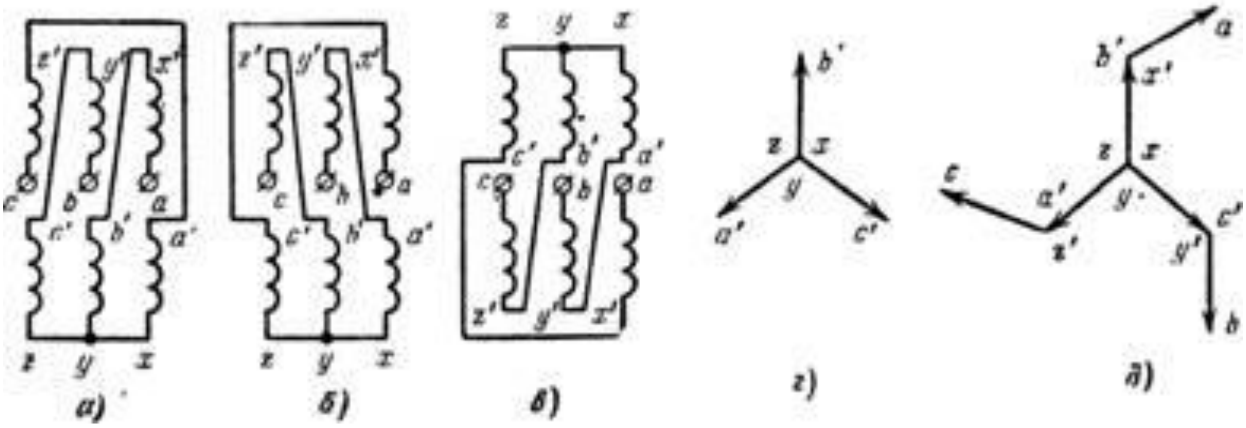


Figure 2.12 - Connecting the NN windings in an equal-shoulder zigzag and vector diagram

Finally, we can also use special balancing devices.

The non-sinusoidal shape of the stress curve (the appearance of higher harmonics in this curve) leads to an increase in the heating of asynchronous motors, an increase in power and energy losses in all network elements. At the terminals of electric receivers, the value of the non-sinusoidal voltage coefficient (the ratio of the current value of the non-sinusoidal voltage to the nominal voltage) is allowed for a long time in the range of up to 5% and up to 10% maximum[23,25].

The results of the study of voltage asymmetry showed that in rural distribution networks, the coefficient of asymmetry almost everywhere exceeds the permissible values and reaches 8%. The inclusion of compensating devices will somewhat reduce the severity of this problem by reducing the flow of reactive power in the network.

However, most of the asymmetry is caused by irrational connection of single-phase consumers to the three-phase network.

Equalizing the loading of individual phases will improve the voltage modes in the network and reduce power losses in it.

Means of local and individual regulation installed at the consumer must be combined with measures to compensate for reactive power, equalize phase loads, and other measures that reduce the negative impact of electricity consumers on the quality of voltage.

Due to the increase in the specific weight of "distorting" electric receivers, the harmonic composition in distribution networks is expected to deteriorate in the future. Therefore, it is necessary to provide measures and technical means to reduce the higher harmonics in the supply voltage curve. Since the distortion is more "due" to the 3 harmonic, it will be effective to use step-down transformers 10 (6)/0.4 kV with a "star-zigzag" winding connection scheme. Such transformers at the same time provide for reduction of voltage unbalance.

To improve the quality of the voltage, it is necessary to use seasonal switching of the power transformer's adjusting solders. Taking into account that the voltage drop in intra-shop networks can exceed 7%, it is advisable to use local voltage regulation tools for responsible consumers of the complex who are in unfavorable conditions for voltage quality. For this purpose, additional voltage regulators can be used. Based on statistical information about voltage deviations, measures are selected to improve the voltage mode. It can be recommended to change the operating branch of the TS transformer, change the voltage setpoint of the power center regulator, change the constantly switched-on power of the capacitor иank, turn on or off the voltage-adding transformer [26].

The cost of transmission and distribution of electricity includes the cost of maintenance and repair of networks (wages and material costs), depreciation and the cost of technological consumption of electricity during transmission and distribution in networks.

Overstating the capacity of transformers and the construction part of power lines leads to an unjustified increase in the cost of the power supply scheme. Replacing transformers, where it is economically feasible, can have a significant effect.

The technological consumption of electricity includes the necessary consumption and the actual loss of electricity. Reducing power losses can be achieved by maintaining the capacity of electrical equipment at the level of optimal values, reducing reactive power flows, leveling load schedules, and carrying out organizational and other measures.

In order to reduce energy and power losses in distribution networks and improve the reliability of power supply, it is advisable to reduce the radius of 10 kV networks and UN-scale 35 kV and 110 kV substations. Reducing the length of lines is carried out during the reconstruction of existing networks by constructing new transformer substations with a voltage of 10/0, 4 and 35/10 kV.

At newly constructed large facilities (poultry farms, livestock complexes), high-voltage deep input substations are used, which significantly reduce the length of distribution networks and electricity losses.

A two-stage power distribution system is used (110/35/0,38; 110/20/0,38;

110/10/0,38 kV), which reduces the need for transformer power and reduces the technological energy consumption.

The approach of a higher-voltage substation to the consumer reduces the technological power consumption by an amount equal to the square of the ratio of voltage levels, i.e. when transmitting power to the consumer's substation along a line at a voltage of 35 kV instead of 10 kV, it reduces losses in it by 12 times.

A noticeable reduction in energy consumption is provided by replacing wires in areas where the load exceeds economically acceptable levels, which is also advisable from the point of view of mechanical strength. Due to the decrease in active resistance with an increase in the wire cross-section, with the same transmitted power, energy consumption is reduced, for example, replacing the AC-35 wire with AC-70 reduces active power losses by 84%.

In each specific case, you can identify opportunities to increase the load of the transformer. In existing networks, you can increase the load of one of the transformers of a two-transformer substation by putting one of the two low-load transformers into cold reserve or replacing the unloaded transformers with lower-power transformers. Reducing reactive power overflows also reduces power losses in the network. In industrial networks, reactive power compensation is mandatory. In rural networks, the task is to increase the power factor to 0.95. Reactive power compensation for agricultural consumers is achieved by installing capacitor banks, mainly on the low side of 10/0. 4 kV transformers.

The reduction of reactive power flows is facilitated by replacing low-load asynchronous motors with lower-power engines, since the reactive power coefficient increases with a decrease in its load, for example, if at 100% load it is 0.75, then at 50% load it is 1.17; and at 30% it is 1.69.

At large livestock complexes and other agricultural enterprises with a significant reactive load, reactive power compensation is required, primarily the reactive power of transformers.

It is possible to reduce technological energy consumption by introducing a fundamentally new technological electrical equipment in the network. The transition from overhead lines to overhead cables reduces the technological consumption of electricity in networks with a voltage of 0.38-10 kV. Simplifying support structures, increasing the length of spans, excluding metal structures, ground loops, and the possibility of installing air cables on the walls of industrial and residential buildings. speeding up installation work during construction helps reduce the cost of air cable lines and makes them competitive. Reduction of the exclusion zone, ecological compatibility of lines when passing the route through forest and agricultural lands give an additional economic effect.

2.7 Rural distribution networks with two-way power supply. Backup power plants as a means of improving the reliability of power supply

Technical means and measures to improve the reliability of power supply include the following:

1) Improving the reliability of individual network elements, including supports, wires, insulators, and various linear and substation equipment.

2) Reducing the range of electric networks. Overhead power lines are the most damaged elements of the rural power supply system. The number of damage increases approximately in proportion to the length of the lines.

In the rural power supply system, significant work has been done to unbundle transformer substations and reduce the range of networks, which for 10 kV lines should be reduced to 15 km everywhere, and in the future-to about 7 km, as is customary in many foreign countries.

3) Application of underground cable networks. Underground cable lines have significant advantages over overhead lines. They are shorter than air ones, since they do not need to be laid along the sides of crop rotation fields, but can be driven along the shortest distance. At the same time, interference with agricultural production is completely eliminated. The main advantage of cable lines is their high reliability in operation. Damage to lines caused by ice and strong winds is completely eliminated, and accidents caused by atmospheric overvoltage are significantly reduced. The number of emergency shutdowns is reduced by 8 ... 10 times [30].

However, the duration of elimination of accidents on cable lines at the current level of operation is about 3 times longer, since it is more difficult to find the place of damage and it is necessary to carry out earthworks to open the trench. With the help of special devices, you can speed up the search for damage. It is especially significant that the investment in cable lines when laying cable laying machines is almost the same as the investment in air lines. Due to these advantages, 10 kV cable lines are very promising for the development of rural electric networks and in the future, as the production of cable by the electrical industry increases, more and more lines will be cable, and 0.38 kV overhead lines will be carried out using insulated wires.

Network and local redundancy. Rural electric networks operate mainly in open mode, i.e. they provide one-way power to consumers. In this mode, you can reduce the values of short-circuit currents, use cheaper equipment, such as switches, disconnectors, etc., reduce power losses in networks, make it easier to maintain the required voltage levels at substations, and so on. Under these conditions, the reliability of power supply to consumers is significantly lower than in closed mode, i.e. with two-way power supply to consumers. A second power line from another substation (or from another bus section of a two-transformer substation) can be used as a backup source. This type of reservation is called a network reservation.

However, especially in areas with high ice and wind loads, both lines may be damaged and power may be cut off. A more independent source is a backup power plant (local backup). In the rural power supply system, small-capacity diesel power plants are most often used as a backup to supply the most responsible consumers during a main line accident, and their use is planned to be significantly expanded.

DES have always excelled in providing electric power to newly created industrial and agricultural facilities in areas far removed from the centers of electric power production. There are many examples of when, after a considerable time, electric energy was supplied from electrical systems, which made it possible not to use DES. In many cases, they were forgotten[32.35].

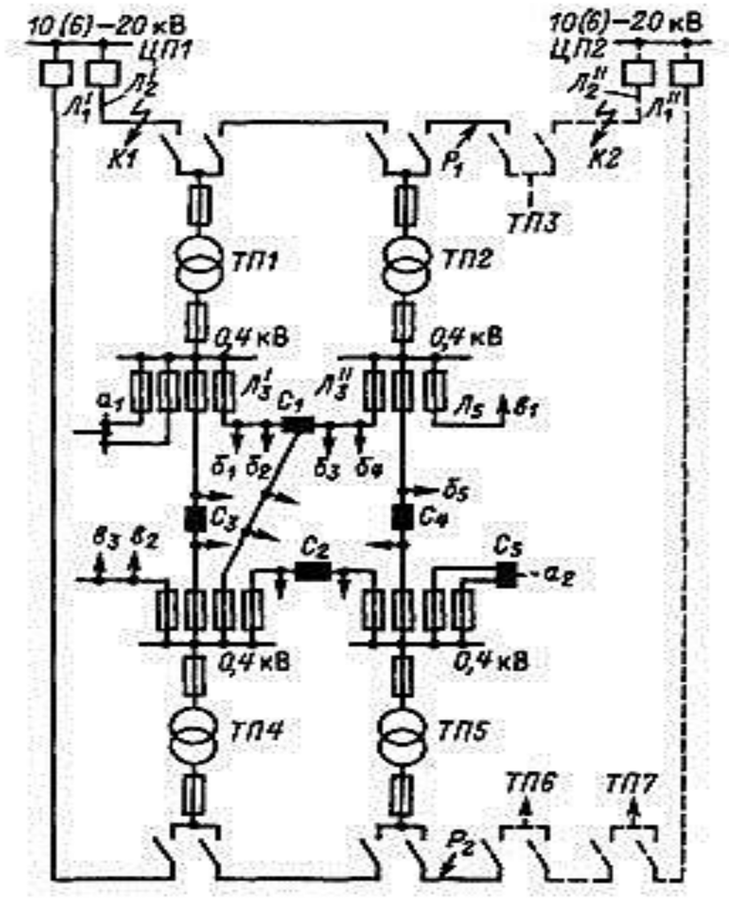


Figure 2.13 - Scheme with two-way power supply and redundancy at the input of 0.4 kV

The current state of agriculture with its infrastructure cannot and should not exist without such a flexible and reliable source of electric energy.

The issues of seasonality and remoteness of agricultural objects cannot be solved in terms of power supply only due to the flexibility of such a source of electric energy as a diesel power station with internal combustion engines.

There is no need to carry out a power transmission line in order to power consumers of electric energy who work for a short time a year according to a temporary scheme.

The creation of livestock and poultry complexes at present cannot be considered at all without such a reliable emergency power source as a DES, due to its features. Moreover, DES have a very wide range of power from 5 kW to 1000 kW.

Automated units and power plants, depending on the degree of their automation, can provide continuous operation without maintenance personnel for 4 -240 hours.

Automation of rural electric networks, including improvement of relay protection, use of automatic re-activation(APV), automatic reserve activation(AVR), automatic partitioning, damage detection automation devices, automatic control of abnormal and emergency modes, telemechanics [36].

When automating networks as a means of improving the reliability of power supply, relatively low costs are required with wide opportunities for use in the operated networks without their serious reconstruction. Automation is one of the main and most effective means of improving the reliability of power supply.

It should be noted that the maximum effect of improving the reliability of power supply can be obtained with the integrated use of various measures and means. Their optimal combinations are determined by specific conditions. They are developing a comprehensive program to improve the reliability of power supply to agricultural consumers, which will include recommendations on optimal sets of tools for various conditions.

Because of frequent damage of air distribution networks with voltage up to 35 kV, which cause about 25 outages per 100 km of these networks is to develop the most advanced and at the same time relatively inexpensive ways to manage these networks is one of the most important problems of the power industry, the successful solution of which depends the reliability of electricity supply. In solving this problem, significant progress has been made related to the creation and use of a new generation of high-voltage devices in distribution networks, called recloser (recloser – literally a switch) [35,38].

A distinctive feature of all these distribution network schemes that take place in rural areas of networks called centralized schemes is that to increase the reliability of power supply in medium-voltage overhead lines that supply consumers, partitioning is used by switching devices (conventional and controlled disconnectors, as well as partitioning points). If damage occurs on any part of such circuits, the protective device on the outgoing feeder is disconnected, and all power consumers of the line lose power for a long time. To localize this damage, by order of the dispatcher, one or more operational teams go to the feeder and manually select the damaged section of the network by several consecutive moves and switching disconnectors and, after localizing it, supply power to all other consumers.

It is obvious that with such a centralized scheme for restoring power supply, a large number of equipment and operational personnel have to be used. At the same time, the time spent on moving operational teams in the case of long lines can be several hours or even days, which leads to extremely low reliability of power supply.

Therefore, instead of the above manual approach to managing emergency modes of distribution networks in a number of post-Soviet States, manual remote control of emergency modes has become increasingly widespread, based on the fact that remote-controlled disconnectors (SD) or remote-controlled partitioning points have been installed in distribution networks instead of manual linear LRS.

The obvious advantage of this approach to improving the reliability of power supply is to reduce the time to locate damaged sections of the network, while significantly reducing the cost of previously practiced numerous crossings, as well as the maintenance of a large staff of operational personnel. At the same time, a significant drawback of this centralized approach is the need for 100% guaranteed communication with each managed element of the network, since if it is not available, the network becomes completely unmanageable and the entire effect of telemechanization of disconnectors is lost.

Thus, a centralized approach to partitioning and managing emergency modes of network operation (regardless of whether such control is manual or remote) does not significantly improve the reliability of power supply to consumers, since the human factor plays an important role in applying both of these methods of managing network accidents.

Therefore, further searches for effective ways to improve the reliability of power supply to consumers were conducted in the following two directions:

- in the direction of implementing an automatic decentralized approach to emergency management, which ensures complete independence of the operation of partitioning points from external management;
- in the direction of developing intelligent devices (first of all, reclosers) that can implement the required algorithms for decentralized management.

With a decentralized approach to managing emergency modes of distribution networks, the operation of partitioning points is completely independent of external control, since each individual device of the power grid, being an intelligent device, analyzes its operating modes and automatically reconfigures it in emergency modes. Thus, automatically, without the intervention of the dispatcher (which excludes the human factor), the location of the damage site is localized and the power supply to consumers is restored to undamaged sections of the network.

With such a decentralized approach to the management of distribution networks, telemechanics does not actually affect the performance of the main functions of partitioning in emergency modes of network operation; it is assigned only a supporting role (providing operational management, monitoring network parameters, etc.). This reduces the requirements for the reliability of communication channels, and the role of the dispatcher is actually reduced to issuing an order to send operatives to localize the damaged section of the distribution network. At the same time, the power recovery time for undamaged sections of the network does not exceed several seconds, which significantly reduces the risk of damage to electricity consumers[38].

To implement decentralized emergency management of distribution networks it is necessary to have a reliable maintenance free uninterruptible power supply system from several independent sources, also the points of the partition, having in its composition of intelligent devices and systems, which can provide the implementation of decentralized management of emergency modes of the network.

2.8 Determination of the number and capacity of consumer substations in large rural localities

We will consider the issues of calculating and designing the power supply scheme of a rural microdistrict, as well as compliance with the rules and regulations of the decisions made. This microdistrict includes residential buildings, the features of which we need to take into account when choosing a power supply scheme to provide consumers with high-quality electricity with reliable and uninterrupted power supply [37].

Since in the current economic situation, the issue of rational use of fuel and energy resources is particularly acute in agriculture, the state of agricultural electric networks, especially distribution networks with a voltage of 0.38 kV, is currently at a difficult stage, expressed primarily by a sharp reduction in the development of networks in quantitative terms. This reduction is primarily due to a decrease in the intensity of rural construction and saturation of networks with measuring and regulating equipment, which is associated with the transition to market conditions of management. In addition, it should be noted that currently prices for the construction of high-voltage power lines have significantly increased. The issue of paying the cost allocated for the construction of land supports, as well as the rent of the land corridor along the line, is becoming more and more common. Therefore, the task of reducing specific capital investments in the construction of new and reconstruction of existing power transmission lines is put forward at various levels. The solution to this problem is related to the maximum use of lines by increasing their capacity and managing the power transmitted through them. Thus, as if under the pressure of external circumstances, rural electric networks are forced to develop in the direction of qualitative improvement.

Modern society is difficult to imagine without the use of electric energy. It is used in all branches of economic activity: in industry, urban, rural and municipal services, in everyday life and in transport.

Features of energy production determine the difficulties of management in the industry, which cause the need to respond to all changes in electricity consumption. At the same time, the dependence of the company's operating mode on the consumption mode has a significant impact on the development of production. This dependence imposes special requirements for planning the operation of not only the power supply facility itself, but also the power supply organization.

Features of energy production, common to all sectors, impose on the utility and the consumers of electric power a particular responsibility for the maintenance of normalized parameters of electricity and reducing the loss due to unsustainable development of the electricity system, on the one hand, and the lack of a systematic approach to the use of electrical energy, on the other hand.

Insufficient knowledge about the distribution of received capacities and the impact of increasing loads on the parameters of the energy system does not allow us to develop a set of measures to stabilize the energy consumption regime, which determines the origin of negative processes, both in low-voltage distribution networks and in the power system as a whole.

Electrical energy is generated at power stations that are usually located near primary energy sources. Power plants are connected to each other and to consumers by electric networks that combine them into power systems that have centralized management. To reduce the cost of electrical energy, it is necessary to distribute the electrical load in a certain way. For example, if there is a sufficient supply of water in the reservoir, the load on hydraulic stations (HES) is increased, while simultaneously unloading thermal stations (TES) and saving fuel.

The quality of electric energy, as an integral attribute of any product, is the most comprehensive characteristic of both the commodity producer (energy supply organization) and the consumer directly, which is the source of introduced distortions in the operation of the power system as a whole.

As an example, we can consider a rural microdistrict consisting of 74 single-family and 28 two-family residential buildings. Also in this locality there is a secondary school, boiler room, shops. The average air temperature in winter is 230C, in summer +200C. The soil is normal-Chernozem. Humidity is 10%, the earth resistivity is assumed to be 35 Om•m. The distribution network of the locality is powered by a 10 kV overhead line.

To supply consumers of rural localities,6 single-transformer complete substations of kiosk type KTPN-10/0, 4-U1 with CSR-392 cameras in the 10 kV RU AND one-way service panels SCHO-70 in the 0.4 kV RU are provided as power sources.

The main criterion for determining the TS capacity of the projected section of the electric network is the calculation of electric loads of consumers.

The calculated load is taken as the highest average value of the total power for 0.5 hours, which may occur at the input of the consumer of electric energy or in the electric network in the calculated year with a probability of not less than 0.95. At the same time, there are daytime and evening loads. The last year of the billing period is taken as the billing year, which in agriculture is recommended to be equal to 10 years.

The calculation of loads in the 0.38 kV network is carried out by summing the loads at the input or network sections, taking into account the simultaneity coefficient separately for the daytime and evening load maxima. Loads of street lighting are accepted according to the relevant standards. Depending on the type of pavement and the width of the roadway and streets, the specific power of lighting systems with an average illumination of 1 to 4 Lk is from 3 to 13 W per 1 m^2. Loads of lines with a voltage of 0.38 kV and TP with a voltage of 6 ... 35/0. 38 kV consist of loads of residential buildings, public and municipal institutions and industrial consumers, as well as loads of street and outdoor lighting.

Taking into account the fact that the number of outgoing lines from one transformer substation is 3-4, we distribute the electric load evenly across the sections of the locality, taking into account equal accessibility to the transformer substation.

Taking into account the daytime and evening modes and the coefficient of simultaneity, we calculate the load on the transformer. The transformer substation (TS) should be located in the center of gravity of loads, and three or four power lines should extend from it. The transformer station will receive power via a 10 kV overhead line.

The main requirements for choosing the number of transformers are:

- reliability of power supply to consumers;
- minimum reduced costs for transformers, taking into account the dynamics

of growth of electrical loads.

The correct determination of the number and capacity of TS is possible only on the basis of comparative technical and economic calculations (TEC).

For large agricultural localities, the number of TS is determined using approximate methods.

The number of TS is usually determined by referring to the geography of the area, combining into groups of consumers, each of which is served by one substation.

In addition, you should pay attention to the choice of the number of TS, since this is the optimal number in the conditions of modern development of the locality, ease of installation and operation, and reduction of the length of overhead lines.

The transformer station will receive power via an overhead line of 10 kV, therefore, its voltage will be 10/0. 4 kV. The coordinates of the TS installation location are found using the known expressions [3]. It should be borne in mind that it is forbidden to feed utility and production loads on the same outgoing line. It is recommended to feed the utility and production load from different TS, in extreme cases, through different outgoing lines.

The 0.38 kV network is located along the streets. It is necessary to avoid crossing the overhead line of the roadway.Consumers are fed via a four-wire system. To power street lighting fixtures, an additional fifth wire is laid. Construction of a two - wire line (phase-zero wire) is allowed at the end sections of the lines when feeding municipal consumers.

Based on the results obtained, a load cartogram is constructed, on which the calculated total capacity of consumers is shown in the form of circles, the areas of which are equivalent to the values of these capacities.

Adopted the rated power of transformers are checked against the conditions of their work in the normal mode of operation for a valid systematic loads in disaster mode - permissible emergency overload.

For normal operation of the substation nominal power of the transformers are checked for a valid systematic load of the transformer, determined by the reference data, depending on the load of the substation and rated power of the transformer for given reference values of average daily temperature estimated season and rated capacity of transformers [38,39].

Verification of the accepted rated power for permissible emergency loads is not required. There is no redundancy over low-voltage networks at a single-transformer substation.If the transformer passes all the criteria, it is accepted for installation according to the design load.

3 HEAT LOSSES OF BUILDINGS AND STRUCTURES AND METHODS FOR THEIR DETERMINATION

The problem of energy saving is an important part of the state's socio-economic policy. In 2009, the law "on energy saving and energy efficiency improvement and on amendments to certain legislative acts of the Republic of Kazakhstan"was approved. Special attention is paid to the energy efficiency of buildings, structures, structures, since a significant part of the territory of the Republic of Kazakhstan is located beyond the Arctic circle, where the heating season reaches 300 days a year. The most stringent requirements for the efficient use of thermal energy are imposed on residential buildings and structures. The specific energy consumption of residential buildings in Kazakhstan (85 WH / m2 * K•day) is significantly higher than in foreign countries (Sweden — 34, USA — 44) [39,42].

Thermal protection of a heated building is one of the most important operational criteria for evaluating its quality, since it affects the favorable microclimate of buildings, heat losses in winter, and the temperature of the inner surface of the fence. This characteristic determines the cost of heating the premises and maintaining a standard microclimate in them.

3.1 Structure of heat losses

Heat energy that goes aimlessly outside the building is called heat loss. Heat losses in typical residential buildings and other buildings occur for three main reasons:

1. Due to heat conduction through walls, roofs, and floors, as well as due (but to a much lesser extent) to radiation and convection.
2. Due to thermal conductivity and to a lesser extent by radiation and convection through Windows and other glazing.
3. By convection and air flow through the elements of the building's exterior fence, which usually occurs through open Windows, doors and vents (forced or natural) or by infiltration, i.e. air penetration through cracks in the building's enclosing structures, for example along the perimeter of door and window frames.

Depending on whether a building has good insulation or not, whether it has many Windows or few, whether there is air movement through it or not, each of these three factors is 20...50% of the building's total heat loss [41.42]. The main sources of heat loss of a building it is almost impossible to consider independently from each other. In this regard, there are two types of heat losses:

1. Transmission losses, which consist of heat flows that the room gives off through the enclosing structures.
2. Ventilation (infiltration) losses, which are understood as the amount of heat required to heat up to the room temperature of cold air that penetrates through the

window leaks and as a result of ventilation.

Transmission heat losses mainly depend on:

- the difference in temperature in the house and on the street (the greater the difference, the higher the loss),
- the thermal protection properties of walls, Windows, floors, coatings (or, as they say, enclosing structures).

External fences usually have different heat resistance. Through fences with low heat resistance (Windows and light structures), heat loss during cold weather will increase sharply, almost following the changes in outdoor temperature over time. Through heat-resistant fences (walls, floors), heat loss during a sharp cold snap increases slightly, and over time, these changes in heat loss will significantly lag behind the decrease in outdoor temperature.

$$Q_{т} = Q_{ст} + Q_{ок} + Q_{вх.дв}. \tag{3.1}$$

$Q_{ст}$ – the heat carried away through the exterior wall; $Q_{ок}$ – heat carried away through the Windows, $Q_{вх.д}$ – warmth carried away through the front door.

Different types of glazing and wall designs differ significantly in the amount of heat passing through them. For example, double glazing will allow half as much heat to pass through as single glazing, and a wall with good insulation will allow about 1/30 (about 4%) of the amount of heat that passes through single glazing. The same amount of heat will be lost through a well-insulated wall of 9x2.5 m and through a single-glazed window of 1,2x0.6 m.

Ventilation heat losses. The amount of outdoor air coming into the room as a result of infiltration depends on structurally-planning decisions of the premise, direction and wind speed, air temperature, integrity of designs of Windows and doors. The General process of air exchange between rooms with outdoor air, which occurs under the influence of natural forces and the work of artificial stimuli for air movement, is called the air mode of the building. Air exchange occurs through all air-permeable elements under the influence of a pressure difference.

3.2 The resistance to heat transfer

The following factors depend on the thermal engineering quality of external building fences:

- a favorable microclimate of buildings, i.e. ensuring that the temperature and humidity in the room are not lower than the regulatory requirements;
- the amount of heat lost by the building in winter;
- the temperature of the inner surface of the fence, which guarantees against the formation of condensation on it;
- humidity mode of the fence, which affects the thermal protection qualities of

the fence and its durability.

Creating a microclimate inside the room is provided by:

- the appropriate thickness of the enclosing structure;
- capacity of heating, ventilation or air conditioning systems. The method of heat engineering calculation is based on the fact that the optimal thickness of the enclosing structure is based on:
- climatic indicators of the construction area;
- sanitary-hygienic and comfortable operating conditions of buildings and premises;
- energy saving conditions.

The method of heat engineering calculation consists in determining the economically feasible resistance to heat transfer of the external enclosing structure. In this case, the heat transfer resistance of the enclosing structure must be at least the required heat transfer resistance[44.45].

3.2.1 Methods for determining heat losses

For qualitative and, more importantly, quantitative assessment of the amount of heat losses that occur during the operation of buildings and structures, it is necessary to determine the thermal resistance of the OK. In this case, it is possible to use two approaches: non-stationary and stationary. The strength of the non-stationary approach to determining the thermal resistance of the OK is the relatively short measurement time required for calculations (less than one working day).

With a stationary approach, the measurement time is 15 days or more [41.43]. Based on computational and experimental studies, it is claimed that the steady-state thermal state of the OK, depending on thermal inertia, is achieved within 120-150 hours. In this case, it is necessary to perform multiple measurements of the temperature head $\Delta t(\tau)$ (the difference in the temperature of the air inside and outside the room).

The approach proposed by A.V. Shishkin [42] consists in solving a General differential equation of non-stationary thermal conductivity with initial and boundary conditions with further substitution of the result in the equation of heat balance on the surface of heat exchange with the atmosphere. According to the author, with this approach, you can get a solution only for the outer surface of the OK. However, the formulas given in [52] for calculating the temperature and specific heat flux on the outer surface of the OK are cumbersome and unsuitable for use. However, the approach based on solving the differential equation of non-stationary heat transfer is promising.

It can be used almost at any time of the year, in unheated rooms, its implementation does not require a long time.

We present a method for solving the problem using parametric identification of heat fluxes and refinement of the thermophysical properties of OK materials [46].

Since the temperature inside the room is maintained almost constant by the heat supply system, the value of heat losses is significantly affected by the heat transfer coefficient on the outer surface of the OK and the outdoor air temperature. Thermal resistance is OK with changing the temperature of the inner wall surface varies slightly, therefore, by measuring the temperature of the outer surface OK, and calculating or measuring specific heat flow through the test plot is OK, you can calculate the thermal resistance of the considered part OK.

The dynamics of one-dimensional heat transfer in OK can be described by a system of ordinary differential equations. Mathematical models in which the heat transfer space is discretized along one axis, and time is considered continuous, are commonly called differential-difference models (DRM) [47].

It is proposed to use the DRM as the main universal model of heat transfer in one-dimensional walls of Windows of various thermal schemes. As an example, consider a homogeneous wall that can be represented as a heat-insulated plate with a thickness of $h = 0.2$ m on the side surface with thermal properties: $\lambda = 0.076$ W / m * K, $c\rho = 1.69 \cdot 105$ D j / $m^3 \bullet K$, where λ, c, ρ - are the thermal conductivity, heat capacity, and material density of approx. The figure shows the thermal scheme (a) and topology (b) of the OK in the form of a plate ($t_{ст.вн}$ and $t_{ст.нар}$ — the temperature of the inner and outer walls, respectively, q — the heat flow).

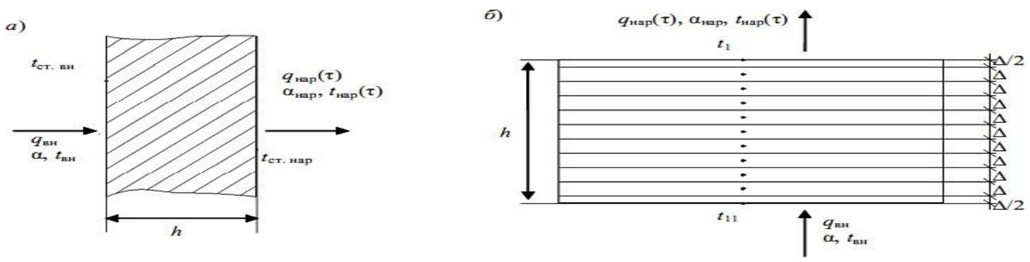


Figure 3.1- Thermal model (a) and topology of DR M (b)

To build a DRM, we divide the plate by thickness h into n layers (in this case, n = 11) with a temperature $t_1, t_2, ..., t_{11}$. The average values of the temperature of the layers, assigned to their centers, make up the state vector of the plate. For calculations, it is convenient to set the thickness of the boundary layers as $\Delta / 2$, and the average values of their temperatures — t_1 and t_{11} — are attributed to the end surfaces.

For each layer, we will create an equation of the thermal balance between the change in its heat content and the heat flows from neighboring layers, and for boundary layers — from the external and internal environment with constant thermal characteristics.

The proposed approach was used to restore the heat flux density from the measured values of the outdoor air temperature for a number of buildings[52].

The results obtained are in good agreement with the data presented in [55]. The described method has been repeatedly tested both for restoring heat flows and for clarifying the thermophysical properties of OK materials, and is currently used by various organizations [56].

In [58], we consider a promising non-stationary method for restoring heat flows passing through the Windows of various buildings and structures, which allows us to conduct research in real time.

3.3 Ways to minimize heat losses. Energy saving measures in buildings and structures

When developing energy saving measures, the parameters of all elements of heating, ventilation and air conditioning systems and their design characteristics are determined from the building design. It is also necessary to clarify the annual operating mode of air control and measurement systems. The design load of ventilation and air conditioning installations is determined from the project of the enterprise or organization. In the absence of such data, it can be determined by analytical methods, taking into account the external and internal volume of buildings, specific ventilation characteristics, and air temperature inside and outside the building. The main characteristics that should be determined when examining ventilation systems are: actual load factors, operating time of installations during the day,indoor air temperature and average outdoor air temperature, air exchange rate.

Energy saving measures in heating, ventilation and air conditioning systems are as follows.

1. Application of economically feasible heat transfer resistance of external fences during construction and additional insulation of external walls during reconstruction of buildings. The event is designed to increase the heat transfer resistance of the exterior walls and reduce the heat loss of the building by improving its thermal protection properties and using effective thermal insulation materials.

2. Installation of ventilated exterior walls. The event is intended to increase the level of thermal protection of external walls.

3. Thermal protection of the external wall at the installation site of the heating device. The event is intended to reduce heat losses from external fences (walls), which are adjacent to heating devices.

4. The device of vented Windows. The event is designed to reduce air permeability and increase the heat transfer resistance of window blocks.

5. Installation of additional (triple) glazing. The event is designed to reduce air permeability and increase the heat transfer resistance of window blocks

6. Application of heat-absorbing and heat-reflecting glazing. The event is designed to reduce heat access to the premises from solar radiation, which leads to comfort in the premises.

7. Installation of glazed loggias. The event is designed to reduce the consumption of cold outdoor air entering the room in winter and increase the temperature in the loggia (behind the outer wall of the room).

3.4 Energy conservation measures in heating, ventilation and air conditioning

Periodic operation of the heating system is used in industrial, civil, educational, sports, commercial, and administrative buildings that are used for part-time work and days of the week when the temperature inside the premises is allowed to decrease during non-working hours. In the mode of operation of the heating system during the day, three characteristic time intervals are observed [59]:

- the main operating mode when the set temperature and humidity parameters are supported in the room;
- standby mode, when after the main mode, the heating system is switched to the mode of maintaining a low temperature in the room;
- forced room heating mode, during which the heating system is switched to the fastest possible heating of the room after cooling.

There is also a weekly cycle in the premises, when on weekends and holidays a full day can be maintained on duty heating mode and a reduced temperature in the room. To maintain the standby mode, water heating is used, which performs the function of maintaining a minimum temperature level. But as a result of some cooling of the room, not only the temperature of the internal air decreases, but also the temperature of the fences. Heating fences and indoor air by the beginning of a new working day requires time and additional power.

The duration and rate of heating the room depends on:

- the thermal resistance of external fences, which affects the temperature decrease during off-hours;
- thermal activity of enclosing structures to thermal effects;
- the intensity of heat transfer from the source of the heating system to the indoor air of the premises and from the air to the surface of the fences;
- temperature pressure in standby and operating mode, as well as the temperature difference of the outside air.

Heating of premises should be accelerated at a high rate, with more power, in contrast to heating in the operating mode, since heat in the heating mode is spent on replenishing heat losses and heating fences and air to the required level [61]. The most flexible mode of operation is the combined heating system. It consists of a basic water heating system and an additional air heating system. Air heating is combined with supply ventilation and in forced heating mode operates in full air recirculation mode.

The operation of periodic heating systems is subject to automation and software control to maintain the design mode. In case of an unexpected sharp drop in the outdoor air temperature, sensors for the permissible minimum indoor air temperature are installed in the control rooms. At a signal from them, the heating system turns on in an additional mode.

The longer the cooling period, the greater the energy savings. To reduce the duration of forced heating, it is necessary to increase the thermal stability of fences, maximize the heat transfer to the fences, using, for example, directed air heating jets or using radiant energy sources (emitters) directed at the fences.

Heating of premises with recirculating air heat. It is recommended to use the heat of recirculating air for industries where air recirculation is allowed, as well as when the air temperature in the upper zone is more than 30 °C and the air supply is not more than 15 m away. The heated air is taken from the upper zone of the production room, cleaned of dust and pumped by a fan through the air ducts into the supply nozzle (cylindrical or slotted shape). Energy saving is provided by utilizing the heat of the removed air.

Application of rotating regenerative air-to-air heat reclaimers.

Air heating systems. Air heating systems are used for residential, public, industrial, agricultural buildings and structures, as well as hotels where the heating function is combined with ventilation. Full or partial air recirculation is possible in the air heating system. Air for heating is heated in heaters or air heaters by hot water, steam, hot air or other heat carrier. The heat and mass transfer process can be carried out in two ways [59]:

a) the heated air enters the room through special channels through air distribution grids and mixes with the internal air;

b) the heated air moves in the internal channels surrounding the room, while heating the walls of the room, the heat from which is transmitted to the internal air of the room. The cooled air is returned to the heater via other channels for reheating or is partially released into the atmosphere when the room temperature is high.

Thus, the air heating system can be fully recirculated, when the air is completely returned for reheating, or partially recirculated, when the air is partially released into the atmosphere and partially reheated.

Air heating systems are actually combined heating and ventilation systems. Advantages of air heating systems: ensuring uniform temperature over the volume of the room, the ability to clean and humidify the air, the absence of heating devices in the room. Disadvantages of air heating systems: large cross-sections of air ducts compared to water and steam heating pipes, a smaller radius of action compared to the same systems, heat loss due to insufficient thermal insulation of air ducts.

To reduce energy costs for heating the outdoor air, it is possible to use regenerative heat exchangers that allow you to utilize the heat of the hot exhaust air. In air heating systems, heat loss is reduced due to the absence of radiator niches-sections of external fences that occur in water and steam heating systems. Energy saving when using air heating is also achieved by automating the system with a low heat capacity of the air, as well as by possibly maintaining a lower air temperature in the room during non-working hours and quickly heating the room before the start of the working day.

Periodic operation of ventilation and air conditioning systems. Periodic modes of operation of ventilation and air conditioning systems are used to stabilize the temperature, moisture content and gas composition of the air.

They are most effective when servicing large-volume premises in public buildings with variable occupancy (auditoriums, retail, sports halls, waiting rooms), where the temperature, humidity, and air composition (carbon dioxide and oxygen content) change simultaneously.Reducing energy consumption by ventilation and air conditioning systems is provided by changing the air flow rate of the required parameters, using complex and expensive air distributors, using advanced methods of regulating the fan operation, and a complex automation system.

An alternative way to regulate systems can be periodic ventilation of premises depending on the condition of the room air, which ensures savings in electrical and thermal energy. The duration of the break depends on the frequency of air exchange, the volume of the room, and the composition of the air. Functional circuits of automatic control control the concentration of carbon dioxide, changes in humidity and air temperature.

Device of air curtains. Air curtains are installed at the entrance, at open openings in public and industrial buildings and structures, workshops, shopping centers, shops, in multi-storey residential buildings with frequently opened entrance doors or with significant gates. The event is aimed at reducing the cost of heat for heating the air coming through entrances, entrances and openings. Use combined air-heat curtains with and without a vestibule, and air intake is carried out from the room or outside.

The air curtain consists of two symmetrically arranged pairs of vertical air distribution risers installed inside the room. The internal pair of risers located closer to the room supplies heated air (up to 60 °C) in the heaters, and the external pair of risers supplies non-heated air taken from the room. When the gate is closed, the outer pair of risers is turned off, and the inner curtain operates in heating mode. When opening the gate, an external pair of risers is connected to work. Energy saving is achieved by reducing the need for heat to heat the supply air and the cost of electricity to move it.

Room heating system using gas infrared emitters. The system is designed for heating permanent and temporary workplaces of production and auxiliary premises; premises and structures on open and semi-open sites during the construction of buildings and structures; snowmelt systems, on the roofs of buildings and structures. Heating devices are burners of infrared radiation. The burner uses low-pressure gas with pre-mixing of gas and air, and the temperature of the radiating surface reaches about 850°C. At this temperature, about 60 % of the heat released during the combustion of gas is transmitted by radiation in the form of infrared (heat) rays. The placement of burners in a room or in an open area, the number of rows, the distance between the burners in a row, the height of their suspension above the floor, the angle of inclination of the burners, is determined based on the irradiation standards and the type of burners. Energy saving is achieved by reducing the heated volume of the room, the absence of overheating of the upper area of the room, low thermal inertia and the use of automatic control[62].

Gas-air radiant heating. Gas-air heating is used for industrial premises, Assembly, mechanical, repair shops, depots, garages, hangars. The function of heating devices is performed by pipelines with high temperature laid in the upper zone of the room, not lower than 4.5 m from the floor. A mixture of heated air and fuel combustion products circulates inside the pipes, which ensures a high temperature of the pipelines. Heat transfer from the surface of the pipes to the room air occurs due to the total heat exchange-convection and radiation. However, the higher the pipeline temperature, the greater the proportion of heat transfer due to radiant heat exchange. Heat-emitting pipes have a diameter of up to 0.4 m and are assembled on flanges.

To reduce heat losses in the upper part or non-working area of the room, the pipes are covered with effective thermal insulation from above, and longitudinal metal screens (canopies) are installed along the side of the pipes, preferably with a high degree of blackness (painted canopies). The temperature of the coolant circulating through the pipelines should exclude the effect of dew point on the inner surface of the pipes and low-temperature corrosion. Energy saving is achieved due to the absence of overheating of the upper zone and the preservation of thermal comfort conditions in the working area [63.65].

Application of heat pump installations and low potential energy (condensate, air).

The main mechanisms of heat transfer (thermal conductivity, convection, radiation) and the laws describing them, discussed in the second Chapter, allow us to get an idea of the physical background of energy saving measures and the fundamental restrictions imposed by nature on our activities in this area.

Existing methods for determining heat losses are either complex and therefore not widely used (non-stationary methods), or they take a long time and require very specific conditions (stationary methods), which reduces their accuracy.

These recommendations for reducing heat loss in some cases are difficult to implement, or do not bring sufficient effect.

The above material allows us to draw a conclusion about the structural complexity of heat losses and the need for a comprehensive informal individual approach to the implementation of measures to save heat energy in each specific case[62].

An important problem, which largely determines the efficiency and economic effect of implementing energy saving measures, is the problem of accounting and controlling the consumption of energy resources.

4 METHODS AND MEANS OF INCREASING ENERGY EFFICIENCY

The previous chapters show the important role of energy saving as a fundamental factor in economic development and energy security in the Republic of Kazakhstan; consider the physical laws and principles underlying all energy saving measures, features of accounting for resource consumption and errors that occur in various accounting methods; pay considerable attention to the study of the legal and regulatory framework governing relations in this area, as well as economic and informational aspects of energy saving.

4.1 Power quality and energy saving

High quality of electricity (CE) together with reliability, efficiency and safety of power supply is one of the most important requirements for systems of production, transmission, distribution and consumption of electricity. The intensification of production leads to an increase in the capacity of non-linear, unbalanced and sharply variable loads, and its modernization leads to saturation with controllers, numerical control devices, automation and telemechanics systems, communications and relay protection.

At the same time, the number and power of single-phase electrical appliances used in everyday life is growing. All of this has led to a significant increase in the level of electromagnetic interference in electrical network enterprises and power systems, which in turn leads to a decrease in the reliability of power supply, increase of energy losses and reduced energy efficiency, deterioration of product quality. Household electrical appliances are also susceptible to reduced power quality and often fail when operating from a network with low power quality.

Let's focus on the problem of the influence of power quality (CE) on the energy efficiency indicators of suppliers and consumers. The greatest economic damage to consumers is caused by deviation from the requirements of GOST 32144-2018 in terms of the established voltage deviation. This is mainly due to the absence or non-use of regulating and compensating devices by power supply organizations and the discrepancy between the parameters of electric networks and existing loads. [66.72]

Power quality indicators and their standards according to GOST 32144-2019:

1. Frequency Deviation is the difference averaged over 10 minutes. Between the actual value of the main frequency and its nominal value. Normally acceptable values are ±0.2 Hz for 95% of the time per week, and the maximum permissible values are ±0.4 Hz for 100% of the time per week (for 10 seconds).

2. The voltage deviation is the difference, averaged over 10 min. Between the actual value of the main frequency and its nominal value. For low and medium voltage networks - ±10% - for 100% of the time per week (10 minutes).

3. Rapid voltage changes. Voltage fluctuations are caused by a sharp change in the load on the considered section of the electrical network.

Flicker dose: long-term no more than 1.0 for 100% of the time per week, short-term-no more than 1.38 for 100% per week. Voltage drop: for low-voltage networks no more than 5%, for medium-voltage networks-no more than 4%.

4. the coefficient of distortion of the sinusoidal voltage curve is characterized by the coefficient of non-sinusoidal (distortion) of the voltage curve. Normally acceptable values for the voltage of 0.38 kV – no more than 8%, 6-25kV-no more than 5%, 35 kV-no more than 4%, 110-220kV-no more than 2% for 95% per week. The maximum permissible values for the voltage of 0.38 kV – no more than 12%, 6-25kV-no more than 8%, 35 kV-no more than 6%, 110-220kV-no more than 3% for 95% per week.

5. The voltage unbalance ratio. Stress asymmetry refers to the inequality of phase or linear stresses in the amplitude and shear angles between them. Normally, the allowed value for the reverse and zero sequence is -2%, for 95% of the time per week in the 10-minute interval. The maximum allowed value for the reverse and zero sequence is -4%, for 100% of the time per week in the interval of 10 minutes.

6. Short-term power interruptions: for networks from a few dozen to a few hundred per year. Long interruptions – more than 3 minutes and short – term interruptions-less than 3 minutes [72.75].

Each failure of the voltage or its excess increase leads to a short-term failure of the process equipment. Different industries react differently to this phenomenon. In the Metalworking industry, this leads to tool breakdowns and product defects. In electric lighting systems, increasing the voltage by only 10% relative to the nominal level reduces the lamp life by about 3 times. The damage caused by low voltage is associated with a decrease in the efficiency of lighting devices and a violation of occupational health.

In asynchronous motors, a 1% increase in voltage leads to a 3% increase in reactive power consumption. When the voltage decreases, the current decreases proportionally, and the reactive power loss increases proportionally to the square of the voltage decrease. This reduces the service life of insulation, reduces the performance of mechanisms and increases the specific power consumption due to the increase in the duration of the technological process.

The amount of active and reactive power loss during voltage deviation largely depends on the load factor of the short-Circuit motor. When K3 = 0.85-1.0 and the voltage is slightly higher than the nominal power loss is minimal. The most effective way to reduce voltage failures, which European countries have taken, is to increase the reliability of energy transport systems, especially overhead power lines with a voltage of 110 kV and higher. In most cases, voltage dips in the distribution network are transformed from higher voltage networks.

Voltage asymmetry, which largely determines the efficiency and reliability of power supply, is characterized by two indicators of power quality:

- the coefficient of voltage asymmetry in the reverse sequence (K2U);

- the zero-sequence voltage unbalance coefficient (K0U). When the multiphase electrical system operates in an unbalanced mode, the operating conditions of one or all phases are not the same.

At the same time, the capacity of network elements decreases, additional heating of electric machines occurs, and losses of active power and energy in power supply systems increase. Current asymmetry causes voltage asymmetry, which in turn leads to deviations in the phase and line voltages of the network.

Thus, the voltage asymmetry that is constantly present in the supply network worsens the indicator of steady-state voltage deviation. Unbalanced loads, being consumers of direct sequence currents and power, are simultaneously sources of reverse and zero sequence currents. These currents, flowing through the elements of the power supply system (SES), cause additional voltage losses of the corresponding sequences in them. From the interaction of currents and voltages of different sequences, there are distorting power flows in the opposite direction.

The power flow of the direct sequence is directed from power stations to consumers; the distorting power flows of the reverse and zero sequences have the opposite direction - from the load in the SES.

The consequence of the phase current asymmetry is a misalignment of the secondary voltage range of network distribution transformers in 6-10/0. 4 kV and the occurrence of additional phase losses. The" skew " of the star, in turn, negatively affects the operation of electric light receivers and motors, which leads to a sharp reduction in the service life of household appliances and incandescent lamps in phases with high voltage and causes an increase in losses in engines.

When the coefficient of asymmetry is within its standard value, the power loss for asynchronous motors (AD) is 2.4 %, for transformers-4 %, for synchronous motors (SD) - 4, 2% of the nominal values. If voltage unbalance of 4% fully loaded AD is reduced by 2 times; if unbalance is 5 % of available engine power is reduced by 5-10 % when asymmetry in 10% of this reduction is 20-50 % (depending on the motor type).

On power transformers, the asymmetry has the same effect as on AD, i.e. it causes additional heating of the windings and a decrease in service life. In the SD, when the voltage is unbalanced, along with the occurrence of additional losses and heating of the stator and rotor, dangerous vibrations can occur caused by torques pulsating with double frequency.

These moments appear as a consequence of the interaction of magnetic flows created by reverse sequence currents in the stator and rotor circuits, as well as flows caused by direct sequence currents. With significant stress asymmetry, vibration can cause damage to welded joints. Requirements for K2U and K0U are defined in GOST 32144-2013.

However, at present, electricity certification is carried out only for two PCE - steady-state voltage deviation (δU_y) and frequency deviation (Δf). According To the civil code of the Republic of Kazakhstan, electricity must meet all the requirements of GOST. Therefore, in the energy supply contracts and in the technical specifications issued by the energy supply organization to a legal entity or household consumer, all PCE must be specified, and not only δUy and (Δf). Non-sinusoidal voltage causes additional losses of active and reactive power, makes it difficult to compensate for reactive power using capacitor banks, reduces the service life of electrical equipment insulation, and creates electromagnetic interference to automation, protection, and communication systems.

In networks with higher harmonics sources, capacitor banks are either disabled by overcurrent protection, or fail as a result of overheating, leading to swelling or even explosions. This is due to the frequency resonance of any of the harmonics in the circuits formed by the capacitance of the capacitor Bank and the inductance of the network. Additional losses from higher harmonics in the networks of electrical systems are 2-4 % of the level of losses at sinusoidal voltage, in the networks of enterprises and electrified railway transport they reach 10-15 %.

Therefore, it is advisable to assess the quality of power supply to consumers in the following sequence:

- justification and establishment of the required number of energy efficiency indicators for each of the components;
- determination of objective standards and their acceptable limits for all surveyed energy efficiency indicators;
- conducting comprehensive energy surveys and determining actual energy efficiency indicators;
- assessment of possible economic damage caused by deviations of actual energy efficiency indicators from the standard ones;
- development of an action plan to improve the surveyed energy efficiency indicators of various components and determination of technical and economic indicators for these measures;
- comparative assessment of damage values based on the energy survey data with the results of proposed measures to improve energy efficiency indicators;
- search for the optimal plan of measures to improve energy efficiency indicators in the scenario of the greatest reduction in damage from non-compliance with standards.

The search for the optimal plan can be carried out based on the principle of analyzing deviations of energy efficiency indicators from their standard 62 values, taking into account weight coefficients that take into account the importance or the highest specific weight in the accepted criteria for the quality of electricity supply[76].

4.2 Typical measures to improve the efficiency of heat and electricity consumption

The main goals of the energy survey are to develop a list of standard publicly available measures (PAM) for energy conservation and energy efficiency improvement.

According to the Order of the Ministry of energy of the Republic of Kazakhstan dated 19.04.2018, the list of standard publicly available measures (PAM) for energy saving is compiled in accordance with Appendix No. 21 Of the requirements for the energy passport. At the same time, typical public events are divided into three groups:

-organizational, low-cost;

- average cost;

- long-term, high-cost.

The list of typical public events mainly covers activities for energy-saving and energy-consuming systems of a General nature. When selecting activities for specific technological processes, reference documents for specific industries should be used.

Typical public events of a General nature imply the need to consider the institution as a whole, as well as to assess the needs and purpose of various systems, their energy characteristics and their interaction. In addition, these typical public events include the following approaches [77]:

- analysis and comparison of the effectiveness of various systems;

- planning activities and investments to optimize energy efficiency, taking into account the economic feasibility and impact on various natural environments;

– in the case of new systems-optimization of energy efficiency in the design of the plant, unit or system, as well as in the selection of technological processes;

– for existing systems, optimize energy efficiency through proper operation and management, including regular monitoring and maintenance.

Therefore, generic public events for individual systems, processes, and equipment types imply that generic public events of a General nature are also applied to the corresponding installations as part of their optimization. Typical publicly available measures to ensure the energy efficiency of common plant activities, systems and processes can be described as follows.

Heat recovery. Objectives typical public measures are to maintain the efficiency of heat exchangers through the methods described below:

- periodic monitoring of efficiency;

- preventing or removing deposits and scale.

Methods for cooling processes and their corresponding PAM consist in finding useful applications of waste heat instead of its dissipation in the cooling process. Where cooling is necessary, you should consider the possibility of using free cooling (using ambient air).

Cogeneration. The goals of typical public events are to find opportunities for cogeneration. In this case, consumers can be located within the installation or outside it (third party).

In many cases, state bodies (local, regional) assist in reaching an agreement with a third party or are themselves such, see law No. 190 "on heat supply".

In the case of electricity supply purposes typical public activities consist of:

- increase the power factor in accordance with the requirements of the local electricity supplier using available methods;

check the power supply system to the presence of higher harmonics and, if necessary, the use of filters;

- optimization of the efficiency of the power supply system.

Subsystems with electric drive. Replacing electric motors with energy-efficient motors (EED) and variable speed drives is one of the obvious measures to improve energy efficiency. However, the feasibility of such measures should be considered in the context of the entire system in which the engines are used; otherwise, there are risks:

- loss of potential benefits from optimizing the operating method and size of systems and, as a result, from optimizing the needs for electric drives;

-energy loss due to the use of variable speed drives in an inappropriate context.

The goals of PAM are to apply the following sequence of steps to optimize electric drives:

- optimize the entire system that includes electric drives (for example, the cooling system);

- then optimize the drives in the system to meet the newly defined load requirements using one or more known methods, where applicable;

After optimizing energy-consuming systems, optimize the remaining (non-optimized) engines using known methods and the following criteria (recommended by European Union Directives):

- the remaining engines, which operate more than 2000 hours per year, are a priority for replacing the EED;

-for variable-load drives operating at less than 50% of the maximum capacity, operating for more than 20% of the operating time, and operating for more than 2000 hours per year, consideration should be given to replacing variable-speed drives[73,75].

4.3 List of typical energy saving and energy efficiency measures

The following list of standard publicly available measures for energy saving and energy efficiency improvement is based on literature sources [81, 82] and practical experience.

Energy production:

1. Application of peak power installations to equalize emerging peak loads in the utilities sector and industry.

2. The use of expander - generators for excess gas pressure for generating electrical energy, cold, heat.

3. Use of unloaded industrial waste turbines to generate heat to replace boilers, etc.

4. Use of low-potential heat from energy sources for heating, ventilation and air conditioning.

5. Utilization of physical heat of exhaust gases of fuel-using installations.

6. Reconstruction of water treatment plants of heat sources.

7. Switching to recuperative and regenerative burners. Reduction of the coefficient of air consumption for Gorenje.

8. Transition to granulated fuel from wood waste, wood, straw, etc.

9. Use of renewable energy sources depending on the climatic conditions of the territory.

10. Application of heat pumps in heat supply systems.

11. Replacement of outdated equipment of coal-fired thermal power plants, replacing it with new installations using efficient environmentally friendly coal technologies.

12. Replacement of depleted DES (diesel power plants). Construction of new DES using modern technologies (cogeneration and trigeneration of energy, mini-thermal power plants, combined power plants).

13. Replacement of boilers that have run out of resources or have excess capacity at mini-thermal power plants.

14. Reduction of energy costs for the sources ' own needs.

15. Creation of automated control systems for power units and facilities (ASKUE / asku TER, etc.).

Heat supply system

1. Implementation of monitoring and diagnostics systems for the current state of pipelines.

2. Introduction of modern types of pipeline insulation (PPU, ppm insulation).

3. Construction of drainage devices for draining channels.

4. Replacement of Central heating points (CTP) with individual ones (ITP).

5. Dispatching of heat networks and energy consumption control systems.

6. Organization of the pipeline corrosion protection system.

7. Installation of frequency-controlled electric drives for heating, hot water, and water supply systems.

8. Introduction of a system of incentives for operating personnel to reduce actual losses in heat networks.

Supply system

1.Carrying out a complex of works on technical re-equipment and reconstruction of power grid facilities of the power system, installation of reactive power compensators, implementation of deep high-voltage inputs.

2.Organization of a system for managing consumer load schedules in order to equalize the peak load on the network.

3. Reconstruction of networks with minimization of unit costs per unit of their length.

4. Reactive power Compensation for consumers (0.4 kV).

5. Reconstruction of substations, replacement of outdated transformers with maximum losses.

6. Organization of technological electricity metering.

7. Improvement of the system of commercial and technical accounting of electricity in electric networks and consumers.

8. Use of devices to protect lighting devices and signs from precipitation.

9.Application of modern energy-saving lamps.

10.The use of reflective color.

11.Use of solar-powered lamps.

12.Replacing the pointers with solar-powered led lights.

13.Creating natural ventilation for ventilation and safe operation of underground structures.

14.The use of reflective coatings in tunnels.

15.Creating a diagnostic system to identify sources of flooding in tunnels.

16.Application of electrochemical protection and high-efficiency cathode stations.

17.Use of led cords to indicate the dimensions of building structures.

Manufacturing activity

1. Creation of the Commission on energy saving for identification of irrational use of energy resources, with the participation of the first managers of the enterprise.

2. Training of specialists in the field of energy surveys.

3. Development and implementation of programs for utilization of secondary and renewable energy resources.

4. Creating a system for energy analysis of economic activity of an enterprise or organization.

5. Use of own combined plants (GTU, CCGT) to increase the efficiency of using fuel and energy resources, cover peak loads (cogeneration, trigeneration).

6. The transition to the turnaround cycle of water supply. Decentralization of air supply.

7. Regular development of regime and technological maps for energy and technological equipment.

8.For thermal energy production facilities under construction and under reconstruction with a capacity of more than 5 Gcal/hour – provision of combined heat and electricity generation.

9.Improvement of technological processes due to the specialization and concentration of individual energy-intensive industries (foundry, thermal, electroplating, etc.).

10.The Use of efficient electric motors.

11.Introduction of a frequency-controlled electric drive.

12.Introduction of efficient industrial lighting systems.

13.Introduction of systems for efficient steam supply and return of water vapor condensate.

14.Introduction of efficient compressed air systems using modern compressor equipment.

Budgetary and municipal institutions

1. Development of restrictions on energy consumption.
2. Inclusion in the cost item of accounting/billing of the cost of servicing energy metering devices.
3. Creating a system of personal incentives for employees of organizations when carrying out energy-saving measures.
4. The choice of the equipment taking into account energy saving features.
5. Shifting the start of the working day in case of reduced energy consumption.
6. Reduction of indoor air temperature during night hours and weekends.
7. Adjustment of modes of ventilation. Installation of recuperators for air heat recovery.
8. installation of reactive power compensators for consumers.
9. use of individual heat points (ITP), with the installation of a frequency-controlled pump drive.
10. Improving the efficiency of lighting systems for budget buildings and service sector buildings. Replacement of incandescent lamps.
11. Transition to heat, natural gas and electricity metering systems for all public sector and service facilities[83,85].

4.4 Technical measures for energy saving and limits of annual savings

Table 4.1 shows typical measures and the level of average annual energy savings achieved during their implementation, compiled according to [83].

Table 4.1 Types of measures and limits of annual savings

№	Name of event	The limits of the annual savings, %
Lighting system		
	Replacing incandescent lamps with energy-saving ones	up to 55-70 % of their electricity consumption
	Switching to a different type of light source with higher light output	up to 8 % of their electricity consumption
	Replacement of fluorescent lamps with lamps of the same size and lower power: 18 W instead of 20, 36 W instead of 40, 65 W instead of 80.	up to 5 % of their electricity consumption
	Application of energy-efficient start-up control equipment (PRA) of gas-discharge lamps	11 % of their electricity consumption
	Optimization of the lighting system by installing multiple switches and dividing the lighting area into zones	10-15%
Heating system		

	Installation of a heat metering device	Up to 30% of
	Preparation of manuals for operation, management and maintenance of heating systems and periodic monitoring by the management of the institution for their implementation	heat consumption
	Hydraulic adjustment of the internal	before 15 %
	Automation of building heat supply systems by installing individual heat points (ITP)	20-30% of the heat energy consumption
	Annual chemical cleaning of the internal heating surfaces of the heating system and heat	10-15%
	exchangers	15-30 %
	Reduction of heat losses through window openings by installing a third glass and insulation of window frames	15-25 %
	Improved thermal insulation of walls, floors and attics	before 15 %
Hot water supply systems (DHW)		
	Preparation of manuals for operation, management and maintenance of DHW systems and periodic monitoring by the management of the institution for their implementation	5-10 % of hot water consumption
	Automation of DHW system regulation	15-30% of heat energy consumption
	Equipment of hot water supply systems with hot water flow meters	15-30 % of hot water consumption
	Consumption reduction through optimization of expenses and regulation of temperature	10-20 % of hot water consumption
	Use of cost-effective water separation valves	15-20 %
Supply system		
	Reduce water costs and losses	up to 50 % of
	The installation of counters of water consumption	water consumption
	Application of frequency control of water supply pumps	up to 30 % of
	Use of cost-effective water separation valves	30-35 %
Ventilation system		
	Replacing outdated low-efficiency fans with modern ones with higher efficiency	20-30 % of their electricity consumption
	Turning off ventilation systems during lunch breaks and after hours	10 - 50 %
	Application of air curtain fan blocking with door opening mechanisms	up to 70% of their electricity consumption
	Application of devices for automatic regulation and control of ventilation installations depending on the outside air temperature	10-15 %
Conditioning system		

	Turn on the air conditioner only when necessary	20-60 % of their electricity consumption
	Exclusion of hypothermia and overheating of the air in the room	before 5 %
	Maintenance of regulators, heat exchanger surfaces, and equipment	2-5 %
Boiler		
	Preparation of manuals and operational maps for the operation, management and maintenance of equipment and periodic monitoring by the management of the institution for their implementation	5-10 % of fuel consumed
	Maintaining an optimal excess air ratio and good mixing with fuel	1-3 %
	Installing a water surface economizer behind the boiler	before 5-6 %
	Application of deep heat recovery installations for boilers, installations using latent heat of vaporization of outgoing flue gases	before 15 %
	(contact heat exchanger)	2 % for every 10 °C
	Increasing the temperature of feed water at the entrance to the boiler drum	1% for 6 °C
	Keeping the external and internal heating surfaces of the boiler clean	before 10 %
	Use of heat from boilers by taking warm air from the upper zone of the boiler room and feeding it to the suction line of the blast fan	1-2 %
	Thermal insulation of external and internal surfaces of boilers and heat pipes, sealing of valves and boiler paths (the temperature on	before 10 %
	the wall surface should not exceed 55 ^{0}C)	The cost of 1 Gcal is reduced by 2-3 times
	Conversion of boiler houses to gas fuel	before 20 %
	Automation of boiler room operation management	before 30 %
	Modernization of boilers of the DKVR type for operation in hot water mode	Efficiency increases up to 94% up
	Installing or upgrading	a water treatment system to 3 % of make-up
	water up	to 30 % of the electricity consumed by them до

The energy savings shown in the 4.1 table are indicative. When conducting an energy survey, it will be possible to more accurately calculate the energy savings from the introduction of a particular energy-saving measure. Also, the approximate amount of energy savings that the surveyed institution has can be estimated using the results of numerous energy surveys.

4.5 Organizational and low-cost activities

Organizational and low-cost measures aimed at improving the efficiency of energy consumption include standard measures.

A significant potential for energy saving is concentrated in organizational measures that allow increasing the efficiency of energy use with minimal financial costs. In the conditions of modern volumes of use of fuel and energy resources and high payments for them, the use of organizational measures allows saving up to 20-25% of energy resources consumed, according to various data.

List of organizational energy-saving measures

1. Development of Regulations on energy saving for the institution;
2. Development of Regulations on the procedure for encouraging employees to save energy and energy resources;
3. Appointment of persons responsible for compliance with the savings regime and the procedure for reporting on savings achieved;
4. Appointment of persons responsible for implementing measures to save energy and improve energy efficiency of the institution;
5. Regular meetings on energy saving;
6. Development and approval of the institution's energy saving program;
7. Use of campaign posters on energy conservation in public places;
8. Appointment of the person responsible for compliance with the heat and electric power supply regime;
9. Financial accounting of the economic effect of energy-saving measures and organization of refinancing of part of the savings in the implementation of new energy-saving measures;
10. Adoption of Regulations on the procedure for placing an order for energy-saving measures in the organization;
11. control over the fact that the purchase of goods and services complies with the rules of energy efficiency;
12. Training of service personnel of institutions in ways and conditions of energy saving;
13. Adoption of regulatory and administrative documents on staff motivation in energy saving;
14. Determination of the possibility of replacing outdated electric receivers (in all power supply systems) with modern ones with high energy efficiency;
15. Revision of contractual relations with suppliers of energy resources with the introduction of data on the differentiation of balance sheet ownership and operational responsibility; on commercial accounting devices, according to the indications of which payment for consumed energy resources will be made in the future;
16. Monitoring the execution of contracts for the supply of energy resources.

List of technical energy-saving measures

1. Painting the surfaces of industrial premises and equipment in light colors to

increase the coefficient of use of natural and artificial lighting;

2. The use of led lamps for street and security lighting.

3. Use of the equipment for the zone off light levels;

4. The use of automatic circuit breakers for emergency lighting;

5. Regular cleaning of transparent elements of lamps and automatic shutdown sensors;

6. replacement of valve taps with lever and keyboard ones;

7. Rationalization of the location of light sources in the premises;

8. Closing unused premises with heating turned off;

9. The adjustable heat output (for time of day, weather conditions, temperature in the premises);

10. Installation of additional vestibules at the entrance doors;

11. use of lighting devices with electronic start-up control equipment;

12. The use of light control systems (dimming);

13. Maximum use of natural light in the daytime and automatic control of artificial lighting depending on the level of natural light. Lighting can be controlled from infrared sensors, the presence of people or movement;

14. The use of automatic circuit breakers for systems or emergency lighting in areas of temporary stay of personnel.

4.6 Improving the energy efficiency of buildings and structures

When developing energy saving measures or conducting an energy audit, the parameters of all elements of heating, ventilation and air conditioning systems and their design characteristics are determined from the building project. It is also necessary to clarify the annual operating mode of air control and measurement systems. The design load of ventilation and air conditioning installations is determined from the project of the enterprise or organization.

In the absence of such data, it can be determined by analytical methods, taking into account the external and internal volume of buildings, specific ventilation characteristics, and air temperature inside and outside the building. The main characteristics that should be determined when examining ventilation systems are: actual load factors, operating time of installations during the day,in door air temperature and average outdoor air temperature, air exchange rate.

Measures for energy saving in heating, ventilation and air conditioning systems are reduced to the following [85, 87].

1. the use of economically feasible heat transfer resistance of external fences during construction and additional insulation of external walls during reconstruction of buildings to increase the heat transfer resistance of external walls and reduce heat losses of the building by improving its thermal protection properties and using effective thermal insulation materials.

2. Installation of ventilated external walls to increase the level of thermal protection of external walls.

3. Thermal protection of an external wall at the place of installation of the heating device for reduction of heat losses from external protections (walls) to which heating devices adjoin.

4. Installation of ventilated Windows to reduce air permeability and increase the heat transfer resistance of window blocks.

5. Installation of additional (triple) glazing to reduce air permeability and increase the heat transfer resistance of window blocks. The use of heat-absorbing and heat-reflecting glazing to reduce heat access to the premises from solar radiation, which leads to comfort in the premises.

6.Installation of glazed loggias to reduce the consumption of outside cold air entering the room in winter and increase the temperature in the loggia (behind the outer wall of the room).

Energy saving measures in heating, ventilation and air conditioning systems related to the operating mode [89, 92]:

Periodic operation of the heating system.

Periodic operation of the heating system is used in industrial, civil, educational, sports, commercial, and administrative buildings that are used for part-time work and days of the week when the temperature inside the premises is allowed to decrease during non-working hours. In the heating system operation mode, three characteristic time intervals are observed during the day:

- the main operating mode, when the set temperature and humidity parameters are maintained in the room;
- standby mode, when after the main mode the heating system is switched to the mode of maintaining a low temperature in the room;
- forced room heating mode, during which the heating system is switched to the fastest possible heating of the room after cooling.

There is also a weekly cycle in the premises, when on weekends and holidays a full day can be maintained on duty heating mode and a reduced temperature in the room. To maintain the standby mode, water heating is used, which performs the function of maintaining a minimum temperature level. But as a result of some cooling of the room, not only the temperature of the internal air decreases, but also the temperature of the fences. Heating fences and indoor air by the beginning of a new working day requires time and additional power.

The duration and rate of heating depend on the thermal resistance of cladding that affect the temperature drop in after hours; thermal activity of walling to thermal effects; the intensity of heat transfer from the source to the heating system to the indoor air and from air to the surface of the fence; the temperature difference in standby and operating mode differential, and ambient temperatures.

Heating of premises should be carried out forcibly at a high rate, with more power, in contrast to heating in operating mode, since heat in heating mode is spent on replenishing heat losses and heating fences and air to the required level.

The most flexible mode of operation is the combined heating system. It consists of a basic water heating system and an additional air heating system. Air heating is combined with supply ventilation and in forced heating mode operates in full air recirculation mode[85].

The operation of periodic heating systems can be automated and controlled by software to maintain the design mode. In case of an unexpected sharp drop in the outdoor air temperature, sensors for the permissible minimum indoor air temperature are installed in the control rooms. At a signal from them, the heating system turns on in an additional mode. The longer the cooling period, the greater the energy savings. To reduce the duration of forced heating, it is necessary to increase the thermal stability of fences, maximize the heat transfer to the fences, using, for example, directed air heating jets or using radiant energy sources (emitters) directed at the fences.

Here are additional measures to save energy [86].

1. Heating of premises with recirculating air heat. It is recommended to use the heat of recirculating air for industries where air recirculation is allowed, as well as when the air temperature in the upper zone is more than 30 °C and the air supply is not more than 15 m away. The heated air is taken from the upper zone of the production room, cleaned of dust and pumped by a fan through the air ducts into the supply nozzle (cylindrical or slotted shape). Energy saving is provided by utilizing the heat of the removed air.

2. Application of rotating regenerative air-to-air heat reclaimers.

3.In air heating systems for residential, public, industrial, agricultural buildings and structures, as well as hotels, in which the heating function is combined with ventilation, the air for heating is heated in heaters or air heaters with hot water, steam, hot air or other heat carrier. The heat and mass transfer process can be carried out in two ways:

1) the heated air enters the room through special channels through air distribution grids and mixes with the internal air;

2) the heated air moves in the internal channels surrounding the room, while heating the walls of the room, the heat from which is transmitted to the internal air of the room. The cooled air is returned to the heater via other channels for reheating or is partially released into the atmosphere when the room temperature is high.

Thus, the air heating system can be fully recirculated, when the air is completely returned for reheating, or partially recirculated, when the air is partially released into the atmosphere and partially reheated. Air heating systems are actually combined heating and ventilation systems.

Advantages of air heating systems: ensuring uniform temperature over the volume of the room, the ability to clean and humidify the air, the absence of heating devices in the room. Disadvantages of air heating systems: large cross-sections of air ducts compared to water and steam heating pipes, a smaller radius of action compared to the same systems, heat loss due to insufficient thermal insulation of air ducts[85, 86].

To reduce energy costs for heating the outdoor air, it is possible to use regenerative heat exchangers that allow you to utilize the heat of hot exhaust air. In air heating systems, heat loss is reduced due to the absence of radiator niches-sections of external fences that occur in water and steam heating systems.

Energy saving when using air heating is also achieved by automating the system with a low heat capacity of the air, as well as by possibly maintaining a lower air temperature in the room during non-working hours and quickly heating the room before the start of the working day.

Periodic operation of ventilation and air conditioning systems. Periodic modes of operation of ventilation and air conditioning systems are used to stabilize the temperature, moisture content and gas composition of the air. They are most effective when servicing large-volume premises in public buildings with variable occupancy (auditoriums, shopping halls, sports halls, waiting rooms), where the temperature, humidity and air composition (carbon dioxide and oxygen content) change simultaneously.

Reducing energy consumption by ventilation and air conditioning systems is provided by changing the air flow rate of the required parameters, using complex and expensive air distributors, using advanced methods of regulating the fan operation, and a complex automation system. An alternative way to regulate systems can be periodic ventilation of premises depending on the condition of the room air, which ensures savings in electrical and thermal energy. The duration of the break depends on the frequency of air exchange, the volume of the room, and the composition of the air. Functional circuits of automatic control control the concentration of carbon dioxide, changes in humidity and air temperature.

Device of air curtains. Air curtains are installed at the entrance, at open openings in public and industrial buildings and structures, workshops, shopping centers, shops, in multi-storey residential buildings with frequently opened entrance doors or with significant gates. The event is aimed at reducing the cost of heat for heating the air coming through entrances, entrances and openings. Use combined air-heat curtains with and without a vestibule, and air intake is carried out from the room or outside[87].

Energy saving is achieved by reducing the need for heat to heat the supply air and the cost of electricity to move it.

1. Room heating system using gas infrared emitters. The system is designed for heating permanent and temporary workplaces of production and auxiliary premises; premises and structures on open and semi-open sites during the construction of buildings and structures; snowmelt systems, on the roofs of buildings and structures.

2.Heating devices are burners of infrared radiation. The burner uses low-pressure gas with pre-mixing of gas and air, and the temperature of the radiating surface reaches about 850 °C. At this temperature, about 60% of the heat released during the combustion of gas is transmitted by radiation in the form of infrared (heat) rays. The placement of burners in a room or in an open area, the number of rows, the distance between the burners in a row, the height of their suspension above the floor, the angle of inclination of the burners, is determined based on the irradiation standards and the type of burners.

Energy saving is achieved by reducing the heated volume of the room, the absence of overheating of the upper area of the room, low thermal inertia and the use of automatic control.

1. Gas-air radiant heating. Gas-air heating is used for industrial premises, Assembly, mechanical, repair shops, depots, garages, hangars.

2. The function of heating devices is performed by pipelines with high temperature laid in the upper zone of the room, not lower than 4.5 m from the floor.

A mixture of heated air and fuel combustion products circulates inside the pipes, which ensures a high temperature of the pipelines. Heat transfer from the surface of the pipes to the room air occurs due to the total heat exchange-convection and radiation. However, the higher the pipeline temperature, the greater the proportion of heat transfer due to radiant heat exchange[87, 88].

3. Heat-Emitting pipes have a diameter of up to 0.4 m and are assembled on flanges. To reduce heat losses in the upper part or non-working area of the room, the pipes are covered with effective thermal insulation from above, and longitudinal metal screens (canopies) are installed along the side of the pipes, preferably with a high degree of blackness (painted canopies). The temperature of the coolant circulating through the pipelines should exclude the effect of dew point on the inner surface of the pipes and low-temperature corrosion.

Energy saving is achieved due to the absence of overheating of the upper zone and the preservation of thermal comfort conditions in the work area.
Application of heat pump installations and low potential energy (condensate, air).

4.7 Energy saving in heating systems of buildings and structures

In order for a person to feel comfortable in a room (residential, industrial, etc.), it is necessary to create a temperature environment in which the body would not experience cooling or overheating. The issue of ensuring a normal temperature situation is especially relevant in the cold season. After all, in addition to the problem of maintaining the necessary air temperature in the room, there is a problem of energy consumption, in particular, issues of energy saving and energy shortage associated with excess or lack of heat, which are not so pronounced in the spring and summer period.

In the premises of buildings during the cold season, create and maintain a thermal regime that meets the specified thermal conditions and meets the requirements of the technological process. At the same time, the thermal regime in the premises can be both constant and variable, depending on the purpose of the buildings. Residential buildings are buildings with a constant thermal regime.

A constant heat regime in the premises is maintained around the clock during the entire heating season in accordance with the requirements of thermal comfort. To determine whether heating is required and how much power, heat losses and heat accesses are calculated in the calculated steady-state mode, when the greatest heat deficit is possible.Equalization of heat access (including heat access from the heating system) and heat loss is called the reduction of the heat balance of the premises. If the heat loss exceeds the internal heat release, heating is necessary. If there is less heat loss in a building that is usually industrial, then it is not necessary to heat the premises. in this case, special measures must be taken to eliminate the heat excess and achieve a heat balance (for example, by means of supply ventilation).In residential buildings, only heat losses through enclosing structures and heat consumption for heating outdoor air entering the premises by infiltration or for ventilation are taken into account. Heat access to the premises occurs due to the release of heat by people, heat pipes and heating technological equipment (furnaces, pipes, appliances, etc.), artificial lighting sources and working electrical equipment, heated materials and products[89,90].

4.8 Classification of heating systems

According to the method of water supply, heat supply systems are divided into closed and open, two - and four-pipe, and others.

In closed heat supply systems, water is not taken from the heating network, but is used only as a heat carrier in water-water heat exchangers for heating cold tap water entering the hot water supply system. The main advantages of a closed heat supply system: stable quality of hot water and easy control of system density. The main disadvantages are the complexity of equipment and operation of subscriber hot water inputs; corrosion of installations due to the supply of tap water to them, as well as the formation of scale and sludge in hot water pipelines [90].

In open heat supply systems, water is taken directly from the heat network and fed to the hot water supply system. In this case, the boiler plant has additional elements: a storage tank for creating a supply of water for hot water supply during maximum consumption hours, pumping pumps, etc. The main advantages of open heat supply systems: simple and inexpensive subscriber hot water inputs, their durability; the possibility of using single-pipe lines.

Disadvantages of open heat supply systems: complication and increase in the cost of water treatment equipment and make-up devices; instability of water entering the hot water supply according to sanitary indicators (color, smell); complication of monitoring of coolant leaks and system tightness [91].

Two-pipe heat supply systems have a common hot water supply pipeline for heating, ventilation and hot water supply and a common return pipeline and are mainly used for thermal loads of more than 58 MW.

Four-pipe heat supply systems are used at loads up to 58 MW and with a small radius of consumers. The boiler house has two water heating units: one for heating water in the heating and ventilation system, and the other for heating water in the hot water supply system.

Heat consumers can be connected directly to the heating networks through Central heating points (CTP) or individual heat points (subscriber inputs), where hot water is prepared and supplied with the necessary parameters for heating, ventilation and hot water supply.

In closed heat supply systems, cold water is supplied to hot water through water-to-water heat exchangers, in which tap water is heated to a temperature of +60...65 °C. In open heat supply systems, water for hot water supply is taken directly from the heat network.

Heating systems are connected to the heating network according to one of the schemes [85]:

- independent-water is heated in a heat exchanger;
- dependent, when directly connected to the heating system;
- connected via an Elevator, in which water is mixed from the supply and return pipelines and the desired temperature of the water going for heating is reached;
- with the mixing pump installed on the bridge between the feed and return lines.

Heat loads of heating, ventilation, and hot water supply in heating systems are regulated centrally by changing [84,85]:

- water temperature in the supply pipeline of the heating system without regulating water flow (quality control);
- network water consumption while maintaining a constant water temperature in the supply pipeline (quantitative control);
- water temperature in the supply pipeline of the heating system with a corresponding change in water flow (qualitative and quantitative control).

To correct the regulation (Central) in the heating networks, additional group local regulation is carried out at the Central heating points, heat points of buildings, as well as local, individual regulation on individual devices. In the considered thermal schemes of boiler houses in heat networks, high-quality regulation of the heat load is accepted.

Heat consumers are divided into consumers of the first and second categories according to the reliability of heat supply. The first category includes consumers whose violation of heat supply is associated with a danger to human life or with significant damage to the national economy, the second category includes all other consumers.

Boiler houses are also divided into two categories according to the reliability of heat supply to consumers. The first category includes boilers that are the only source of heat in the heat supply system and provide consumers of the first category who do not have individual heat sources, and the second category includes all other boilers.

4.9 Decentralized heating systems for buildings and structures

Over the past two decades, energy policy in Kazakhstan has been characterized by a rapid increase in the share of decentralized heat supply in the total volume of ensuring the functioning of heat-consuming systems of buildings for various purposes.

The concept of "decentralized" in this case implies providing these systems with a heat carrier (usually hot water) from their own heat generator (water boiler) installed directly on the object that consumes heat. This can be a separate building or a complex of functionally related construction objects. In this case, the heat generator (one or more) with all the necessary other technological equipment is placed in a special room (in the boiler room) located in the building itself or in the immediate vicinity of the serviced object. In addition, the heating system is designed on the basis of various equipment [84, 85, 86].

There are several reasons for the widespread use of decentralized heat supply in Kazakhstan today. First, there is a significant increase in individual suburban housing construction. As is customary in the West, a single-family residential building (cottage) and in Kazakhstan, as a rule, is equipped with its own heat generator. Secondly, due to the increased, most often, point development in large cities, there is a problem of heat supply to new buildings from existing urban centralized heating networks, which by their design capacity and technical condition no longer meet the increased needs. It is necessary to resort to decentralized heat supply schemes using, for example, roof or attached individual boilers.

The functioning of a modern heat supply scheme is not possible without means of regulation and automation, designed both to solve the main problems of the heat supply scheme and various heat-consuming systems of the serviced object, and to ensure the operability of all technological equipment included in the General scheme. It should be noted that the availability of modern, often using the most advanced electronic control circuits, automation tools, on the one hand, significantly reduces the number of service personnel, but, on the other hand, imposes qualitatively new, increased requirements for their level of professional training and qualifications.

The mandatory set of control and automation tools depends, first of all, on the General principles of its operation adopted in a particular heat supply scheme. Their volume, and, accordingly, the cost will largely depend on the number and variety of heat-consuming systems present in this scheme, as well as on the desired level of reliability and safety of the equipment used chosen by the designer in agreement with the Customer.

The possibility of diversity in the technology of the heat supply scheme, as a justification for the required principle and level of its automation, can be shown by the example of a combination of the two most common heat-consuming building systems: Central heating and hot water supply. Usually, when designing, one of two possible schemes is accepted.

First, the frequent pattern (Fig.4.1, a) provides for a complete cessation of the circulation of the coolant in the heating system (O) in the case where the control unit (A) received signal to reduce the required water temperature in water heater (VVP) hot water system (SW). In this case, the three-way switch or valve (TK) is automatically switched to the position at which the coolant begins to circulate in the VVP. The heat source (K) must work with the maximum possible power (the ow temperature from the boiler increases to the maximum possible) in order to reduce the time of heating the water in the VVP.

After increasing the water temperature to the required one set on block A, the T K valve is switched to the previous position, the circulation of heating water in the GDP is stopped,and the heating system is restored to its previous mode. To ensure the circulation of the coolant through both systems in such a scheme, one common pump (CN) is sufficient, which operates constantly. The required level of hydrostatic pressure in such a normally closed system is maintained by an expansion membrane tank (RB). This technology is used, for example, in the case when a wall-mounted gas single-circuit boiler (the so-called fuser) is used as a heat generator in combination with a separate VVP heater, which is very common in the West.

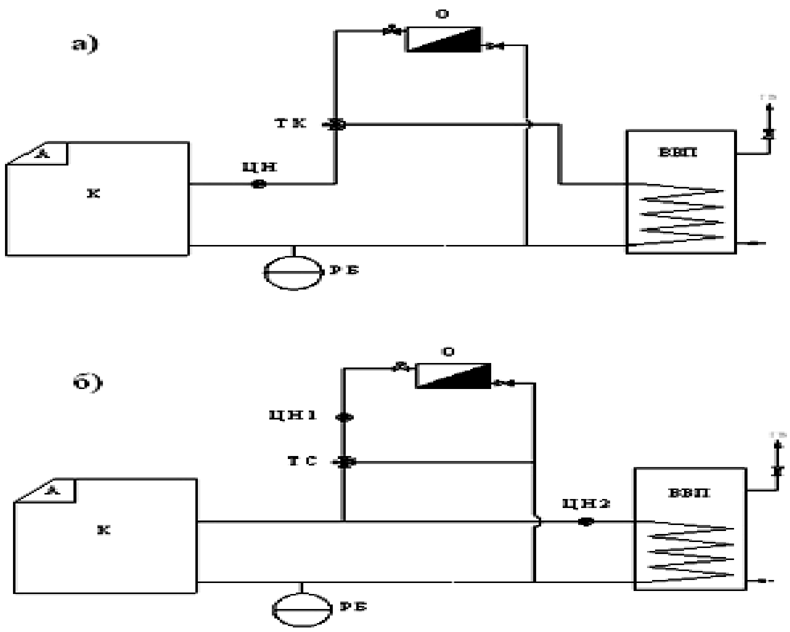


Figure 4.1- Basic technological schemes of decentralized heat supply of Central heating systems and hot water supply of the building: a-with priority of operation of the hot water supply system; b - with independent operation of both systems

It should be noted that experts often refer to this scheme as the "boiler priority" scheme, which should be recognized as not quite technically competent, since " boiler "here means a VVP heater, and the English word" boiler "is translated as"steam boiler".

Another scheme (Fig. 4.1, b) provides for independent operation of both systems-O and SW. Water circulation in each of them is carried out by its own pumps, and the pump of the Central heating system CH1 is constantly running, and the pump of the Central heating system CH2 is turned on only if it is necessary to heat the tap water in the VVP. In this case, the boiler must also automatically switch to the maximum power mode.

In this case, a three-way mixer installed in the O system is used to maintain the required temperature mode of operation of the heating system. Its task is to maintain the required temperature of the water supplied to the heating system by partially mixing it with the cooled coolant returning from the heating system.

As you can see, the functional purpose and control principles of the mixer TC in the second and the valve TC in the first schemes are different.

The first of the considered schemes has a significant cost advantage, since when choosing a heat generator, its calculated heat capacity is taken according to the maximum value of the calculated capacity of one of the serviced systems – O or SW. In the second scheme, you will have to sum up both calculated capacities when choosing a boiler. However, the final choice of the scheme, and hence automation designer needs to do after a thorough analysis of possible consequences for guests of the building in the event of the suspension of the circulation of the coolant in the heating system provided in the first scheme.

The first part of the scheme itself is quite complex and in addition to the main task – providing consumers with heat in the required amount, it also solves its own problems, which will be discussed below.

The peculiarity of the scheme of heat consumers in a modern building is that they differ significantly both in design and operating conditions, both in terms of heat capacity, heat carrier parameters (temperature and flow) and the limits of their change, and in the duration and frequency of operation. Below is a brief description of them, which basically defines the principles of their automation.

Water circulation is provided by its own circulation pump (CP), selected based on the estimated heat demand (heat loss) of the building and the temperature parameters of the coolant. Temperature control of the water supplied to the system (so-called "quality" control) is carried out by a three-way mixer (TS) installed in front of the pump, with theoretically constant water flow in the system at the current outdoor temperature ("perturbation"control).

The modern scheme of decentralized heat supply of a building in its maximum possible volume (Fig. 4.2) is a combination of various engineering equipment that is in a constantly changing thermal and hydraulic relationship. Functionally, such a scheme is divided into two parts: the scheme of binding heat generators (K1 and K2) and the scheme of heat consumers.

Central heating system (O1 and O2 in Fig. 4.2). During the heating season, the system operates almost continuously. Perhaps a short-term cessation of circulation in the transition period, and also short-term periodic triggering of system in the warm period (e.g., to run pumps).

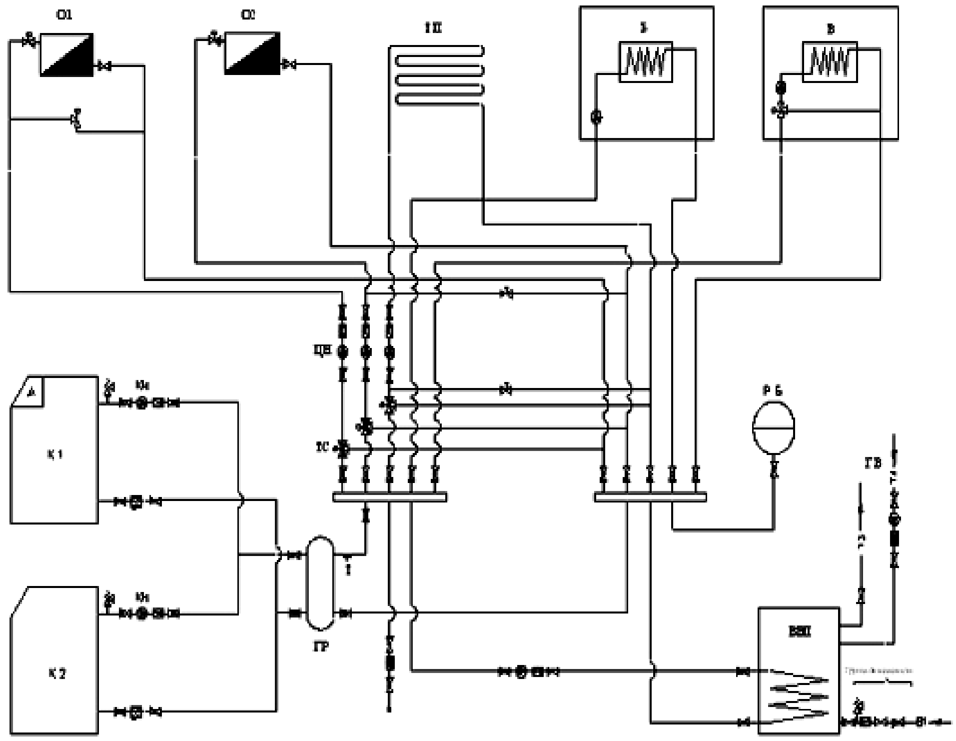


Fig. 4.2 Basic technological scheme of decentralized heat supply of a building with various heat-consuming systems

When regulating the heat supply to the heating system according to the internal air temperature in the control room of the building (regulation " by deviation») it can be carried out by periodically shutting down the system (regulation by "passes"). When installing control valves with a thermostatic head (thermal valves) in the heating system, the so-called "quantitative" regulation of the system occurs due to changes in the water flow in the devices and, accordingly, in the heating system as a whole. Most often, both methods of regulation are combined, complementing one another. In this case, the heating system operates with constantly changing water flow and temperature parameters ("qualitative-quantitative" control).

Floor heating system (TP). According to its purpose, it can be of two types. The first one performs purely heating functions (compensation for heat loss in the building premises), replacing or supplementing the functions of the Central heating system. In this case, the system operates with a variable water temperature in accordance with the specified schedule of quality control. The second possible type

- a purely comfortable system (for example, heating the bypass paths of the pool), operating at a constant temperature of the coolant. In both cases, the main feature is the reduced, in comparison with the Central heating system, the calculated temperature of the supplied coolant (no higher than 50 ° C) and the difference in the water temperature in the system (no more than 15 ° C).

The calculated water consumption directly in the heating circuit increases by

25 %, but the amount of water coming from the heat source is reduced by ~65 %. This is ensured by the appropriate manual adjustment of the control valve on the bridge in front of the circulation pump of the TP system (see Fig. 4.2). the water flow In such a system should be kept constant, since quantitative regulation can lead to uneven heating of the heated floor areas and reduce the durability of its structure. However, the flow rate of water coming from the distribution collector will automatically change under operating conditions due to the operation of the three-way mixer of the TP system.

Ventilation (air conditioning) system (B). Depending on the purpose of the ventilated room, the system can be permanent or periodic. The required heat output of the water heater is provided, as a rule,due to high-quality control using a mixer. The adjustable parameter (supply air temperature) is provided by the own mixing group (pump + mixer) of the ventilation unit or, if it is not available, by a similar group installed in the boiler room at the distribution manifold. Thus, the water flow from the boiler when the installation is running will vary depending on the position of the regulating body of the three-way mixer of system B. When the ventilation system is not working, a small water consumption (~5%) is saved to protect the supply air heater from freezing.

Hot water supply system (HW). It is characterized by pronounced peaks of maximum heat consumption during the day (morning and evening). The operation of the system largely depends on the type of water heater adopted by the company. In the case of a high-speed (for example, plate) heat exchanger, the heat consumption mode is variable and coincides with the water intake level. When using a capacitive water heater for hot water preparation, it will be warmed up periodically in forced heat mode (see above). In this case, the estimated power consumption of the water heater and, accordingly, the supply of the heating water pump, the frequency and duration of its operation will depend on the selected volume of the GDP heater. Its main adjustable parameter is the required design water temperature in the HW system, set on the control unit A, which is accepted according to the norms of the order of 60^0C.

Pool water heating system (B). It is activated periodically by a signal from the pool's own automatic water treatment system. To ensure rapid water heating, the system operates in forced heat mode (the maximum possible temperature of the coolant and its flow rate corresponding to the required capacity of the pool water heater). The duration of operation of the system mainly depends on the volume of water in the pool and can range from 1-4 hours in the normal periodic heating mode to 2-3 days when the pool is initially filled.

In addition to the above systems, other heat consumers may be present in the heat supply scheme. For example, an antifreeze heating system for outdoor areas adjacent to the building (sidewalks, garage entrances, entrance stairs, etc.), or an anti-icing system for heating the roof.

Depending on the architecture and layout of the building, there may be several heating and ventilation (air conditioning) systems in the scheme, and with different calculated heat load and operating period. The total number of hydraulically parallel heat-consuming systems in the heat supply scheme of a complex building can reach ten or more.

Thus, analyzing all the above, we can conclude that the second part of the General heat supply scheme is a complex "living organism" with constantly changing both smoothly and abruptly, thermal and hydraulic parameters. It is not possible to ensure its "vital activity" without modern control and automation tools.

Hydraulic stability of the first part of the scheme (binding of heat generators) and its protection from difficult predictable processes in the second part (groups of heat consumers) is provided by the hydraulic separator GR, which is currently often found in schemes of decentralized heat supply to buildings. Its other common name is taken from a literal translation from German:

"Hydraulische Weiche" – "hydraulic arrow". The gr separator itself is not part of the automatic control system, but its presence in the heat supply circuit determines the location of the temperature sensor (T) (at the water outlet from the separator), which is automatically controlled by the main current parameter of the heat generators – the temperature of the coolant supplied to the distribution collector.

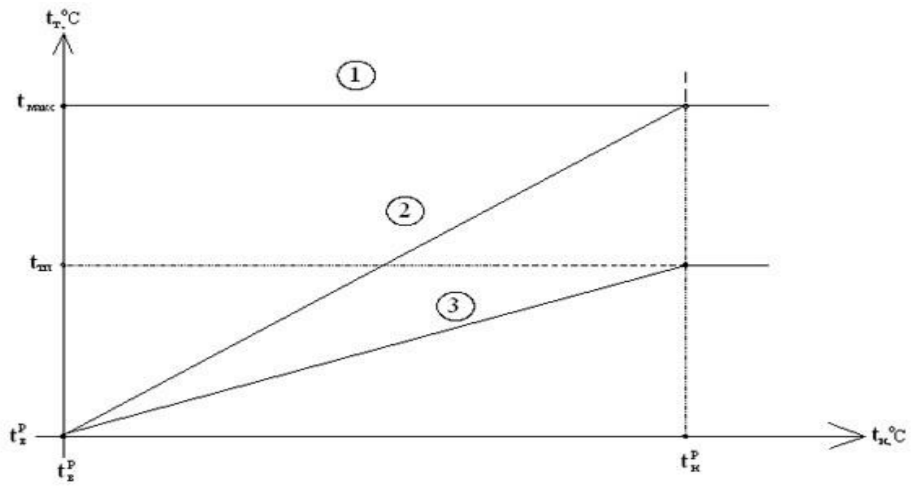


Fig. 4.3- Principles of building schedules for quality regulation of the building's decentralized heat supply system

It should be noted here that the technological capabilities of various modifications of the control unit from different manufacturers may differ significantly. First of all, this concerns the number of various heat-consuming systems controlled from the unit. In this regard, the designer who chooses a particular model and brand of the heat generator for a specific heat supply scheme must first analyze the possibility of using an automatic control unit combined with the generator in this scheme. In this case, it is not enough to be guided only by the power capabilities of boilers.

The main feature of the modern system of management and regulation of the scheme of decentralized heat supply is that most of the features of the General algorithm steps is performed with a single control unit (A) installed directly on the heat source (or one of them – the host, if any). Such a block is usually developed and provided by the manufacturer of boiler equipment. If a company uses a similar unit developed by another company specializing in the development and manufacture of automation tools, it adapts to its use in a specific heat generator design. The control unit can most often be inserted directly into the boiler body in a special niche or fixed on top of its body. Less often, the control unit is placed on the wall next to the boiler. The unit is a microprocessor equipped with a display that tracks all the necessary parameters and the results of its configuration. Such devices of most Western companies that supply to Kazakhstan are equipped with Russian-language text. In any case, this unit automatically controls the entire heat supply scheme: the heat generator with its hydraulic strapping equipment, and all heat-consuming systems that are part of the General heat supply scheme.

The main task of automation of any heat supply system is to provide the required current temperature of the coolant TT. In the most common case of "perturbation" control, its value is determined by the current outdoor temperature tn, controlled by a sensor installed on the Northern facade of the building being serviced. The required combination of these two parameters at a given time is set on the boiler control unit in the form of a quality control schedule (Fig. 4.3). First of all, compliance with this dependence is necessary for systems whose required heat output is determined by the current weather conditions outside the building. For Central heating and ventilation (air conditioning) systems (graph 2 in Fig. 4.3), the maximum water temperature Tmax, most often chosen from the calculated maximum temperature of the boiler unit (it must also be the calculated temperature of the coolant when designing these systems), corresponds to the calculated outdoor air temperature tn [87,88,90].

According to [86] in Kazakhstan, this temperature is taken depending on the construction area according to climatological standards [87] equal to the average temperature of the coldest five-day period with a security of 0.92. For example, for the city of Nur-Sultan, it is currently equal to -28 OS. With a further decrease in th, the water temperature Tmax remains unchanged. The left calculation point of the graph is the water temperature equal to the calculated internal air temperature TVR, which is assumed to be typical for most heated rooms of the building. For a residential building, its value is usually about 20 OS. The quality control schedule for the Underfloor heating system (graph 3) will be more flat, since the estimated water temperature for the TP TTP system is lower than for the Central heating system (see above). The schedule of temperature control TT set during the initial commissioning of the boiler on the control unit A during the operation of the building can be adjusted by slightly changing the position of its boundary points. Thus, in the end, its position can be selected, corresponding to the maximum possible thermal comfort in the premises of the building.

As noted above, for individual heat consumers (GW or B systems), if they are switched on, the maximum boiler power is required. In this case, the automation switches the heat generator operation mode to graph 1 (see Fig. 4.3), at which the temperature of the coolant tends to the maximum Tmax. This is achieved, for example, by gradually putting into operation individual stages of the boiler. Ensuring that the required quality control schedules for heating and ventilation systems are worked out automatically using vehicle mixers (see Fig. 4.2, 4.3). Schedule 1 can also be used when the heating system is regulated "by deviation" by monitoring the air temperature in the building being serviced. In this case, a temperature sensor is installed in its most representative room, depending on the readings of which the thermal power of the heat generator is changed. The difficulty in this case is to choose a characteristic room. In any case, bringing the level of comfort in each specific room of the building should be carried out using the second stage of regulation – quantitative regulation of the heat transfer of each heating device using an automatic thermal valve installed on it.

The boiler control unit performs other equally important functions. First of all, these are the functions of setting up and protecting the heat generator. With the help of the unit, the Adjuster can check the performance of individual elements of the boiler, connect a laptop to it and identify not only the current parameters of the heat supply scheme as a whole, but also track changes in the parameters of individual heat-consuming systems during a given period of time. This is very important for a full technical assessment of their performance.

Important functions of boiler protection are its emergency automatic shutdown when the water temperature in it exceeds the design temperature or in the event of a possible overturning of the draft in the chimney, through which combustion products are removed from the boiler. The same function should include ensuring the heating of cold boilers when they are turned on in order to avoid falling out on their internal heating surface of the products of incomplete combustion of the fuel used. In this case, in the circuit of the switched-on heat generator using kN boiler pumps (see Fig. 4.3) water is circulated until its temperature reaches a value of about 40 ° C. Only after this, the automation turns on the circulation pumps of the Central heating systems.

Any automatic control unit also has a certain number of additional features that increase the efficiency of operation of a modern heat supply scheme. These include, first of all, the ability to set all the above parameters independently for each system, both by day of the week and by hour of the day. The second case should include a very common opportunity in the West to establish the so-called "day-night" mode. It involves automatically reducing the temperature of the heat carrier in the heating system, and, accordingly, the temperature of the internal air in the premises of a residential building at night, which is considered very useful from a medical point of view. This also has a significant economic effect by reducing fuel consumption at night. By the way, a similar mode can be set using a room temperature sensor in the case of using the method of thermal regulation of the heating system "by deviation".

Additional features regulated by the control unit include, for example, the possibility of so-called "boiler sanitation".This refers to the function of periodic temperature increase in the capacitive water heaters of the GDP of the hot water system GW is much higher rated (up to 90 ^{o}C) with the aim of destroying perhaps fifteen bacteriological impurities. The temporary functionality of the control unit can include setting the period of switching on the circulation pump of the HVAC system, corresponding to the actual time of its use at a specific object, as well as periodically switching on the circulation pumps of heating and ventilation systems in the warm period of the year in order to maintain their performance during prolonged inactivity.

There are even "talking" models of boilers for blind users, which voice reports, if necessary, all the current parameters of its operation. Some companies provide an opportunity for the user of their equipment to "contact" their boiler by phone and make sure that the boiler is functioning normally in its absence.

Now many manufacturers of heat generators, improving their equipment, are actively working to create a remote control system using the Internet. This makes it possible, first of all for service companies, not only to control all the current parameters of the boiler operation and the heat supply scheme as a whole without going to the serviced object, but also to change the control unit setting if necessary.

In addition to the main system of automatic control and regulation of operating parameters in a modern boiler room, there is also other equipment that works in an Autonomous mode. It can include safety and control valves that control the required level of hydrostatic pressure in the system, automatic air vents, sensors and gas pressure regulators in the case of its use as fuel for boilers. On the flues from boilers, either pressure regulators are installed in them, or special relief valves that operate when the permissible pressure is exceeded. In automatic mode, the system is fed with water from the external water supply, the required pressure is maintained in the expansion tanks, and liquid fuel is supplied to boilers with diesel burners. To ensure safety in gas boilers, the level of gas contamination of the air is monitored. Many boiler houses are equipped with remote control systems for all operating parameters with access to a special control panel[91].

4.10 Power supply options for agricultural consumers. Types of different power supply sources

Agricultural production is increasingly based on modern technologies that widely use electric energy. In this regard, the requirements to the reliability of power supply to agricultural facilities, to the quality of electric energy, to its economical use and rational use of material resources are increasing.

The absolute majority of agricultural consumers receive electricity from a centralized source - the power system. The impact of the quality of electricity supply on the final results is not the same for enterprises of different levels, and it affects large specialized enterprises to the greatest extent. In such enterprises, the quality of electricity supply becomes a factor affecting the efficiency of agricultural production [92].

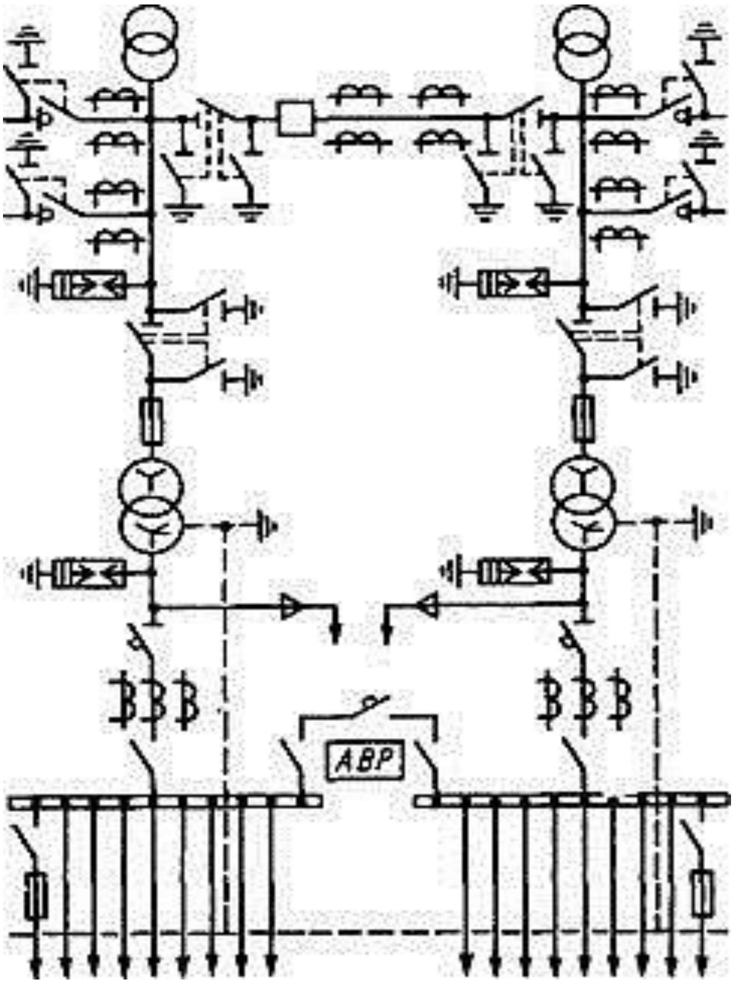


Figure 4.4 - Diagram of a closed-type transformer substation with a voltage of 20/0. 4 kV with two transformers up to 400 kVA

Usually, enterprises that produce livestock and poultry products are located on agricultural complexes. Complexes or poultry farms include buildings, structures, equipment, utilities, etc. for main and auxiliary purposes. Depending on the power consumption, a typical transformer substation is selected for the complex (figure 4.4) and a power supply scheme is developed.

The quality of General-purpose electric energy, i.e. for the main variant of rural power supply, is determined by the stability and frequency levels of current and voltage for consumers, as well as the degree of asymmetry and non-sinusoidal voltage.

For complexes with a design load of more than 1000 kW, regardless of the distance to the power center, you should consider building a separate dead-end transformer substation of 35 or 110 kV (figure 4.5).

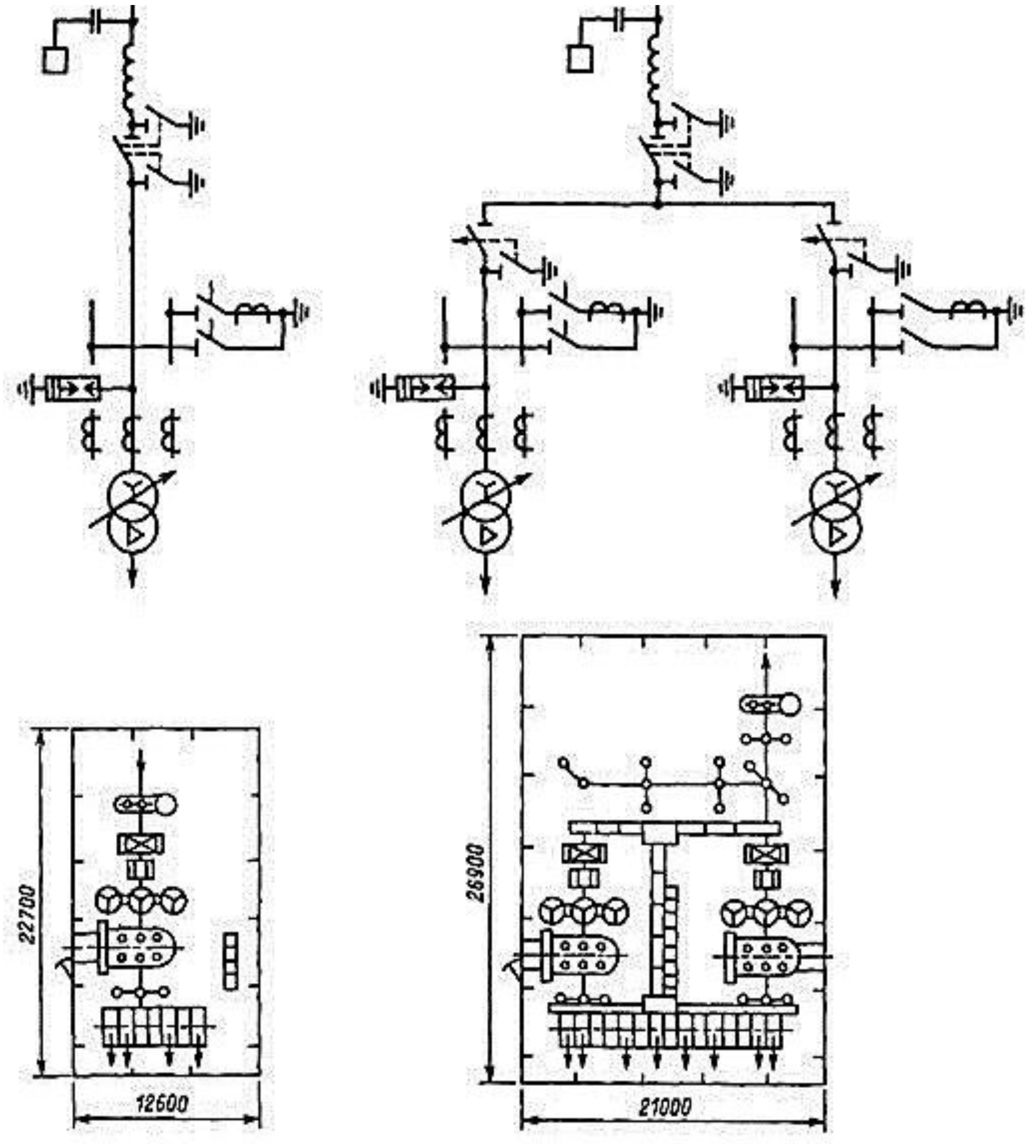


Figure 4.5 - Diagrams of dead-end transformer substations with a voltage of 35/10 kV of the line-transformer block and the enlarged line - two transformers with a 35 kV separator in the transformer circuit.

An important task of rural power supply is to maintain the required voltage levels for consumers. Changes in voltage, especially in excess of the permissible value, have a significant impact on the operation of consumers. As a result of reducing the voltage, the power decreases and, consequently, the operation of electric receivers deteriorates. Increasing the voltage also adversely affects the operation of the latter, reducing their service life.

When developing external power supply schemes in technical and economic calculations, it is recommended to consider the possibility of building separate 10 kV overhead lines for complexes with an estimated load of up to 1000 kW located from power centers (35 or 110 kV transformer substations) at a distance of up to 10 km.

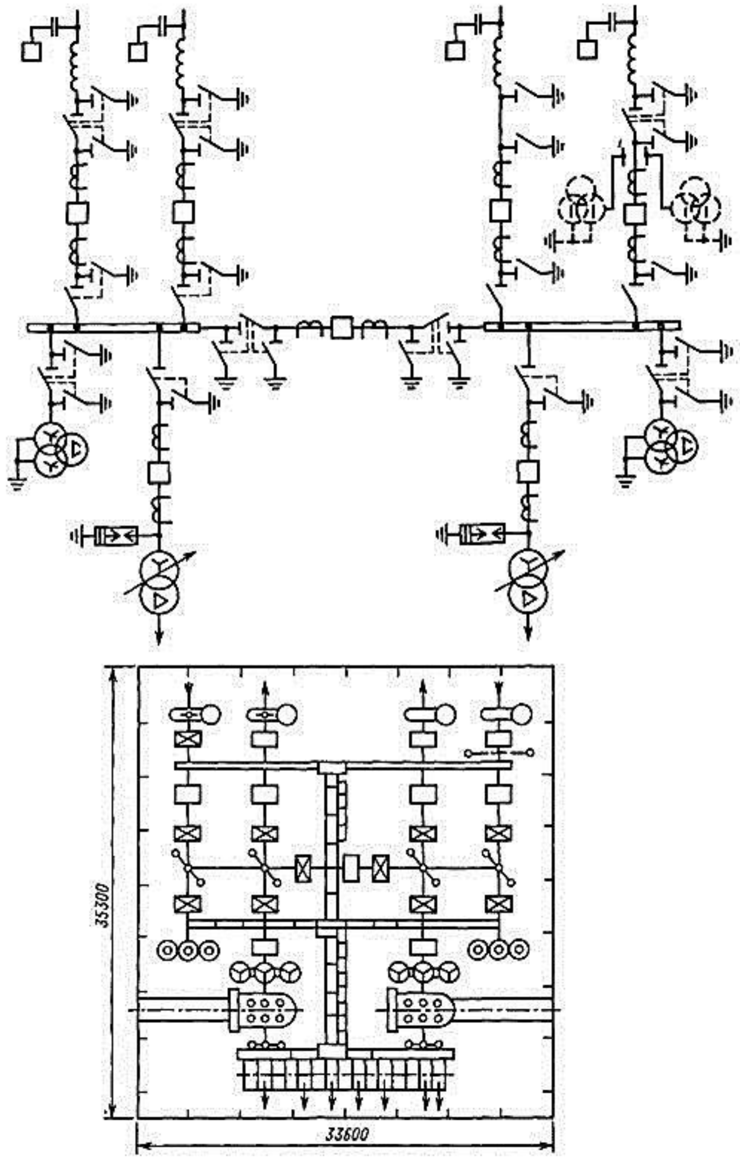


Figure 4.6 - Diagram of a 35/10 kV node transformer substation partitioned with a switch, with a bus system of up to 10 connections and a 35 kV switch in the transformer circuit

Node transformer substations in the rural power supply system can be made according to the scheme shown in figure 4.6.

If the distance is more than 10 km, it is advisable to consider the possibility of building a separate 35 or 110 kV transformer substation.

It is not recommended to connect other consumers to 10 kV overhead lines intended for power supply to complexes and poultry farms. Transmission lines for external power supply, as a rule, should be accepted by air.

The distribution of electricity from consumer transformer substations to inputs to industrial buildings, along with overhead and cable lines, can be performed by bus lines.

Transformer substations of 20/0.4 kV up to 500 kVA located on the site of the complex should be provided primarily as complete, open-type substations.

Types of power supply sources.

Autonomous permanent power plants are being built in sparsely populated areas that are not covered by power grids. They are considered rural if more than 50% of the load is made up of agricultural consumers. Primary engines at rural stations can be internal combustion engines or hydraulic turbines.

Power plants with internal combustion engines are built as the main source of power when consumers are far away from power systems, and local conditions do not allow the construction of a hydroelectric power station. Diesel engines are most often used as primary engines at such stations.

In addition to diesel power stations, stations with internal combustion engines are being built. They use gas.

Diesel power stations (DPS) are used as the main source of power supply to consumers in areas remote from the power grid networks, and the prospects for their connection to the power system are not expected in the coming years.

From synchronous generators diesel power plants can be native and static excitation systems.

Generators with a capacity of more than 150 kV-A are equipped with excitation boost devices that provide an increase in voltage during short circuits, as well as stability during parallel operation of generators.

Automatic voltage regulation at rural power stations is also performed by compounding the excitation of generators.

For parallel operation, generators are usually enabled by self-synchronization.

Issues of environmental cleanliness set the task of searching for non-traditional renewable energy sources (sun, wind, heat of the earth, seas and oceans, small water flows, biomass). The first thing that a person used from the list of renewable energy sources was the energy of water flows. After the creation of electric generators, they began to actively use the potential and kinetic energy of water flows where there was such an opportunity.

In places where there is hydroelectric power, it is advisable to build hydroelectric power stations of small capacity. Using the potential of small rivers is beneficial even in areas where there are networks of power systems. The best use of water flow is provided by the parallel operation of hydraulic stations with thermal or power systems.

Hydraulic power plants (HPP) have a number of advantages over thermal power plants. The cost of electricity generated at them is lower, and the consumption of electricity for their own needs is many times less than at thermal power plants. Starting and loading the hydrogenerator takes place within a few minutes. Rural hydroelectric power plants are mostly low-pressure. The exception is hydroelectric power stations built on mountain rivers. At low-pressure rural hydroelectric power plants, axial, radial-axial and rotary-blade turbines are used, which are characterized by higher efficiency over a large load range [91].

Under operating conditions, the pressure on the turbine does not remain constant, since with changes in the load, and therefore the flow of water through the turbine, the marks of the upper and lower reaches change. At low-pressure rural hydroelectric power plants, the pressure varies from 10 to 20% during operation. Its changes are especially great during flood periods. The optimal operating mode of the turbine is expected at the maximum value of the product *Hη:*

$$\frac{Q}{P} = \frac{1}{9{,}81 \cdot H \cdot \eta}. \tag{4.2}$$

Water flow in the river during the day, usually changing slightly, and working in compliance with the water regime of the river power hydro constant. But the load of the hydroelectric station fluctuates during the day.

Example of load change HPP for the day is shown in figure 4.7. The graph shows that the load of the HPP during the day has a maximum of 100 kW from 16 to 22 h. the Area of the load diagram are necessary to consumers, the daily amount of electrical energy.

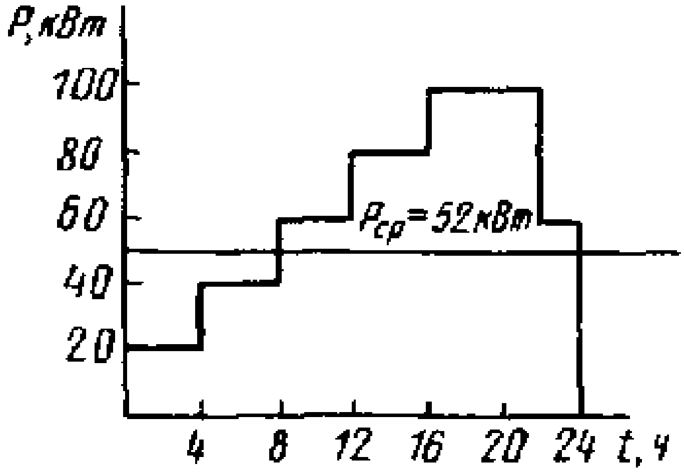


Figure 4.7 - Daily load schedule of a hydroelectric power station

Dividing the daily electricity consumption (the area of the load graph) by 24 hours, we get an average daily power of 52 kW.

If a hydroelectric power station has a reservoir, then during periods of excess capacity, it can accumulate water, and during periods of shortage, the created reserve can be triggered. By redistributing the daily flow rate of the river, it is possible to increase the capacity of hydroelectric power plants during the maximum load and thus improve the conditions of power supply to consumers.

Due to daily regulation, the HPP capacity increases during peak load hours.

A relatively small reservoir capacity is required for daily regulation.

To better provide consumers with electric energy and improve the operation of a hydroelectric power station, it must work in parallel with a thermal power plant or power system. A heat station combined with one or more hydroelectric power stations in a local power system generates energy at a time when the hydroelectric power station's energy is not sufficient to supply consumers.

A wind power station.

Wind power can be a source of electricity supply for areas that are remote from high-power grid networks. Wind is one of the unconventional sources of energy. It is established that modern wind power installations can be effectively used in areas with an average annual wind speed exceeding 3...5 m/s.

Wind power stations are widely used in Denmark, the USA, Holland, Germany, England, etc. There are more than 100 thousand people in the world. WES. Wind power can be a source of electricity supply for areas that are remote from high-power grid networks. For wind farms, special devices are used that accumulate wind energy to some extent, as well as voltage and speed regulators. This makes it possible to supply consumers with electricity for lighting and electric drive. Wind turbines use various storage devices that smooth out the pulsations of energy received from the wind and in some cases limit the power developed by the wind turbine, as well as store energy for the period of calm days.

According to the principle of operation of Accu-mulating devices used in wind power, there are mechanical, electrical, hydraulic, and thermal devices, which were discussed above.

4.11 Design requirements for selecting parameters of the power supply system for an agricultural area

When designing electrical networks, the following types of work are considered: new construction, expansion and reconstruction. New construction includes the construction of new power transmission lines and substations. Expansion of power grids usually applies only to substations - this is the installation of a second transformer at an existing substation with the necessary construction work. Reconstruction of existing networks involves changing the parameters of the power grid, while maintaining partially or completely the construction part of the objects, to increase the network capacity, reliability of power supply and the quality of transmitted electricity.

Reconstruction includes work on replacing overhead line wires, switching networks to a different rated voltage, replacing transformers, switches, etc. equipment due to changes in power or voltage, installation of automation equipment in networks. The power supply system for agricultural consumers is designed taking into account the development of all sectors of the national economy in the area under consideration, including non-agricultural ones [93].

The design assignment for 0.38 kV lines and 10/0. 4 kV transformer substations includes:

- the basis for the design;
- the area of construction; type of construction;
- line length 0.38 kV; type of transformer substations;
- project design stages; the duration of the project;

- construction start date; name of the design and construction organizations;
- capital investment.

In addition, the task for designing 0.38 kV networks is accompanied by: technical specifications of the power system for connection to electric networks; the act of assessing the technical condition of 0.38 kV networks; data on the achieved level of electricity consumption for a residential building, etc. materials.

Power lines of 0.38 ... 10 kV, as a rule, should be carried out by air. Cable lines are used in cases where the construction of overhead lines is not allowed according to the PUE, for power supply to responsible consumers and consumers located in areas with severe climatic conditions (IV-special area for ice) and valuable land.

Transformer substations with a voltage of 10/0.4 kV are used as closed-type and complete factory-made ones.

Justification of technical solutions is based on technical and economic calculations. Among technically comparable options, preference is given to the option with minimal reduced costs.

Circuit solutions of electric networks are selected according to normal, repair and post-accident modes.

The distribution of voltage losses between the elements of the power grid is performed on the basis of the calculation on the basis of the allowable voltage deviation (tolerance normal voltage deviation at the consumer is ±5% of nominal, maximum deviation allowed ±10%) in electrical equipment and voltage levels on the buses nutrition center.

Voltage losses should not exceed 10 kV - 10% in electric networks, 0.38/0.22 kV - 8% in electric networks, 1% in the wiring of single - storey residential buildings, 2% in the wiring of buildings, structures, two - and multi - storey residential buildings.

In the absence of initial data for calculating the voltage deviation of electric receivers, it is recommended to take voltage losses in the elements of the 0.38 kV network: in lines that supply household consumers - 8%, production-6.5%, livestock complexes-4% of the nominal value.

When designing electric networks for agricultural purposes, the power of compensating devices should be determined according to the condition of ensuring the optimal reactive power coefficient, at which the minimum of the reduced costs for reducing electricity losses is achieved.

Design requirements for power transmission lines with a voltage of 0.38 / 0.22 kV.

On the sections of parallel lines of 0.38 and 10 kV, the technical and economic feasibility of using common supports for joint suspension of the wires of both overhead lines on them should be considered.

The choice of wires and cables, the power of power transformers should be made at a minimum of the above costs.

Electric lines with a voltage of 0.38 kV must be with a dead-earth neutral, on lines extending from one 10/0.4 kV substation, it is necessary to provide no more than two or three wire sections.

The selected wires and cables are checked:

— for permissible voltage deviations in consumers;
— for permissible long-term current loads under the heating condition in normal and post-accident modes;
— to ensure reliable protection operation in single-phase and inter-phase short circuits;
— to start asynchronous motors with a short-circuited rotor.

Cables with plastic insulation and protected by fuses must be checked for thermal stability against short-circuit currents.

The conductivity of the zero wire of 0.38 kV lines that supply mainly single-phase loads (more than 50% of power), as well as electric receivers of livestock and poultry farms, must be at least the conductivity of the phase wire. The conductivity of the zero wire may be greater than the conductivity of the phase wire, if this is required to ensure acceptable voltage deviations for outdoor lighting lamps, as well as if it is impossible to provide the necessary selectivity for protecting the line from single-phase short circuits by other means. In all other cases, the conductivity of the zero wire should be assumed to be at least 50% of the conductivity of the phase wires.

On overhead lines to individual consumers with a concentrated load, it is necessary to provide suspension of eight wires with splitting of the wire of one phase into two on supports with a common zero wire. When the wires of two lines connected to independent power sources are suspended together on common supports, it is necessary to provide independent zero wires for each line.

Street lighting wires should be placed on the side of the roadway. The phase wires must be located above zero.

Street lighting fixtures are connected to specially designed phase wires and the common zero wire of the electrical network. Placement of lamps is performed in a staggered order when installing them on two sides of the street. Switching on and off of street lighting fixtures should be automatic and carried out centrally from the transformer substation panel. 0.38 kV overhead lines are equipped with aluminum, steel-aluminum wires, as well as aluminum alloy. In areas with one-story buildings, it is recommended to use self-supporting wires with weather-resistant insulation for branches from lines to building entrances. The choice of routes of 10 kV overhead lines should be made in accordance with the requirements of regulatory documents for the selection and survey of lines. If it is necessary to construct overhead transmission lines that run in the same direction as existing ones, technical and economic calculations should be carried out to justify the feasibility of building new or increasing the capacity of existing lines. The nominal phase-to-phase voltage of distribution networks above 1000 V should not be lower than 10 kV. When reconstructing and expanding existing networks with a voltage of 6 kV, it is necessary to provide for their conversion to a voltage of 10 kV using, if possible, installed equipment, wires and cables. Maintaining a voltage of 6 kV is allowed, as an exception, with appropriate feasibility studies. On 10 kV overhead lines with pin insulators, the distance between anchor supports should be no more than 2.5 km in I-II areas on ice and 1.5 km in III-special areas. On 10 kV overhead lines, it is recommended to use steel-aluminum wires, in areas with a standard thickness of the ice wall of 5-10 mm and a high-speed wind pressure of 50 N/sq. m, aluminum wires can be used.

Cable lines are recommended to be made with aluminum cores with plastic insulation.

Overhead lines can be constructed from wooden and metal supports using reinforced concrete vibrating and centrifuged racks.

Steel poles of 10 kV is recommended at intersections with engineering structures (Railways and roads), water spaces, on tight tracks, in a mountain area of valuable agricultural land, as well as the angle-poles double circuit lines.

It is recommended to use double-chain supports of 10 kV overhead LINES at large crossings over water obstacles, as well as on sections of overhead lines passing through land occupied by agricultural crops (rice, cotton, etc.), and on approaches to substations, if another line is planned to be built in this direction.

10 kV overhead lines are made with the use of pin and suspended insulators, both glass and porcelain, but preference should be given to glass insulators. Suspended insulators should be used on 10 kV overhead lines for power supply to livestock farms and on anchor type supports (end, anchor-corner and transition supports).

Design requirements for 10 kV transformer substations.

Substation 10/0,4 kV should be placed: in the centre of electrical loads; in the vicinity of the driveway to ensure easy approaches overhead and cable lines; in flood-free areas and, as a rule, areas with groundwater level below shallow foundations.

It is recommended to provide power supply to domestic and industrial consumers from different substations or their sections.

It is not recommended to place substations with air inlets near schools, children's and sports facilities.

Substation schemes are selected based on the development schemes of electric networks 35...110 kV areas and technical and economic calculations of expansion, reconstruction and technical re-equipment of electric networks with a voltage of 10 kV in the districts of electric networks and are specified in the working projects of power supply to real objects.

The choice of schemes for connecting 10/0.4 kV substations to power sources is made on the basis of an economic comparison of options, depending on the category of electric receivers for the reliability of power supply in accordance with the "Guidelines for ensuring the design of regulatory levels of reliability of power supply to agricultural consumers".

Substations of 10/0. 4 kV that supply consumers of the second category with a design load of 120 kW or more must have two-way power supply. It is allowed to connect a 10/0. 4 kV substation that feeds consumers of the second category with a design load of less than 120 kW by a branch from the 10 kV main line, partitioned at the branch point on both sides by disconnectors, if the branch length does not exceed 0.5 km.

Substations of 10/0. 4 kV,as a rule, should be designed as single-transformer substations. Two-transformer substations of 10/0. 4 kV should be designed to supply consumers of the first category and consumers of the second category who do not allow a break in power supply for more than 0.5 hours, as well as consumers of the second category with a design load of 250 kW or more.

It is recommended to equip two-transformer substations with devices for automatic switching on of backup power on 10 kV buses under the following mandatory conditions: availability of category I and II electric receivers; connection to two independent power sources; if one power transformer simultaneously loses power supply when one of the two 10 kV supply lines is disconnected. At the same time, category I electric receivers must be additionally provided with automatic redundancy devices directly at the input of 0.38 kV electric receivers.

Closed-type 10/0. 4 kV substations should be used: for the construction of transformer substations that connect more than two 10 kV lines to 10 kV switchgears; for power supply to consumers of the first category with a total design load of 200 kW or more; in conditions of cramped development of settlements; in areas with a cold climate at air temperatures below-40°C; in areas with a polluted atmosphere of grade III and higher; in areas with snow cover of more than 2 m. Substations of 10/0. 4 kV should be used, as a rule, with air inputs of 10 kV lines. Cable entries of lines should be used: in cable networks; in the construction of substations that have only cable entries of lines; under conditions when the passage of overhead lines on the approaches to the substation is impossible and in other cases where it is technically and economically justified.

10/0. 4 kV transformers are usually used with switching branches without excitation (PBV) for voltage regulation.

For power supply of municipal and agricultural consumers, 10/0. 4 kV transformers with a capacity up to 160 kVA inclusive should be used with the "star-zigzag" winding scheme with the 0.4 kV winding neutral output.

4.12 Comparison of centralized and local power supply. Expenses for maintenance of networks and Autonomous power sources

Everyone who uses electricity at home, at least once faced with its sudden shutdown. Whether we watch TV, do Laundry, work on the computer, or cook food, the lack of electricity can seriously interfere with our plans.

What about the countryside? The efficiency of local services and organizations responsible for repairing power supply systems is significantly lower. This is due to a number of quite objective factors: a large service area, a shortage of qualified personnel, problems with transport, and sometimes with access to objects in need of repair, poor logistics. The reliability of electricity supply in rural areas can also be affected by the human factor.

It turns out that the electricity supplier is simply not able to provide uninterrupted power supply. But what to do if such important facilities as hospitals, operational services, and continuous-cycle enterprises are disconnected from the" power supply"? The current Rules for electrical installations (PUE) classify electricity consumers into three categories of power supply reliability. Electric receivers of the first and second categories are provided with electricity using two independent power sources, and a special group of consumers of the first category - even through three. The first category is switched to the backup source automatically, the second category is transferred manually [95].

According to the PUE, the first group of consumers will be insured against the occurrence of such situations when a power supply interruption may lead to danger to people's lives, significant material damage, disruption of a complex technological process, disruption of the functioning of particularly important elements of public utilities, communications and television facilities. In this case, disconnecting consumers of the second category from electricity will only lead to mass undersupply of products, mass downtime of workers, machinery and industrial transport, and disruption of the normal activities of a significant number of urban and rural residents. The third group of electric receivers includes those whose power supply interruption, according to the PUE, may be delayed for a day. To protect yourself from the troubles associated with a sudden power outage, you need to install a backup power source.

Classification.

Autonomous energy sources can be divided into two large groups. The first includes units that convert other types of energy into electricity, while their operation does not depend on the main power supply system. They are fully Autonomous and can be used for a long time or even as the main source of power supply if a number of conditions are met. The second group should include devices that accumulate electricity (charge) at a time when the main source regularly supplies energy to the consumer. Their autonomy is limited, although the period of time during which they are able to provide electricity may be quite long. In turn, devices belonging to the first group are divided into those that convert any type of energy (generators based on internal combustion engines, hydro and wind generators) and those that convert radiation of a particular spectrum into electricity (solar panels, thermoelements). Electric generators based on internal combustion engines are less dependent on factors such as the number of Sunny days per year, wind strength, hydro and thermal resources, which are necessary for the efficient and cost - effective use of solar panels, wind and hydro generators, and thermoelements. We should also mention the existence of electric generators built on the basis of external combustion engines: a steam engine, a Stirling engine, and various types of steam and gas turbines. The steam engine and Stirling engine have a low efficiency, and it is not advisable to use them as a source of electricity.

Mini power plants.

An enlarged mini-power plant is an aggregate consisting of an internal combustion engine, the shaft of which drives (rotates) the movable winding of the generator, systems for powering the engine, controlling and converting the generated energy into electricity with standardized consumer parameters: three phases (380 V) or one phase (220 V, 50 Hz).

Mini-power plants can be built on the basis of internal combustion engines running on various types of hydrocarbon fuel. The most widespread at the moment are diesel and gasoline units, and gas devices also have good prospects. Today, they are quite firmly established in the segment of stationary mini-power plants of high capacity.

With the exception of the engine type, these units do not have fundamental technical differences - hydrocarbon fuel burns in the cylinders, rotates the crankshaft, which, in turn, turns the shaft of the *electric generator*. The latter converts the rotational movement of the crankshaft into *electricity*.

If the consumer does not intend to limit the consumption of electricity during the operation of an Autonomous source and plans to enjoy all the benefits of civilization, the task is simplified - as a starting point for the calculation, the electric power allocated by the centralized energy supplier to the electrical installation is taken. In the case of a three-phase wiring scheme and, accordingly, with a three-phase mini-power plant, it is important to observe the approximate equality of the electric capacities of consumers at different phases (the difference should not exceed 20-25%) in order to avoid "phase skew".

Another important criterion is the type of power unit. In favor of the gasoline engine, its low cost indicates. However, the choice of a gas generator set is justified only if interruptions in the centralized power supply are short-term and rare. In situations where electricity is cut off for a long time, or a mini-power plant will be used as the main source, or the required power is large enough, preference should be given to a diesel electric unit. Despite the high cost, it is characterized by lower operating costs, a large resource and long continuous operation.

An important component of Autonomous power supply is the control system. In the simplest case, when the generator is used as an emergency power source, its power is low, and the performance requirements are minimal. It all comes down to the installation of a switch switch, which eliminates the simultaneous supply of energy from the main power supply network and from the power plant. Mini-power plants equipped with an automatic start - up system start working "without a reminder" - the estimated time interval after switching off the main source is from 30 seconds to a minute. The same system turns off the power plant when the power supply is restored.

The power supply system at home includes a battery pack. In principle, this is the same uninterruptible power supply, only larger in size, power and power consumption. The use of Autonomous battery power sources has other positive aspects. They can serve as a damper that dampens voltage surges, and the joint use of batteries and voltage converters allows you to influence the quality of electricity parameters.

One of the most important problems in the energy sector, in addition to obtaining energy, is to ensure its storage and transportation. Chemical current sources, known for more than 100 years, allow you to generate, store and convert energy. They are the indispensable companions of any Autonomous sources of energy.

Humanity needs energy, and the need for it increases every year. However, the reserves of traditional natural fuels (oil, coal, gas, etc.) are finite. Nuclear fuel reserves are also finite. Almost inexhaustible reserves of thermonuclear fuel-hydrogen, but controlled thermonuclear reactions have not yet been mastered, and it is not known when they will be used for industrial production. In connection with these problems, it is becoming increasingly necessary to use non-traditional energy resources, primarily solar, wind, and geothermal energy, along with the introduction of energy-saving technologies.

The earth receives a thousand times more energy from the Sun every day than it is generated by all the power plants in the world. The task here is to learn how to use at least a small amount of it practically.

It cannot be said that the large-scale use of solar energy will not have any consequences for the environment, but they will still be incomparably smaller than in traditional energy.

In the era of coal and fuel oil power, it was necessary to get electricity and heat at large stations, and then transfer them to consumers located at a distance. Such systems were justified, they arose in those years when the main source of energy for the country was coal. It is difficult to burn it - you need a complex technique for grinding. In addition, it was necessary to place the station away from housing. Then there were power plants and fuel oil boilers. But fuel oil is a fuel available only for burning in large installations, and with an abundance of toxic gases released in the emissions from chimneys. Nuclear power plants cause no less damage. Utilization of spent fuel of nuclear reactors and heat, consequences of radioactive releases and accidents - an incomplete list of disadvantages of the " peaceful atom».

Often we cannot Express in absolute terms the damage that any heat or power plant always causes. The choice of energy development options is reasonable only if not only positive, but also negative factors are compared.

The main objects of discussion are thermal, hydraulic and nuclear power plants. Each of these "electricity factories" has serious disadvantages, of which the environmental damage they cause is put in the first place. The main contribution to atmospheric carbon dioxide pollution is made by thermal power plants, GRES and cars. Nuclear power plants do not emit carbon dioxide, and therefore the "greenhouse effect" has become the main argument among supporters of nuclear energy.

Proven gas reserves have a fairly large energy potential. From an environmental point of view, natural gas has two disadvantages: emissions of nitrogen oxides and carbon dioxide that increases the greenhouse effect. When gas is skillfully burned, in combined-cycle plants, nitrogen oxides are formed slightly, and carbon dioxide emissions are about half as low as when using coal or oil.

Before we learn how to get energy in large quantities from fundamentally new sources, traditional fuels will be used.

Therefore, new deposits are being developed and processes are being investigated that allow more efficient use of fuel energy and, in this regard, reduce environmental pollution.

Since the creation of the geocentric theory of the existence of the Earth, the mechanism of wind formation due to the rotation of the Earth relative to its axis has become clear, which leads to the movement of air masses of the atmosphere relative to any point. In addition, the heating and cooling of the planet during the day creates convective flows of heated air in the atmosphere towards the cold, which in turn also manifests itself in the form of wind. On the planet Earth, the interaction of two atmospheric flows with different directions and energy is formed, both over land and over the ocean. Humanity has long learned to use this energy with the help of windmills in limited quantities on land and in the form of a sailing fleet at sea.

Only after a sufficient degree of accuracy began to assess the reserves of underground energy resources, such as coal, oil, gas, and came to the conclusion about their limited number, people thought about the intensive use of wind energy.

Wind power, which uses wind wheels and wind carousels (carousel-type engines), is being revived now, primarily in ground installations. More and more, our planet is covered by a network of wind power plants, the energy of which can replace part of the electrical energy generated by stations that use non-renewable energy sources. From what has been said, we can conclude that wind energy is an inexhaustible source as long as the Earth exists as a planet. In Kazakhstan, wind units are being researched and created that can take on part of the consumed electric load.

The traditional layout of windmills - with a horizontal axis of rotation - is a good solution for units of small size and capacity. When the span of the blades increased, this arrangement was ineffective, since the wind blows in different directions at different heights. In this case, not only is it not possible to optimally Orient the unit in the wind, but there is also a risk of destruction of the blades. However, despite this, wind turbines with a horizontal axis of rotation (winged) have found wide application in practice. Wind turbines with a vertical axis of rotation (carousel: vane and orthogonal) are also used, occupying their segment in the wind power market.

The sun is a giant luminary with a diameter of 1392 thousand km. Its mass (1.9•1026 tons) is 333 thousand tons. the volume is 1.3 million times the mass of the Earth. Inside the Sun there are thermonuclear reactions converting hydrogen into helium and every second 4 billion kg of matter is converted into energy radiated by the Sun into outer space in the form of electromagnetic waves of various lengths.

The upper limit of the Earth's atmosphere reaches the solar energy flux in the amount of $5.6 \cdot 10^{24}$ joules per year. The earth's atmosphere reflects 35 % of this energy back into space, and the rest of the energy is spent on heating the earth's surface. The average annual amount of solar energy received per 1 day per 1 m^2 of the Earth's surface ranges from 7.2 MJ / m^2 in the North to 21.4 MJ / m^2 in the deserts and tropics.

Hence the conclusion that the most economical way to use solar energy is to direct it to obtain secondary types of energy in the Sunny areas of our planet. The resulting liquid or gaseous fuel can be moved to places where there is a shortage of solar energy.

The rapid development of solar power was made possible by reducing the cost of photovoltaic converters per 1 W of installed capacity from $ 1,000 in 1970 to $ 3 ... 5 in 1997 and increasing their efficiency from 5 to 18%. Reducing the cost of a solar watt to 50 cents will allow solar installations to compete with other Autonomous energy sources, such as diesel power plants. Operational experience shows that the Sun is already able to meet the energy demand of at least all residential buildings in the country. Solar installations, located on roofs and walls of buildings, on noise-proof fences of highways, on transport and industrial structures, do not require expensive agricultural or urban areas to be located. Solar installations require almost no maintenance costs, do not need to be repaired, and only require the cost of their construction and maintenance in cleanliness. They can work indefinitely.

5 AUTOMATED HEATING SYSTEM CONTROL UNIT

5.1 Huge fuel and energy resources

Huge fuel and energy resources are spent on heating buildings. This means that modern heating systems must operate at a high level, that is, the amount of heat supplied to each room of the building to maintain a comfortable temperature regime should be determined by the current demand in accordance with the wishes of the consumer.

These requirements can only be met by automated heating systems equipped with heat metering devices.

Automation of the heating system includes a local adjustment of parameters of the coolant in the thermal point, individual control of supply of heat from heating appliances systems as well as automatic maintenance regimes in the pipe network.

Individual regulation has the greatest technological capabilities and allows you to [56]**:**

1. Adjust the temperature of the coolant in the supply pipeline depending on the outside air temperature (select the desired temperature schedule);
2. Adjust the temperature of the coolant in the return pipeline depending on the temperature of the coolant in the supply pipeline;
3. Limit the supply of heat energy depending on the mode of operation of the building at different times of the day (day/night) and days of the week (working days/weekends);
4. Maintain the set temperature in the hot water system;
5. Maintain the hydraulic mode of the heating system;
6. Provide protection against defrosting of the heating system;
7. Provide intensive heating of the premises before the start of the working day;
8. Monitoring and automatic control of contour recharge.

Currently, an important factor in the effectiveness of a solution is the expected savings in physical and monetary terms. A natural question is to determine the effectiveness of the introduction of an automatic heating control system, according to the instructions for determining the economic efficiency of using funds aimed at energy-saving measures, one of the most important indicators is the payback period.

Let’s consider an example of calculating annual savings, without taking into account operating costs, from the introduction of an automated heating system control unit for one of the Primorsky territory school buildings based on the results of a mandatory energy survey.

Introduction of an automated control unit for the heating system, modernization of ITP with the installation and configuration of equipment for automatic control of water parameters in the heating system depending on the outdoor temperature.

The automated control unit of the heating system is a type of individual heat point and is designed to control the parameters of the heat carrier in the heating system depending on the outdoor temperature and operating conditions of buildings.

The unit consists of a correction pump, an electronic temperature controller that supports the specified temperature schedule, and differential pressure and flow regulators. Structurally, these are pipeline blocks mounted on a metal support frame, including a pump, control valves, elements of electric drives and automation, control and measuring devices, filters, and sumpers.

Costs are determined when choosing an implementation company. The complete set of control nodes is made taking into account the recommendations of the company's specialists who provide consulting services in the development of these nodes.

The node works as follows. When conditions occur when the temperature in the heat network exceeds the required temperature, the electronic controller turns on the pump, and it adds to the heating system as much cooled coolant from the return pipeline as is necessary to maintain the set temperature. The hydraulic regulator, in turn, is covered, reducing the supply of mains water.

The operation mode of the automated control unit in winter is round-the-clock, the temperature is maintained in accordance with the temperature schedule with correction for the return water temperature.

If desired, a temperature reduction mode can be provided in heated rooms at night, on weekends and holidays, which gives significant savings. Reducing the air temperature in residential buildings at night by 2-3 °C does not worsen sanitary and hygienic conditions and at the same time provides savings of 4-5%. In industrial and administrative – public buildings, heat savings by reducing the temperature during off-hours are achieved to an even greater extent. The temperature during non-working hours can be maintained at 10-12 °C.

The total heat savings with automatic control can be up to 25% of the annual consumption. During the summer period, the AUU is closed.

Reconstruction of an individual heating station with the installation of weather-dependent regulation.

The main factor in reducing energy consumption is the reduction of heat output at night and on weekends. To determine the projected energy savings, we make the following assumptions:

- The duration of the heating season is 198 days (4704 hours);

– The average number of working days during the heating period is 160 days (160*12=1920). Hours) –

- 38 days off (38*24=864 hours);

- Night hours on working days 160*12=1920 hours;

- The time of intensive heating of the premises is 24 hours;

– Indoor temperature during working hours t 18= 180C;

– Indoor temperature outside working hours tin15=150C;

– Outdoor temperature of the coldest five-day period text= -24 0C;

– Average outdoor temperature for the heating period tht= -3.90 C;

Heat consumption for heating needs is 330.21 Gcal / year.
For the calculation, use the following formula for the enlarged calculation of heat consumption

$$Q=q*a*(t_{in}-t_{ht})*V_h, \tag{5.1}$$

where Q - average heat consumption for heating; q - the specific load on the heating 0,07 Gcal / h; a - correction factor for specific heating load, depending on local climatic conditions: 0,99; V_h - the volume of the building.

Studying the expression, we see that when the average indoor air temperature changes, all other parameters remain the same. Based on this, we obtain an expression for determining the amount of heat consumed when the average indoor air temperature decreases in the following form:

taking into account the duration of work on the specified parameters:

$$Q^{15}=320,21*(15-(-3,9))/(20-(-3,9))/4704*2784 = 168,66 \text{ Gcal / year};$$

$$Q^{18}=320,21*(15-(-3,9))/(20-(-3,9))/ 4704*1920 = 116,32 \text{ Gcal / year}.$$

Calculate the annual heat savings, Gcal, from the implementation of the event:

$$Q^{после}= (Q^{15}+ Q^{18})$$

$$Q_ф - Q^{после}=320,21 - (168,66 +116,32)= 45,23 \text{ Gcal / year}.$$

The calculations are based on thermal energy tariffs for the base year.

5.2 Automated system for integrated accounting of fuel and energy resources

Automated system for integrated fuel accounting- it is intended for automation of complex (commercial and technical) accounting of consumption and sale of fuel and energy resources (fuel and energy resources) at the objects of a certain administrative-territorial entity (ATE), for making commercial settlements with suppliers/consumers of fuel and energy resources, for technical control over non-productive expenses in the production process, using the data obtained during rationing, for planning consumption volumes, forming a balance of purchase/sale, operational control of fuel and energy consumption modes, statistical reporting and transfer of accounting data to the automated control SYSTEM servers and automated workstations (AWS) of users.

Taking into account the specifics of the implementation objects, the ASC TER performs the following tasks: [89]:

-commercial accounting of consumption and release of fuel and energy resources (electric energy, heat energy, steam, hot water, cold water, heating oil, waste water, etc.) in the divisions of the corresponding implementation facility;

-technical control of consumption of all energy resources supplied to structural divisions within the boundaries of a certain object of the corresponding ATO;

-control of the release (transit) of all types of fuel and energy resources to third-party consumers.

The main purpose of the system the ASA TER is to analyze the efficiency of energy consumption by uses, and the development of reasonable control actions to reduce wasteful use of energy resources. This goal is achieved by developing tools within this system to save costs for consumption, production and release of fuel and energy resources at a specific object of implementation of the automated control SYSTEM. The tools provide automation of a set of functions of the following types:

-information-computing and measurement functions of the System;

-service function.

-as part of the service functions include [89]:

-testing and diagnostics of the CCC;

-monitoring and analysis of equipment start/stop;

-configuration of the system's software and hardware complex;

-authorized access;

-documentation of events.

Information-computing and measurement functions of the automated control SYSTEM are a set of functions for implementing the tasks of integrated fuel and energy accounting, measuring fuel and energy consumption parameters, processing them, archiving them, and transmitting them to the appropriate users.

In General, the implementation of these functions provides:

-creation of mechanisms for commercial and technical accounting of consumed fuel and energy resources in the divisions of the corresponding ATO;

-control over specific energy costs per unit of production (services);

-building qualified relationships with suppliers and consumers.

5.3 Organization of work and operating conditions of the automated system of integrated accounting of fuel and energy resources

The control of the technological process of collecting data on fuel and energy consumption, monitoring the performance of software and hardware and technological equipment of power supply networks of ATO facilities is carried out in the FOLLOWING modes:

-automated;

-remote or setup and configuration mode.

In automated mode, the main technological operations for collection of commercial data from fuel and energy metering stations, control of technological parameters (pressure, flow rate and temperature in heat supply systems and water consumption, in places of fuel oil arrival and steam consumption) are performed under the control of computer equipment. Software provides for signalling when any parameters go beyond the limits of their permissible changes or increased consumption of fuel and energy resources in order to avoid emergencies. In this mode, the System user monitors the progress of the technological process and can intervene in the process to clarify the emergency situation. Automated mode is the main mode and ensures the operation of the system in the normal operation of equipment and devices.

In the mode of setting up and configuring the system of the TEC control SYSTEM, all necessary operations are performed by the system user using the control tools on the PC mnitors of the system server [87].

This control mode provides hardware configuration and configuration of data collection devices for a specific number and type of fuel and energy metering devices, interfaces and communication lines. In the setup mode, you can change the order of the survey of integrated fuel and energy metering devices, as well as get operational data for the selected fuel and energy metering unit or energy facility about its operability and fault diagnostics.

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5.4 Structure of the automated system for integrated accounting of fuel and energy resources

In order to implement the above tasks the system is to ASK TER was built in the form of a three-level hierarchical system, structural and technological scheme, which is shown in Fig. 5.1.

According to this structure, the task of ACS implemented the software and technical means of the Autonomous metering of fuel and energy resources (AU FER) the lower level system (level of IVCA), means middle level (IPC) and program - technical means of upper level System (level IVKS).

On the lower level of the System are located information and computing systems energy metering (CPI) based on Autonomous nodes of a particular type of resource (OUTER Auel, AUCHUS, AUGUS, AUTA, AUKT, AUP).

The specific instrument composition of each OUTER node is given in the subsection of the site "Autonomous units of integrated accounting of fuel and energy resources - AU TER".

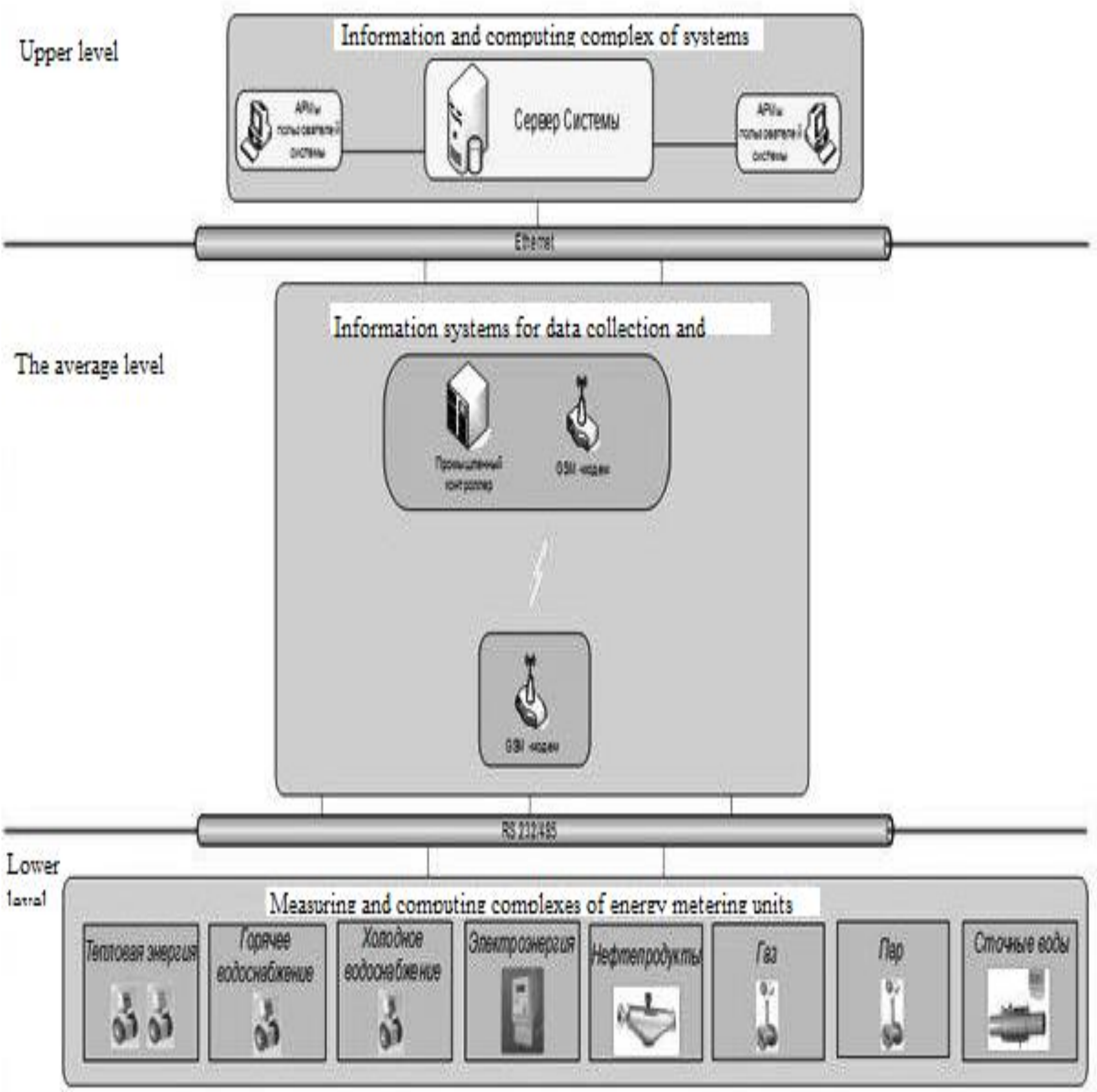

Figura 5.1- Structural and technological scheme of ASC TER [89]

The structure of the middle level of the system ASC TER-channel-forming communication level includes information systems for data collection and transmission (IST) from the fuel and energy accounting units of the lower level of the system to the upper level. IST complexes are built on the basis of information transmission means and data collection and transmission devices based on industrially-assembled controllers.

As communication channels for data transmission from fuel and energy metering devices in the system, as a rule, the RS-485232 interface, SPD network channels and GSM wireless communication channels are used.

Top-level tools include software and hardware of the ASKU server, which is the center for integration and processing of information coming from metering devices and converters of technological information through the IST, and automated workstations (AWP) of managers and specialists of services of structural divisions of the objects of system implementation.

At this level, the storage of all commercial and technical data used in the system is organized, as well as access to this data by top-level software and hardware tools. At the same level, access to the resources of the ASKU TER system is organized for managers and top-level specialists of the System implementation object.

As a rule, the following main functions are implemented on the system server [90]:

- collection of commercial data from fuel and energy metering devices and primary converters of technological parameters for monitoring fuel and energy parameters and equipment operation;
- registration of deviations in the modes of production and consumption of energy resources, as well as in the operation of power equipment;
- keeping astronomical time;
- correction of astronomical time in metering devices, calculators;
-maintenance of databases;
- archiving of commercial fuel and energy accounting data.

The activities of staff, ensure the functioning of the ACS is to control the operation of the equipment and operation of equipment for technological parameters. In case of violations in the technological process of fuel and energy consumption and the appearance of possible malfunctions in the system equipment, the operator's attention is attracted by an automatic light alarm with the output of information in the event protocol.

6 USE OF RENEWABLE ENERGY SOURCES AND SECONDARY ENERGY RESOURCES

6. 1 Renewable energy sources

Federal Law No. 261 and its by-laws oblige during energy surveys to identify the possibility of using renewable energy sources (RES).

Potential. All energy resources are usually divided into non-renewable and renewable. Calculating energy reserves is a complex task, so the estimates of different authors differ. In addition, coal, oil, and gas reserves are classified by category: proven (i.e. more or less confirmed by exploration drilling and other methods), forecast, etc.

The following are approximate data on the total energy reserves on the planet Earth [91].

Non-renewable sources, t y. t.:

-Thermonuclear energy – $12300 \cdot 10^{12}$;

-Nuclear energy – $74 \cdot 10^{12}$;

-Chemical energy of fossil organic fuels – $7{,}4 \cdot 10^{12}$;

-Earth's internal heat (geothermal energy) – $0{,}0165 \cdot 10^{12}$;

Sources that are renewable during the year, t. t./year:

-Energy of the sun's rays reaching the earth's surface – $78 \cdot 10^{12}$;

-Energy of sea tides – $9{,}4 \cdot 10^{12}$;

-Wind energy – $0{,}23 \cdot 10^{12}$;

-The energy of rivers – $0{,}0024 \cdot 10^{12}$;

Biofuels (renewable within 1-50 years), t. t./year – $0{,}006 \cdot 10^{12}$.

Let's briefly consider the possibilities and degree of use of each of the listed types of energy resources.

Thermonuclear energy is the energy of the synthesis of helium from deuterium. Deuterium reserves in the water of the oceans are enormous. But the fusion reaction takes place at a temperature equal to millions of Kelvins. Such temperatures occur in the depths of the Sun and stars, when a hydrogen bomb explodes. The implementation of a thermonuclear fusion reaction in stationary conditions on Earth faces enormous difficulties associated with the hydrodynamic instability of the plasma (a mixture of atomic nuclei and electrons that gas turns into at these temperatures). In the "Tokomak" devices created by Soviet scientists, it was possible to get the desired temperature and carry out the reaction within a very short fraction of a second. In Russia, work in this direction has almost stopped. Negotiations are underway with Western countries that are far behind the USSR to create an international consortium to build a pilot reactor for joint research (presumably in France).

The problem of using thermonuclear energy for peaceful purposes is unlikely to be solved, at least until the middle of the 21st century.

Nuclear energy is the energy of the decay of uranium – 235 and plutonium nuclei. It is already widely used in nuclear power plants. In France, for example, they generate more than 80 % of electricity, in Sweden-about 50 %, in Russia-15 %. The energy potential of nuclear fuel stored on Earth is comparable to the potential of organic fuels, and when using uranium dissolved in the waters of the seas and oceans (which is economically unprofitable today), it significantly exceeds it.

Chemical energy of fossil organic fuels. These include coal, oil, natural gas, oil shale, and peat.

The largest amount of energy of organic fuels is stored in coal deposits, as can be seen from table.6.1 [95].

Table 6.1- Proven reserves of organic fuels on Earth

Fuel	Full, proven reserve, billion tons of cu.	Easily extracted reserve, billion tons of cu.
Coal (including brown)	10100	636
Oil	275	88,6
Gas	360	81
Peat	5	5

At the 28th International conference held in 2003 on the use of coal, the following data were presented: of all the energy resources consumed in the world in 2001, the structure of their consumption was: oil – 38 %, coal – 24 %, natural gas – 24 %, hydroelectric power – 7 %, nuclear energy-7 %.

With this consumption, the reserves of organic fuel would be enough for humanity for more than 300 years, but among the reserves, coal is 68 gas – 19 %, and oil-only 13 %, i.e. the reserves of the most qualified fuels – oil and natural gas-are much smaller than coal, and their deposits are located on the Ground very unevenly. So the reserves of its own oil in the United States are protected as a strategic raw material. Of the approximately 1,000 million tons of oil consumed by the United States per year, domestic production is only about 311 million tons per year (table 6.1).

Foreign experts estimate the proven oil reserves in Russia at 10,500 million tons, which is more than 9.2 % of the world's proven reserves. According to the International energy Agency, Russia's proven natural gas reserves account for 27 % of the world's reserves. Russia ranks first in the world as a gas exporter and as an oil exporter.

The internal heat of the Earth is used mainly in places of tectonic activity, primarily for heating buildings, greenhouses, etc. Geothermal power plants (GEOS) are built in the presence of powerful underground sources of hot water and steam, New Zealand, USA (valley of geysers), etc. Russia has built 3 large geo-power Plants in Kamchatka:

Mutnovskaya, with a capacity of 50 MW; Pauzhetskaya and Verkhne-Mutnovskaya (with a total capacity of 23 MW) and 2 small (1 MW) on the Kuril Islands. In General, the contribution of geothermal energy to global energy production is negligible (0.5 %).

From renewable sources, the largest role is played by hydroelectric power. Currently, the world's hydroelectric power plants provide 9 % of total energy production, and their contribution to the world's total energy consumption is, as indicated above, about 7 %. The creation of large hydroelectric power plants requires huge costs that only rich countries can afford. In the Soviet Union, the largest hydroelectric power stations in the world were built, including Sayano-Shushenskaya with a capacity of 9 GW. Currently, the most powerful hydroelectric power plant "Three gorges" on the Yangtze river (18.2 GW) is being built in China. In Russia in 2003 finally, the first turbine of the Bureyskaya HPP, which began construction under the Soviet Union 30 years ago, was put into operation. According to the Soviet project, 8-9 turbines were supposed to be installed at this HPP.

Solar energy, despite the huge flows to Earth, makes up a negligible share of the world's energy balance. The main reason is the low radiation density per unit area of the Earth, and its dependence on the time of day and year, clouds, etc. Outside the atmosphere, 1.356 kW of energy falls on every square meter of the surface perpendicular to the sun's rays. A significant part of it is absorbed in the atmosphere (dust, some gases, clouds), and some is reflected into space (by the same clouds). The surface of the Earth reaches about 50 % of the above figure. Approximately half of the time (night), each piece of Land is not illuminated by the Sun. Taking into account the angle of inclination of the Earth's surface, it turns out that on average, 200-300 W of solar energy per 1 m^2.

Currently, solar energy is used mainly in countries located in the lower latitudes for hot water and heating. In Russia, solar collectors for hot water supply in the summer do not pay off even in the Krasnodar territory, where more than 50 solar installations with a total area of about 3,600 m^2 operate. However, they allow you to save organic fuel, so in a number of countries, the use of solar heaters (as well as renewable energy sources in General) is encouraged by governments through various benefits and tariffs. The largest solar water heater with an area of 3000 m^2 was built near a thermal power plant in Denmark in 1990. It allows you to provide hot water in the summer without burning fuel at the CHP. In total, solar water heaters with a total area of 60,000 m^2 were used in Denmark in 1990.

To generate electricity from the energy of solar rays, semiconductor solar cells are most often used, the efficiency of which does not exceed 10 (rarely 15) %. Nobel prize Winner Zh.I. Alferov, speaking at USTU-UPI, said that by the middle of the century, the efficiency of heterophase semiconductors will reach 40%. At efficiency = 0.15, the surface of solar cells is required to obtain one kilowatt of electric power on average per day, equal to $1 : (0{,}3 \cdot 0{,}15) \approx 20$ $м^2$. It is expensive.

Electricity from solar installations costs about 6 times more than from burning organic fuel, but the government of a number of countries again encourage such projects. In total, the planet has installed photovoltaic converters with a total capacity of approximately 500 MW. For comparison, the Reftinskaya GRES in the Sverdlovsk region has a capacity of 3,800 MW. The largest semiconductor power plant had a capacity of 12 MW. It was installed on the station for the flight to Mars, launched in the USSR. The 10 MW land-based solar power plant in Bavaria covers an area of 24,800 m^2 (i.e. roughly 0,5x0,5 km), an 11 MW station is under construction (in Portugal), there is a 15 MW station project (South Korea).

Wind energy is used on a somewhat larger scale than solar energy (at least for electricity production), but its contribution to the world's energy balance is also extremely small. At the end of the twentieth century, the installed capacity of wind farms on the planet was 5,250 MW. Along with small wind farms (mainly for driving pumps that take water from wells on large farms) and power plants (for power supply to individual radio stations and other facilities), wind farms with a wind turbine capacity of 2 or even 5 MW have recently been built in a number of countries. Such stations are built, as a rule, on the coast of the oceans, sometimes-in the sea at a distance of up to 10 km from the coast, where strong winds constantly blow (the Northern coast of great Britain, Germany, Denmark).

Many wind farms are built in the United States in the "windy" California valley. Often in a" windy " area (North wells, California), a group of wind farms with a unit capacity of 0.5-3 MW is built, transmitting electricity to an industrial area via a single power line. In the valley of the winds of California, a Park of 11 thousand wind turbines has been created.

The energy of sea tides is not used yet, as well as the energy of sea waves. Only experimental power plants are available.

Biofuel. Currently, biofuels are practically understood as wood, animal waste (manure) and crop products for alcoholic fermentation. Wood is receiving increasing attention, in particular because its combustion does not increase the concentration of CO2 in the atmosphere, if we assume that when growing a new tree, instead of the burned one, the carbon dioxide generated by burning will be absorbed.Gorenje First of all, waste from logging, woodworking and other industries is burned in furnaces, but there are already examples when fast-growing trees (acacia, willow, poplar, etc.) are specially grown for fuel. The Swedish experience is interesting in this regard. There, electricity is generated mainly by hydroelectric power plants (50%) and nuclear power plants (50%), while coal and wood are used in industrial heat power and in everyday life (heating, hot water supply). Sweden does not have its own coal, as well as oil.

Thus, imported coal in some countries is cheaper than domestic wood. For example, the Swedish government imposed such import duties that wood was the cheapest fuel. This is an example of a regulated market.

Wood fuel plays a significant role in the energy balance of the planet. The area of forests on Earth is about 20 million km^2 , of which in Russia-about 8 million km^2.

The use of animal waste allows, first, to dispose of them (on large pig farms in Russia, for example, their burial results in a problem), and secondly, to get energy from them. In Central Asia, dung (dried manure) is used as fuel. But bioreactors are more widely used (especially in countries with warm climates). In fact, these are vats (usually dug into the ground), in which liquid manure is fermented at a temperature of 32-36 ° C (sometimes 50 ° C). This releases a gas consisting of methane (≈ 60 %) and CO_2 (≈ 40%). The remaining waste, which has a liquid consistency, is used as fertilizer. Biogas is used in everyday life and even for power generation. A huge number of small primitive reactors are available in China, India and other countries with warm climates. In Russia, bioreactors are almost not used, since maintaining the desired temperature in the reactor in our harsh climate requires a lot of energy.

One of the options for using biowaste (for example, the remains of sugar cane – bagasse – after obtaining sugar from it) is their alcoholic fermentation. The resulting ethyl alcohol is used as fuel in engines either in its pure form, or (more often) as an additive to gasoline (this mixture is called "gasohol"). In Brazil, in the late 80's (after the oil crisis), more than 5 million cars used pure ethanol and 9 million used gasohol. In the US, gasohol accounts for 10 % of the fuel market and is used in 100 million engines.

The use of food resources as fuel is a controversial issue and it is unlikely that this direction is promising.

Developed countries have adopted long-term programs to develop energy supply systems from renewable energy sources. Let's show their scale on the example of Germany. In 2008, electricity production from renewable sources in Germany amounted to 92.7 TWh (92.7 billion kWh), which is 15.1% of all electricity consumed in the country.

For comparison, we note that Germany produces electricity from renewable sources almost 2.5 times more than the total amount of electricity consumed in the Sverdlovsk region. But an even more important feature of the production of this type of energy is that all these power generators in the number of 469,800 units with a total installed capacity of 38140 MW are included in the unified electric network of Germany. If it were possible for any person in our country to connect their generating plant to the unified distribution network of the corresponding settlement, then energy supply systems from renewable sources would also be widespread.

The capacity structure of this type of installations in Germany (2008) is of interest: 22833 MW – wind power; 5955 MW – photovoltaic; 3997 – hydroelectric; 3698 MW – biogas. In 2008, the most actively developed photovoltaic component was 34.6% and HPP-13 %.

6.2 Secondary energy resources

Secondary fuel and energy resources (ver) – fuel and energy resources obtained as waste or by-products (emissions) of the production process. Secondary fuel and energy resources are found in the form of heat of various parameters and fuel.

Ver includes: heated exhaust gases of technological units; gases and liquids of cooling systems; waste water vapor; waste water; ventilation emissions, the heat of which can be usefully used.

Ver in the form of fuel includes: solid and liquid waste, gaseous emissions from oil refining, oil production, chemical, pulp and paper, woodworking and other industries, urban garbage, etc.

Blast-furnace gases with a calorific value of about 4000 kJ/m3 are classified as ver fuels, but since they have a pressure higher than atmospheric (up to 0.3 MPa), they can be used as ver with excess pressure in a gas-free recovery turbine to generate additional electricity or drive blowers. Water cooling of blast furnaces and metal structures can produce a significant amount of low-potential heat (with a temperature of 15-20 ^{o}C). The method of evaporative cooling, while reducing the consumption of water and electricity for pumping it, allows you to produce low-pressure steam (up to 0.8 MPa), used for heat supply needs.

The temperature of the exhaust gases of blast furnace air heaters ranges from 150-600 ^{o}C, the temperature of the exhaust gases of cowpers reaches 250-500^{o}C. Their heat can be used to generate steam, hot water, or to heat blast furnace gas. It is promising to use the heat of slags, which in non-ferrous metallurgy come out with a temperature of up to 1300 ^{o}C and carry away up to 15-70 % of the total heat. In ferrous metallurgy, significant waste heat is generated in agglomeration and Ferroalloy production (the average temperature of slags ranges from 500-550 ^{o}C).

At present, heat waste at machine-building enterprises is the physical heat of exhaust gases, the heat of cooling of heating and thermal furnaces and wagons, and the heat of spent steam from forging and pressing equipment.

In the construction materials industry, thermal ver is formed during the firing of cement clinker and ceramic products, the production of glass, bricks, lime, refractories, and the smelting of heat-insulating materials. These include the physical heat of the exhaust gases of various furnaces (tunnel, mine, rotating, etc.).

Large consumers of steam of various parameters, electricity, hot and warm water, as well as cold are almost all branches of the food industry, so the thermal ver of food industry enterprises is also very diverse. This is, first of all, the heat of waste hot gases and liquids; liquid and solid production waste; spent steam of power plants and secondary steam, which is obtained by evaporation of solutions, rectification and drying; heat installations; heat contained in the products of production.

Secondary energy resources are also available at thermal and hydroelectric power plants. At hydroelectric power plants, waste heat is generated as a result of heat generation in electric generators. For thermal power plants, the most significant source of ver is the low — potential heat of the heated cooling water of condensing devices, which can lose up to 50 % of the heat of the fuel consumed at the power plant. The source of ver is also considered to be flue gases from boiler plants at steam turbine stations or waste products from the combustion of gas turbine plants.

For cooling installations, the source of thermal ver can be heated cooling water from air coolers and regenerative heat exchangers. The source of ver can be heated cooling water from the cooling system of power plant generators. Significant thermal waste is also present at nuclear power plants: heat of condensate, heat of cooling systems, etc.

Thus, the main sources of ver formation in various industries are technological devices, which are usually not sufficiently advanced from the energy point of view, since modern technology allows the operation of technological installations with a low fuel utilization rate.

The output and use of ver is calculated either in a unit of time (1 hour) of operation of the ver source unit, or in specific indicators per unit of production (raw materials).

The specific (hourly) output of ver is determined by multiplying the specific (hourly) amount of energy carrier by its energy potential.

The energy potential of energy carriers is determined by:

-for combustible ver — low calorific value $Q^{р}_{н}$;

-for thermal ver — by the enthalpy difference Δh;

-for ver overpressure-isentropic expansion function l.

As the unit of measurement of capacity of accepted units of energy is the kilojoule, kilowatt.

Units of measurement of the amount of energy carrier are units of mass-kilogram (kg), ton (t); for gaseous heat carriers — units of volume-cubic meter under normal physical conditions (m^3 at n. o., Nm^3): P = 760 mmHg and t = 0 ^{o}C.

The specific total ver yield is determined by the formulas, kJ / h [91]:

- for combustible ver

$$q_{г} = m \cdot Q^{p}_{н}\,; \tag{6.1}$$

-for thermal ver

$$q_{т} = m \cdot c \cdot (t - t_o) = m \cdot \Delta h; \tag{6.2}$$

-for ver overpressure

$$q_{и} = m \cdot l. \tag{6.3}$$

The total output of ver:

Here m — specific (hourly) amount of energy carrier in the form of solid, liquid or gaseous products, kg (m^3)/h; Δh — available energy carrier enthalpy difference, kJ / kg; l — work of isentropic expansion, kJ / kg; $Q_{вых}$ — the total output of ver during the period under review, kJ; M — output of main products or consumption of raw materials (fuel) for the period under review; τ — number of operating hours of the ver source installation for the specified period; q — specific ver output as a percentage of the output of the main product or raw material consumption; $q_{ч}$ — hourly specific output of ver, determined by the formulas (6.1).

Sometimes, in practical calculations, the specific and total volume of ver output is attributed not to a unit of time, but to a unit of production: kJ / unit of production, percentage / unit of production.

The lowest calorific value of combustible ver QRN is determined experimentally or by formulas known in heat engineering depending on the elementary composition.

The difference in enthalpies Δh for thermal ver, it is determined depending on the temperature of the energy carrier at the outlet of the unit (ver source), as well as on the ambient temperature. Calculations usually determine the average ver output for a steady state process mode.

The ver output for the considered time period (day, month, quarter, year) is determined based on the specific or hourly output using the formula, GJ:

$$Q_{вых} = q \cdot \Pi \cdot 10^{-6},\ Q_{вых} = q_ч \cdot \tau \cdot 10^{-6}, \qquad (6.4)$$

Here q — specific output of ver, kJ / unit of production; Π — output of main products (consumption of raw materials, fuel), to which the specific output of ver is attributed, for the period under review, unit of production; $q_ч$ — hourly ver output, kJ / h; τ — operating time of the ver source unit for the period under review, h.

Let's calculate the output and actual production of ver for a metallurgical plant with a full technological cycle [92].

Main equipment composition:

- Sinter plant with two agglomerates, sintering area of 80 m^2. The possible capacity of the agglomerate is 1140 thousand tons / year.
- A blast furnace shop with three working blast furnaces with a total volume of 620 m^3. Pig iron production 500 thousand tons / year.
- Open-hearth shop with four open-hearth furnaces. Production capacity up to 900 thousand tons of steel per year.
- Rolling production, which includes three heating furnaces. The volume of processed metal is 600 thousand tons / year.
- The actual production of ver was:
- Combustible ver (blast furnace gas) - 112,000 tons of cu/year.
- Thermal ver (steam) — 53,500 tons of cu/year.

The calculation is performed based on the enlarged indicators of the output and use of ver at the ferrous metallurgy plant.

-The specific yield of combustible ver in blast furnaces will take 3800 m3 of blast furnace gas per 1 ton of cast iron with a calorific value of 4187 kJ/m3. Therefore, the yield of combustible ver will be $(3800 \cdot 4187):29310 \approx 540$ kg u. t. / t of cast iron.

-The specific output of thermal ver in open-hearth furnaces (physical heat of flue gases and evaporative cooling of furnace structures) is about 0.37 Gcal/t of steel (53 kg of cu/t of steel).

-The specific yield of thermal secondary energy resources in heating furnaces (natural heat of the flue gases) it is about 0.1 Gcal / t (14 kg cu/t).

The possible production of ver will be at the above nominal volumes of metal production:

blast furnace gas: 0,54 · 500 000 = 270 000 t u. t./year;

thermal energy: 0,053· 900 000 + 0,014 · 600000 = 56 100 t u. t./year.

Fuel economy generally depends on the direction of use of ver and the power supply scheme of the enterprise where they are used. There are different directions: thermal, electric power, fuel and combined.

With the thermal direction of use and a separate power supply scheme of the enterprise, the fuel economy of the V_{ec}, t. u. t., is determined by the formula,

$$B_{эк} = b_з \cdot Q_и = b_з \cdot Q_т \cdot \delta, \tag{6.5}$$

where $b_з$ — specific fuel consumption for heat generation in the replaced boiler plant, t u. t./GJ (Gcal); $Q_и$ — use of thermal ver, GJ (Gcal); $Q_т$ — generation of thermal energy due to ver in the recycling plant, GJ (Gcal); δ— coefficient of use of thermal energy generated by ver.

When using ver to produce cold in absorption refrigeration units, fuel economy can be determined by the formula (6.4), substituting instead of $Q_и$ amount of cold generated $Q_х$, divided by the refrigeration coefficient:

$$B_{эк} = b_з \cdot Q_х/\varepsilon \tag{6.6}$$

For the electric power direction of ver use, the fuel economy is equal to, kg cu. T. (t y. t.):

$$B_{эк} = b_з \cdot W, \tag{6.7}$$

where $b_з$ — specific fuel consumption for electricity generation in the replaced power plant, kg cu. T. (t. t.)/ kWh; W — electric power generation, kWh

In the fuel direction of using fuel ver, fuel economy is determined from the expression

$$B_{эк} = B_и \cdot \eta_{ВЭР}/\eta_т. \tag{6.8}$$

Here $B_и$ — the amount of use of combustible ver, t y. t.; $\eta_{ВЭР}$ — Efficiency of the fuel-using unit when working on combustible ver; $\eta_т$ — The efficiency of the same unit when operating on the primary fuel.

Based on calculations of fuel economy due to the use of ver, the ver utilization coefficient is determined, which characterizes the degree of use of certain types of ver at the enterprise, in the holding, in the city, region, industry, etc. a

Generalized scheme for calculating fuel economy when using ver is shown in figure 6.11.

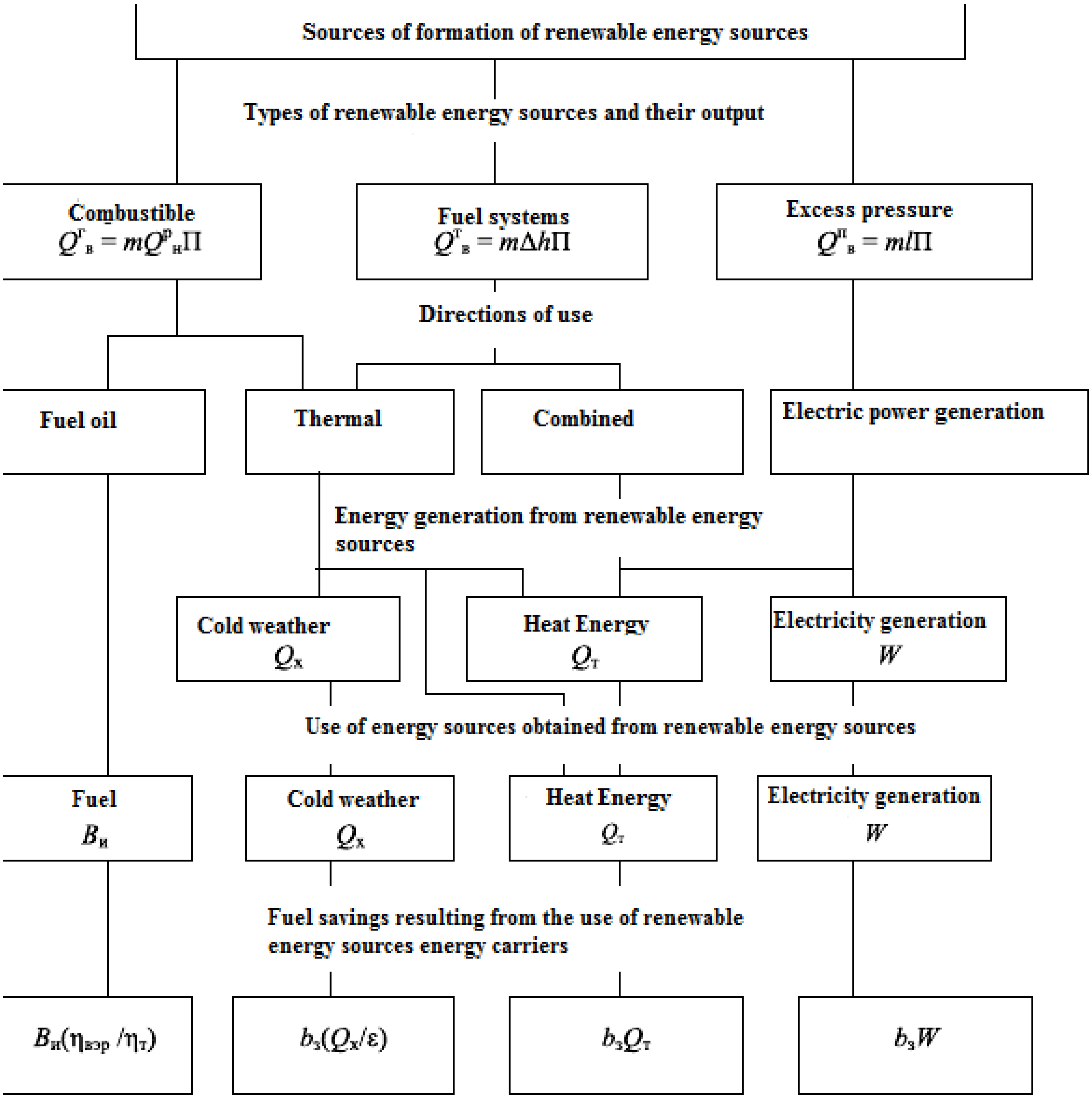

Fig. 6.1- Scheme for calculating fuel economy due to the use of secondary energy resources

However, the above calculation scheme does not allow comparison of interventions according to their effectiveness. Their investment efficiency can be evaluated using the following formula:

$$ЗР + З_э < В_{эк}Ц,$$

where З — costs of implementing activities, rub.; Р — level of profitability of production assets; $З_э$ — operating costs when using this event (conditionally constant, without the cost of energy costs), rub.; $В_{эк}$ — possible fuel economy after the implementation of measures related to primary fuel, t (m ^{3}); Ц— price of this type of fuel, rub (t / m ^{3}).

By difference $В_{эк}S$ — $(ЗР+З_э)$ you can evaluate the possible profit and compare options based on their effectiveness. The use of ver will become relevant by 2010, if the forecasts of the Ministry of economic development of the Russian Federation and Gazprom about increasing gas prices to 4-5 thousand rubles/1000 $м^3$ come true.

Table 6.2 shows generalized indicators of the use of ver in some industries [91].

Table 6.2 Possible increase in the use of secondary energy resources

Ver source aggregates	Event	Possible fuel and energy savings
1	2	3
Refining industry		
Tube furnace	Waste gas heat recovery from furnaces	20-50 thousand kcal / t of raw materials
The installation of HFC-82	Use of steam condensation heat in butane and isobutane columns to heat the bottom of the isobutane column	82 thousand. Gcal / year
LG-35/11-300 (catalytic reforming)	Heating the bottom of the column with gasoline fraction heat	5,3 thousand. Gcal / h
Engineering		
Heating furnaces (capacity 300-20000 kg / h)	Utilization of physical heat of exhaust gases by means of heat recovery boilers, air heaters	Fuel-up to -20—25 %
Heat treatment furnaces (capacity 150-9000 kg/h)	Utilization of physical heat of exhaust gases by means of heat recovery boilers, air heaters	Fuel-up to 15—20 %
Heating and thermal furnaces	Using the heat of exhaust gases to heat the air of heat curtains	Up to 50 % of the heat consumption for heat curtains
Steam presses and hammers	Waste steam heat recovery in scrap boilers and heating installations	Heat energy - up to 75%
Building materials industry		
Glass furnaces	Introduction of thermosyphon heat recovery boilers (TCU) behind low-power furnaces	50-70T cu/year per boiler
Glass furnaces	Introduction of waste heat boilers of the G-1030B, G-345, KU-16, KU - 40 types	2-33 thousand tons of cu/year per boiler
Glass furnaces	Introduction of recycling water heaters with High heating capacity	190-170t cu/year per installation

Rotary kilns for firing expanded clay	Using the heat of exhaust gases when their temperature is reduced from 600 to 300 °C to heat the blast air	Reduced specific fuel consumption by 34 %
Tunnel kilns for firing clay bricks	Using the heat of exhaust gases to dry bricks	Reduction of specific fuel consumption by 15—20 %
Autoclaves for steaming silicate bricks steam	Transfer from one autoclave to another	The heat—23 %
Slotted and roller kilns	Use the heat of exhaust gases to heat water	0, 3-0. 5 kg cu/m3
Food industry		
Units for continuous cooking of starchy raw materials with a capacity of 3000 dal /day	Introduction of an extra steam heat exchanger	225 t. t. / year per installation
Dephlegmators	Introduction of a set of devices	136 t. t. / year
distillation and rectification plants gave 3000/day	for heat recovery of dephlegmator water	per installation
Alcohol shop evaporation stations	Introduction of thermosiphon heaters for heating alcohol brew due to the heat of acid condensate	9 Gcal / h
Bragorectification plants with a capacity of 3000 dal / day	Introduction of steam injection plants for heat recovery of Barda and Luther water	42 t. t./year
Beer and alcohol industry		
Malt dryers with a capacity of 20 t / day	Use of waste gas heat from the furnaces of malt dryers	30 tons of cu/thousand tons per unit
Wort coolers	Use of waste water heat in the process	62T cu/USD million.
Fat and oil industry		
Oil extraction line with capacity 500-1000 t / day	Using the heat of the hot oil from the 3rd stage distiller to heat the water	95 t. t. / year
Line hydrogenation of fats	Using the heat of salomas after hydrogenation to heat fats and oils	20 т у.т./год

It should be noted that over the past 30 years, a large number of guidelines on energy consumption standards for various energy-consuming equipment and certain technological processes have been introduced.

6.3 Renewable energy sources in Kazakhstan

Kazakhstan is among the world leaders in the diversity and quantity of minerals. Since oil and gas, coal and other minerals are the most important for the country's economy, which is why the legislative framework in these sectors of the economy is so developed, historically the government has been less focused on the development of alternative energy sources. For example, most power plants in Kazakhstan currently run on natural gas, coal, or petroleum products.

However, the recent crisis in the global economy and the awareness of the need to reduce the energy intensity of the economy and the impact on the environment forced the country's leadership to actively focus on creating favorable conditions for the use of renewable energy sources "RES".

The concept of renewable energy According to the Kazakh legislation, renewable energy means:

-energy sources that can be renewed by natural processes, including:

-energy of solar radiation energy;

- wind power;
- hydrodynamic energy of water;
- geothermal energy (heat of soil, groundwater, rivers and water bodies);
- anthropogenic sources of primary energy resources: biomass;• biogas;
- other fuels from organic waste used in the production of * electrical and / or thermal energy.

Government support includes:

1. Preferential fixed electricity tariffs for renewable energy facilities for a period of 15 years. The approved fixed tariffs are subject to annual indexation taking into account inflation in the order determined by the Government of the Republic of Kazakhstan.
2. Reservation and priority in the provision of land plots for the construction of renewable energy facilities.
3. Mandatory connection of objects for the use of renewable energy sources to the networks of energy transmission organizations. new and reconstructed facilities using res have the right to• easy and non-discriminatory access to the next technically implemented point of connection to the electric networks of energy transmission organizations. Renewable energy in Kazakhstan is the costs of connection of RES (including strengthening of networks), with the exception of costs for the transmission line between the power station and network, as well as other components of the new electricity producer.
4. Priority transfer of electricity produced using renewable energy sources.
5. Mandatory purchase of electricity produced using renewable energy sources.
6. Exemption from renewable energy charges for the transmission of electricity over networks.

7. Exemption from liability for balancing for individual RES producers; Special balancing group for all RES.

8. Lack of licensing.

9. Provision of investment preferences and benefits to legal entities, as well as various support measures:

- tax exemption;
- customs duties;
- state natural grants;
- Subsidizing investments (compensation of up to 30 percent of actual costs);
- Guarantees of stability when changing the legislation of the Republic of Kazakhstan.

10. measures of state support for subjects of industrial and innovative activity:

- financing, including co-financing, projects, financing * leasing;
- provision of guarantee certificates and loan guarantees;
- lending through financial institutions;
- subsidizing the interest rate on loans issued by financial institutions and coupon interest on bonds;
- making investments in the authorized capital;
- guaranteed order;
- provision of innovative grants;
- provision of qualified human resources;
- provision of engineering and communication infrastructure;
- provision of land plots and subsoil use rights;
- support in the domestic market;
- attracting foreign investment;
- development and promotion of export of domestic products and services.

Future prospects for renewable energy, In short, today the use of renewable energy has become an important and mandatory direction for the development of future energy.

Kazakhstan has all the necessary resources in this regard. Given the shortage of electricity in the country, especially in the southern regions, the wider use of alternative sources is of particular importance.

The inefficiency of the centralization of energy supply in the conditions of the vast territory of Kazakhstan, which occupies 2.7 million square kilometers, with a low population density (5.5 people / square kilometer) leads to significant losses of energy during its transportation. therefore, the use of renewable energy sources will reduce the cost of electricity supply to remote settlements, significantly save on the construction of new power lines. small hydroelectric power plants are the most actively developing area of renewable energy use in kazakhstan.

So, in the period from 2017 to 2020, five small hydroelectric power plants with a total nominal volume of about 20 MW were commissioned in the Almaty region. The construction of such hydroelectric power plants, which operate without dams on small rivers, is one of the important directions of improving the energy efficiency of the economy of Kazakhstan. According to experts, the best result will be the construction of cascades of safe small hydroelectric power plants on the rivers of Southern Kazakhstan.

In the long term, wind power has the greatest potential. On the territory of 50 thousand square kilometers, which is 2% of the area of Kazakhstan, the average annual wind speed exceeds 7 m/s. The capacity of these territories alone is sufficient for the development of 1 trillion kWh per year, which is many times higher than the country's electricity needs. The total annual energy potential of wind in Kazakhstan is estimated at 1.8 trillion kWh, and its density in some places is 10 MW per square km. In particular, the regions of Northern, Central, Western and South-Eastern Kazakhstan, especially the Dzungarian Gate and the Shelek corridor, where the average annual wind speed is 7-9 m / s and 5-9 m/s, respectively, as well as Nur-Sultan, Shevchenko Port and Arkalyk have a significant resource. Their possibility from the point of view of using air flows in generating electricity can be called unique. By 2020, 34 facilities using renewable energy sources will be put into operation in the republic. The total capacity of the new power plants will be 1362.34 MW.

Most of the energy will be developed by 13 wind farms - 1081 MW. 17 hydroelectric power plants will give 205.45 MW, and four solar power plants-76 MW. The main capacity of hydroelectric power plants is concentrated in the Almaty region. A total of 11 hydroelectric power stations are planned to be built by 2022. The largest of them, 60.8 MW, will appear on the Shelek River. In addition, the hydroelectric power station will be launched in East Kazakhstan, Zhambyl and South Kazakhstan regions. Solar energy for electricity production will be used in Almaty, Zhambyl and Kyzylorda regions. The most powerful power plant - 24 MW - is planned to be built in Zhambyl region. a number of projects are already actively funded. So, LLP "First wind power plant" (subsidiary of LLP "Samruk-green energy") and the Eurasian development Bank signed the agreement about opening of credit line worth 14.2 billion tenge for financing the "turnkey" construction project of the first major wind farm in Kazakhstan on the platform of Ermentau in Akmola region is 45 MW.

Development of the electric power industry more than 172 million kWh per year without consumption of hydrocarbon fuel will save more than 60 thousand tons of coal and increase the reliability of electricity supply in the region. Within the framework of the upcoming EXPO-2017 Renewable Energy Sources in Kazakhstan, it is planned to provide energy supply to the exhibition facilities at the expense of energy that will be developed by this wind power plant. The role of renewable energy in the power of the future will be determined by the possibilities of developing new technologies, materials and structures to create competitive power plants. Today, the cost of renewable energy remains high, but with consistent development and cost reduction, alternative energy will take its place in the global energy balance.

7 STATUS OF THE ISSUE AND RESEARCH OBJECTIVES

7.1 Classification of electrothermal installations

Electro-thermal installation (ETIS one) klassificeret according to the following criteria:

- the nature of current;
- DC frequency;
- modes of heat transfer;
- technology application;
- according to the method of transforming electrical energy into heat and other characteristics;
- power supply;
- at the operating temperature.

Classification of electrothermal installations by the method of converting electric energy into heat :

1) resistance heating;
2) heating with the electric arc;
3) heating in an alternating magnetic field –induction method;
4) heating in an alternating electric field –a dielectric method;
5) heating by an electron beam;
6) quantum heating (infrared, laser heating methods);
7) plasma heating.

Classification of electrothermal installations by type of current: 1) direct current DC; 2) alternating current AC.

Electrothermal installations are classified by current frequency:

- industrial frequency (50 Hz);
- high frequency;
- high frequency;
- ultra-high frequency.

According to the type of heating, electrothermal installations can be divided into 2 groups: 1) direct heating; 2) indirect heating.

Electrothermal installations are divided into 2 groups according to the operating mode: 1) continuous operation; 2) periodic operation.

According to the operating temperature, electrothermal installations are classified into: 1) low-temperature (up to 500...600^{0}C); 2) medium-temperature (up to 1250^{0}C); 3) high-temperature (over 1250^{0}C).

Electrothermal are the voltage: up to 1 kV; over 1 kV; safe voltage.

According to the technological purpose, electrothermal installations are classified into: universal; special.

7.2 Tasks and content of design of electrothermal installations

Electrothermal installations are designed to perform certain technological operations and, therefore, it is the technological requirements that determine their design.

The task of such design is to create operating electrothermal equipment that provides this technological process with the maximum use of the plant's capabilities and the minimum operating costs, creates conditions for the greatest productivity of service personnel, and complies with safety regulations, rules for the design and operation of electrical installations.

When starting to design an electrical installation, it is necessary to have, first of all, a technical task jointly developed and agreed with technologists and engineers. The technical specification specifies the purpose of an electrothermal installation, its performance, temperature conditions, heating speed, operating conditions, safety requirements, environmental features, power supply conditions, automation requirements, and power control limits.

There are verification and constructive (design or complete) calculation of electrothermal installations.

Verification calculation is performed to determine the passport data of the electrothermal installation in their absence or to establish the possibility of using the finished installation in specific, different from the passport, operating conditions.

The complete calculation of an electrothermal installation includes thermal, electrical, aerodynamic, hydraulic, and mechanical.

Thermal calculation is carried out in order to determine the technical data of installations (power, surface temperature of heating elements, heat transfer intensity, thermal insulation parameters, thermal efficiency) that provide technological requirements that are determined by a single method for all electrothermal installations.

Electrical calculation is closely related to thermal calculation and consists in choosing the supply voltage, type of current, frequency, determining the geometric dimensions of the heater, electrical efficiency and power factor, developing a control scheme and a method for regulating power.

The aerodynamic calculation is related to finding the flow rate of air (gas) passing through the installation, selecting fans, determining the cross-section of air ducts and the size of distribution grids. The correct solution of this issue depends on the heat transfer of heating elements, and, consequently, the service life, thermal and electrical efficiency.

Hydraulic calculation is performed to determine the flow of liquid through the installation, select the pump and the pipeline section.

Mechanical calculation is carried out to determine the geometric dimensions of the installation, weight, material consumption and its mechanical strength.

7.3 Through-heating induction installations, calculation methods and operation features

For the first time, the problem of induction heating for heat treatment and its technical solution were formulated by E. F. Norhrup [1] in 1918. In the future, intensive research in this area began, which led to the creation of a powerful and highly efficient industrial sector of the world economy. In Russia, this direction was headed by the outstanding scientist V. P. Vologdin [2]. The current stage of development of the industry is characterized by the presence of developed scientific schools in the field of induction heating in technical universities and other institutions. the founders and leaders are: LETI and VNIITVCH (Saint Petersburg)- V. P. Vologdin , G. I. Babat, A. N. Shamov, V. N. Bogdanov, S. N. Perovsky [93]; SamSTU - E. Ya. Rappoport [94].

Scientific directions have been developed:

-creation of analytical methods for calculating electromagnetic induction systems and solving thermal problems with induction heating, which formed the basis of modern numerical methods of calculation (A. E. Slushotsky) [95];

- theoretical bases of development of power supply schemes for induction systems and methods of their analysis (A. S. Vasiliev, D. N. Bondarenko) [96];

-numerical methods for analyzing electromagnetic processes (V. B. Demidovich, V. S. Nemkov,V. N. Timofeev) [97].

It should be noted that a large number of fundamental problems in the field of induction heating of metals have already been solved. However, the intensive development of industrial production poses new theoretical and applied problems that require new approaches, development of modern methods and techniques, as well as computer technologies and tools for their solution [98].

7.3.1 Basic concepts and definitions in induction heating technology

Induction heating installations are electrothermal equipment.

Electrothermal equipment (ETE) according to the terminology established by current standards, is a set of technological equipment and devices for the implementation of the electrothermal process [92]. Electrothermal process - the technological process of thermal effects on the load using electric heating. In addition, there are such concepts as an electrothermal installation, an electric furnace, an electrothermal device and an electrothermal unit. Electrothermal installation - a set of electrothermal and other technological equipment together with structures and communications that ensure the conduct of the electrothermal process.

An electrothermal device is a part of an electrothermal equipment that performs an electrothermal process in an open working space. An electrothermal unit is a set of electrothermal equipment and other devices United by a thermal process [92].

Induction electrothermal device - an electrothermal unit in which the electrothermal process is carried out by induction heating. Induction means heating of bodies in an electromagnetic field due to the thermal action of an electric current, induction in a load or an intermediate device (in an electrically conductive crucible) due to the phenomenon of electromagnetic induction [92].

Induction installations are understood as a set of devices that ensure the implementation of the electrothermal process (including power sources, automation and control devices, accessories, current lines, and some auxiliary devices) [94]. An induction heating system differs from a melting plant in that the final heating temperature of the load is always lower than the melting temperature of the material.

The most important element of any induction heating installation is an inductor, which is a conductor or a system of conductors of a certain configuration, connected to an external AC source and designed for remote (non-contact) guidance in the heating product of an alternating electromagnetic field and electric current that warms the product [94]. The inductor is usually wound from a copper wire in the form of a single-turn or multi-turn coil, the design of which is determined by the size and configuration of the heated products, as well as the requirements of the heating technology [95]. The products themselves, placed in the inductor and subjected to induction heating, are called loading. In some cases, it is advisable to heat the load by exciting an electric current not directly in it, but in some intermediate device (in a coupling or an electrically conductive crucible). This type of loading heating is called indirect induction heating, and the furnace used for its implementation is called an indirect heating induction furnace [92]. In practice, the concept of induction heater (IH) is also used. It includes all elements of the induction unit, except for power sources.

7.4 Inductors. Features of induction heating

Inductors. Features of induction heating if a piece of metal is placed in an alternating magnetic field, an alternating EMF will be induced in it, under the influence of which eddy currents (Foucault currents) will arise in the metal.

The passage of these currents in the metal will cause it to heat up. This method of heating metal is called induction. The heating effect increases with increasing field strength and depends on the properties of the material and the distance of the coil from the surface of the part, i.e., on the geometry of the "inductor – part" system. For induction heating, industrial (50 Hz-30 MHz) and high-frequency (8-10 kHz, 70-500 kHz) currents are used[95].

Induction heating allows you to effectively and quickly heat conductive materials (metals, graphite, etc.) by inducing eddy currents in them(Figure 1.1).

Figure 7.1 - Induction heating of metal

The device by which eddy currents are induced in a heated body is called an inductor. The inductor can be supplied with a voltage of industrial or high (medium, high) frequency. The frequency of the voltage supplied to the inductor determines the efficiency and the depth of the simultaneously heated metal layer.

During the drying process, the wood temperature (Figure 7.2) is higher than the ambient temperature, resulting in a positive temperature drop in the stack, which intensifies the process of removing moisture from the material. The duration of induction drying is half as long as compared to chamber drying of lumber in normal modes[6].

Figure 7.2 - Induction drying of wood

The main element of the drying unit is a magnetic circuit, which creates an alternating magnetic field, and a current line for connecting it to an electric power source. The power supply of the induction unit is provided from the AC network with a voltage of 220—380V.The ever-expanding variety of technologies that use induction heating determines the variety of forms and types of inductors, the functional, power and frequency range of induction equipment.

Today, induction heating occupies a dominant position in a number of technologies, replacing other types of heating. For example, the foundry sections of most machine-building enterprises are equipped with induction installations, and only high-frequency heating is used for soldering tools.

The essence of this method is that the electric current passing through the winding causes induction (eddy) currents that create heat in the metal masses, which is used for drying. Induction currents very quickly give off heat to the product, so this method is faster than all other methods in terms of heating and drying.

Induction heating is carried out in an alternating magnetic field. Conductors placed in the field are heated by eddy currents induced in them according to the laws of electromagnetic induction.

Intensive heating can be obtained only in magnetic fields of high intensity and frequency, which are created by special devices - inductors (induction heaters), powered by a network or individual high-frequency current generators (Figure 7.3). The inductor is like the primary winding of an air transformer, the secondary winding of which is the heated body.

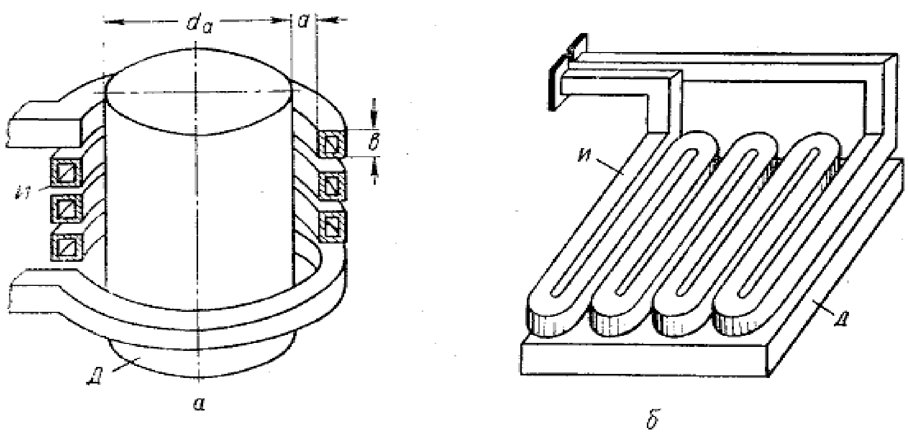

Figure 7.3- Inductors: a - cylindrical,b - loop for heating flat parts, I-inductor, D-part

Depending on the frequencies used, the induction heating units are divided as follows:

a) low (industrial) frequency (50 Hz);

b) medium (increased) frequency (up to 10 kHz);

C) high frequency (over 10 kHz).

The division of induction heating into frequency ranges is dictated by technical and technological considerations. The physical nature and General quantitative regularities for all frequencies are the same and are based on the concepts of absorption of the electromagnetic field energy by the conducting medium.

Frequency has a significant impact on the intensity and nature of heating. At a frequency of 50 Hz and a magnetic field strength of 3000-5000 A/m, the specific heating power does not exceed 10 W/cm^2, and with high-frequency (HF) heating, the power reaches hundreds or thousands of W/cm^2. At the same time, temperatures are developed that are sufficient for melting the most refractory metals.

At the same time, the higher the frequency, the lower the depth of penetration of currents into the metal and, consequently, the thinner the heated layer, and Vice versa. Surface heating is performed at high frequencies. By reducing the frequency and thereby increasing the depth of current penetration, it is possible to carry out deep or even through heating, the same throughout the entire cross-section of the body. Thus, by choosing the frequency, you can get the heating character and intensity required by the technological conditions. The ability to heat products to almost any thickness is one of the main advantages of induction heating, which is widely used for hardening surfaces of parts and tools.

Surface hardening after induction heating significantly increases the wear resistance of products compared to heat treatment in furnaces. Induction heating is also successfully used for melting, heat treatment, metal deformation and other processes.

7.4.1 Inductors (induction heaters)

An inductor is a working element of an induction heating system. The higher the heating efficiency, the closer the type of electromagnetic wave emitted by the inductor is to the shape of the heated surface. The type of wave (flat, cylindrical, etc.) is determined by the shape of the inductor.

The design of inductors depends on the shape of the heated bodies, the purposes and conditions of heating, figure 1.4. the simplest inductor is an insulated conductor placed inside a metal pipe, stretched or coiled. When an industrial frequency current is passed through the conductor, eddy currents that heat the pipe are induced in the pipe. In agriculture, attempts were made to use this principle for heating the soil in closed ground, roosts for poultry, etc.

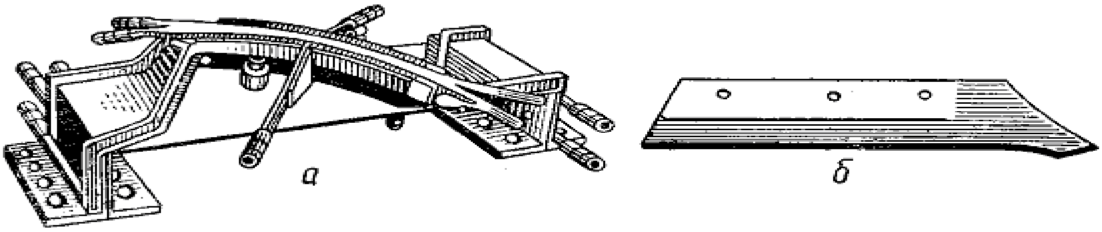

Figure 7.4 - Inductor for quenching ploughshares: a - inductor, b – ploughshare

In induction water heaters and milk pasteurizers (work on them has not yet gone beyond the experimental samples), inductors are performed according to the type of stators of three-phase electric motors. A cylindrical metal vessel is placed inside the inductor. The rotating (or pulsating in single-phase design) magnetic field created by the inductor induces eddy currents in the vessel walls and heats them. Heat is transferred from the walls to the liquid in the vessel.

During induction drying of wood, a stack of boards is shifted with metal grids and placed (rolled up on a special cart) inside a cylindrical inductor made of large-section conductors wound on a frame made of insulating material. Boards are heated by metal grids in which eddy currents are induced.

These examples explain the principle of indirect induction heating installations. The disadvantages of such installations include low energy performance and low heating intensity. Low-frequency induction heating is quite effective for direct heating of massive metal workpieces and a certain ratio between their size and the depth of current penetration.

Inductors of high - frequency installations are made uninsulated, they consist of two main parts-an inductive wire, which creates an alternating magnetic field, and current leads for connecting the inductive wire to an electrical energy source.

The design of the inductor can be very diverse. Flat inductors are used for heating flat surfaces, cylindrical workpieces - cylindrical (solenoid) inductors, etc. Inductors can have a complex shape due to the need to concentrate electromagnetic energy in the right direction, supply cooling and quenching water.

To create high-voltage fields, large currents are passed through the inductors, calculated in hundreds and thousands of amperes. In order to reduce losses, inductors are manufactured with the lowest possible active resistance. Despite this, they are still intensively heated both by their own current and by heat transfer from the workpieces, so they are equipped with forced cooling. Inductors are usually made of copper tubes of round or rectangular cross-section, inside which running water is passed for cooling.

7.5 Energy relations of the inductor – product system

Specific surface power. The electromagnetic wave emitted by the inductor falls on the metal body and, being absorbed in it, causes heating. The power of the energy flow flowing through a unit of the body surface is determined by the formula (7.1)

$$\Delta P = \frac{1}{2} \cdot \frac{k}{\sigma} H_0^2 e^{-2kz}, \qquad (7.1)$$

The specific power on the surface of the body can be obtained by substituting, in the given expression z = 0; $\frac{1}{\sigma} = \rho$ and the value of k from the formula

$$z_a = \frac{1}{k} = \sqrt{\frac{2}{\omega\mu_a\sigma}} \qquad (7.2)$$

with the expression

$$z_a = 503\sqrt{\frac{\rho}{\mu f}}.$$

After conversion, we get (W/m^2)

$$\Delta P \approx 10^{-3} H_0^2 \sqrt{\rho\mu f}, \qquad (7.3)$$

In practical calculations, the dimension D P in W/cm^2 is used, then

$$\Delta P \approx 10^{-4} H_0^2 \sqrt{\rho\mu f},$$

where H_0 is in A/cm; r is in Ohms×cm. The value $\sqrt{\rho\mu f}$ is called the power absorption coefficient.

We Express D P in terms of the ampere turns of the inductor. With a known approximation the magnetic field strength H0 can be represented as the product of the effective value of the inductor current I and the number of turns w 0 per 1 cm of its height:

$$H_0 = \sqrt{2} I \omega_0, \qquad (7.4)$$

Substituting the obtained value H_0 in the formula (7.4), we get

$$\Delta P \approx 2 \cdot 10^{-4} (I\omega_0)^2 \sqrt{\rho\mu f}. \qquad (7.5)$$

Thus, the power released in the product is proportional to the square of the ampere turns of the inductor and the power absorption coefficient. When the magnetic field strength is constant, the greater the heating intensity, the greater the resistivity r , the magnetic permeability of the material m, and the frequency of the current f.

The formula (7.5) is valid for a plane electromagnetic wave. When cylindrical bodies are heated in solenoid inductors, the wave propagation pattern becomes more complicated. Deviations from the relations for a plane wave are greater the smaller the ratio r/z a, where r is the radius of the cylinder, and z a is the depth of current penetration.

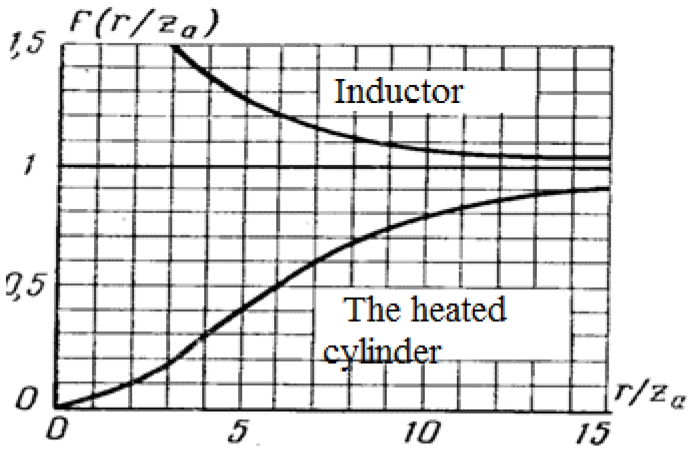

Figure 7.5 - Birch Functions for calculating the power at the surface of the inductor released in the heating cylinder and the inductor

In practical calculations, however, they use a simple dependence (7.5), introducing correction coefficients - birch functions that depend on the r/z ratio (Figure 7.5). Then

$$\Delta P \approx 2 \cdot 10^{-4} (I\omega_0)^2 \sqrt{\rho\mu f}\, F(r / z_a), \tag{7.6}$$

Efficiency of induction heating. With a known approximation, we can assume that the magnetic field strength at the surface of the workpiece and the inductor conductors is the same (in fact, it is higher). Under this assumption, the active power released in the inductor (loss power) can be determined by a formula similar to (7.6). Denoting the values related to the product and the inductor, respectively, by the indices "a" and "I", we have

$$\Delta P_a \approx 2 \cdot 10^{-4} (I\omega_0)^2 \sqrt{\rho_a \mu_a f}\, F_a(r_a / z_a), \tag{7.7}$$

$$\Delta P_и \approx 2 \cdot 10^{-4} (I\omega_0)^2 \sqrt{\rho_и \mu_и f}\, F_и(r_и / z_a). \tag{7.8}$$

Taking the height of the product and the inductor to be the same, we take the ratio of the total powers R_A and R_i, which are proportional in this case to the radii r_a and $r_и$, where $r_и$ is the inner radius of the cylindrical inductor:

$$\frac{P_a}{P_и} = \frac{r_a \sqrt{\rho_a \mu_a}\, F_a(r_a / z_a)}{r_и \sqrt{\rho_и}\, F_и(r_и / z_a)}. \tag{7.9}$$

The formula (7.9) is valid for a solid inductor without gaps between turns. If there are gaps, losses in the inductor increase. As the frequency increases, the functions $F_a(r_a, z_a)$ and $F_и(r_и, z_a)$ tend to unity, and the power ratio - to the limit

$$\lim\left(\frac{P_a}{P_u}\right)_{f\to\infty} = \frac{r_a}{r_u}\sqrt{\frac{\rho_a\mu_a}{\rho_u}} \quad . \qquad (7.10)$$

The formula allows you to get the maximum efficiency value. induction heating for solenoid inductor and cylinder

$$\eta_{max} = \frac{1}{1+\frac{r_u}{r_a}\sqrt{\frac{\rho_u}{\rho_a\mu_a}}} \quad . \qquad (7.11)$$

It follows from the expression (7.11) that the efficiency decreases with increasing air gap and resistivity of the inductor material. Therefore, inductors are made of massive copper tubes or tires. As follows from expression (7.10), the efficiency value is approaching its limit already at r/za>5=10. This allows you to find a frequency that provides a sufficiently high efficiency. Using the above inequality and the formula (7.11) for the penetration depth za, we obtain

$$f > (0{,}6 \div 2{,}5)10^7 \frac{\rho}{\mu r^2} \quad .$$

Power factor of the inductor. The power factor of the heating inductor is determined by the ratio of the active and inductive resistances of the inductor - product system. At high frequency, the active and internal inductive resistances of the product are equal, since the phase angle between $\overline{E}$ the $\overline{H}$ vectors and is 45° and |D P| = |D Q|. Therefore, the maximum value of the power factor is

$$\cos\varphi = \frac{\Delta P}{\sqrt{\Delta P^2 + \Delta Q^2}} = \frac{1}{\sqrt{2}} = 0{,}707 \quad .$$

However, the internal inductance of the product is added to the inductance due to the presence of a magnetic flux in the air gap between the inductor and the product. Therefore the actual value of cos j is always less than 0.707 and when heated with high frequencies is calculated by the formula

$$\cos\varphi = \frac{\mu z_a}{\sqrt{2a}} = \frac{503\sqrt{\rho\mu}}{\sqrt{2a}\sqrt{f}} \quad ,$$

where *a*- is the air gap between the inductor and the product, m.

Thus, the power factor depends on the electrical properties of the product material, air gap, and frequency. As the air gap increases, the scattering inductance increases and the power factor decreases.

The power factor is inversely proportional to the square root of the frequency, so an unjustified overestimation of the frequency reduces the power indicators of installations. You should always try to reduce the air gap, but there is a limit due to the breakdown tension of the air. During the heating process, the power factor does not remain constant, since r and m (for ferromagnets) change with temperature changes. In real conditions, the power factor of induction heating installations rarely exceeds the value of 0.3, decreasing to 0.1-0.01. Compensating capacitors are usually included in parallel to the inductor to unload the networks and the generator from reactive currents and increase the socf.

7.6 Modes and optimal frequency of high-frequency induction heating

The main parameters that characterize the modes of induction heating are the current frequency and efficiency. Depending on the applied frequencies, there are two modes of induction heating: deep heating and surface heating.

Deep heating ("low frequencies") is performed at a frequency f when the penetration depth za is approximately equal to the thickness of the heated (quenched) layer XC (figure 7.6, a). Heating occurs immediately to the entire depth of the XC layer. the heating rate is chosen so that the heat transfer by thermal conductivity to the depth of the body is insignificant.

Since in this mode the penetration depth of the currents za is relatively large (z_a), then, according to the formula:

$$z_a = 503\sqrt{\frac{\rho}{\mu f}}$$

the frequency of the inductor current should be relatively low ("small"). Heating the entire HC layer at once requires a relatively large generator power. This mode is appropriate for in-line production in conditions of high equipment load.

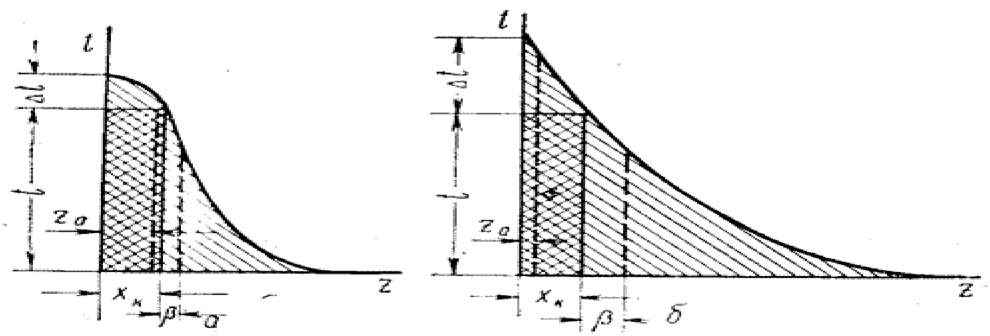

Figure 7.6- Temperature distribution from the surface to the depth of the body under deep (a) and surface (b) induction heating

Surface heating ("high frequencies") is carried out at relatively high frequencies. In this case, the depth of penetration of mA currents is significantly less than the thickness of the heated layer XC (figure 7.6 b). Heating for the entire thickness of the HC is due to the thermal conductivity of the metal.

When heating in this mode, less generator power is required (in figure 7.6, the net power is proportional to the shaded areas with double hatching), but the heating time and specific power consumption increase. The latter is due to heating due to the thermal conductivity of the deep metal layers. the heating efficiency is proportional to the ratio of the areas with double hatching to the entire area bounded by the t curve and the coordinate axes, in the second case it is lower.

However, it should be noted that heating to a certain temperature of the metal layer thickness b , which lies behind the quenching layer and is called the transition layer, is absolutely necessary for a reliable connection of the quenched layer with the base metal. With surface heating, this layer is thicker and the connection is more reliable.

With a significant decrease in frequency, heating becomes generally impracticable, since the penetration depth will be very large and the energy absorption in the product is insignificant.

Both deep and surface heating can be performed by induction. With external heat sources (plasma heating, in electric resistance furnaces), deep heating is not possible.

According to the principle of operation, there are two types of induction heating: simultaneous and continuous-sequential.

When simultaneously heated, the area of the inductive wire facing the heated surface of the product is approximately equal to the area of this surface, which allows you to simultaneously heat all its sections. During continuous-sequential heating, the product moves relative to the inductor wire, and heating of its individual sections occurs as the working area of the inductor passes.

Frequency selection. A sufficiently high efficiency. it can be obtained only at a certain ratio between the size of the body and the frequency of the current. The choice of the optimal current frequency was mentioned above. In the practice of induction heating, the frequency is chosen based on empirical dependencies.

When heating parts for surface hardening to a depth of x_k (mm), the optimal frequency (Hz) is found from the following dependencies: for simple-shaped parts (flat surfaces, bodies of rotation)

$$f = \frac{5 \cdot 10^4}{x_k^2},$$

for complex shape parts

$$f = \frac{5 \cdot 10^5}{x_k^2}.$$

When end-to-end heating of steel cylindrical billets with a diameter of d (mm), the required frequency is determined by the formula

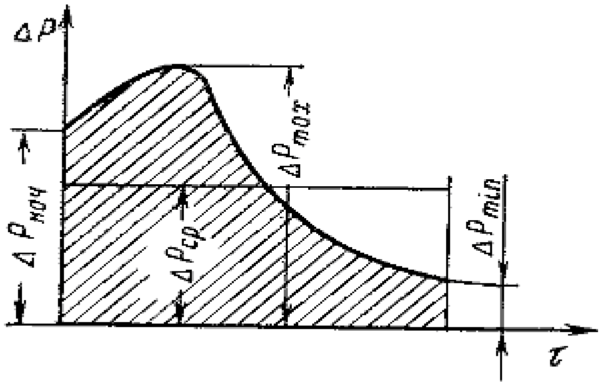

Figure 7.7 - Change in the specific power released in steel, in the process of heating for quenching

During heating, the resistivity of metals r increases. In ferromagnets (iron, Nickel, cobalt, etc.), the magnetic permeability value m decreases with increasing temperature . When the Curie point is reached, the magnetic permeability of ferromagnets drops to 1, meaning that they lose their magnetic properties.

The usual heating temperature for quenching is 800-1000° C, under pressure treatment 1000 - 1200° C, that is, above the Curie point. A change in the physical properties of metals with a change in temperature leads to a change in the power absorption coefficient and the specific surface power entering the product during heating (figure 7.7). At the beginning, due to an increase in r, the specific power of D P increases and reaches the maximum value of D Pmax= (1,2÷1,5) D Pmach, and then, due to the loss of magnetic properties of steel, it falls to the minimum D Pmin. To maintain heating in an optimal mode (with a sufficiently high efficiency), the installations are equipped with devices for matching the parameters of the generator and the load, that is, the ability to regulate the heating mode.

If we compare the through heating of workpieces under plastic deformation by induction method and electric contact method (both refer to direct heating), we can say that electric contact heating is appropriate for long workpieces of relatively small cross - section, and induction-for short-sized workpieces of relatively large diameters.

7.7 Induction heat treatment as a technical system

When considering induction heat treatment, we came to the conclusion that this technical system is hierarchical and complex.

Consisting of many components that perform a common task: the object (part or billet) that is subjected to induction heat treatment, and the technology of this exposure and equipment for its implementation (Figure 7.8).

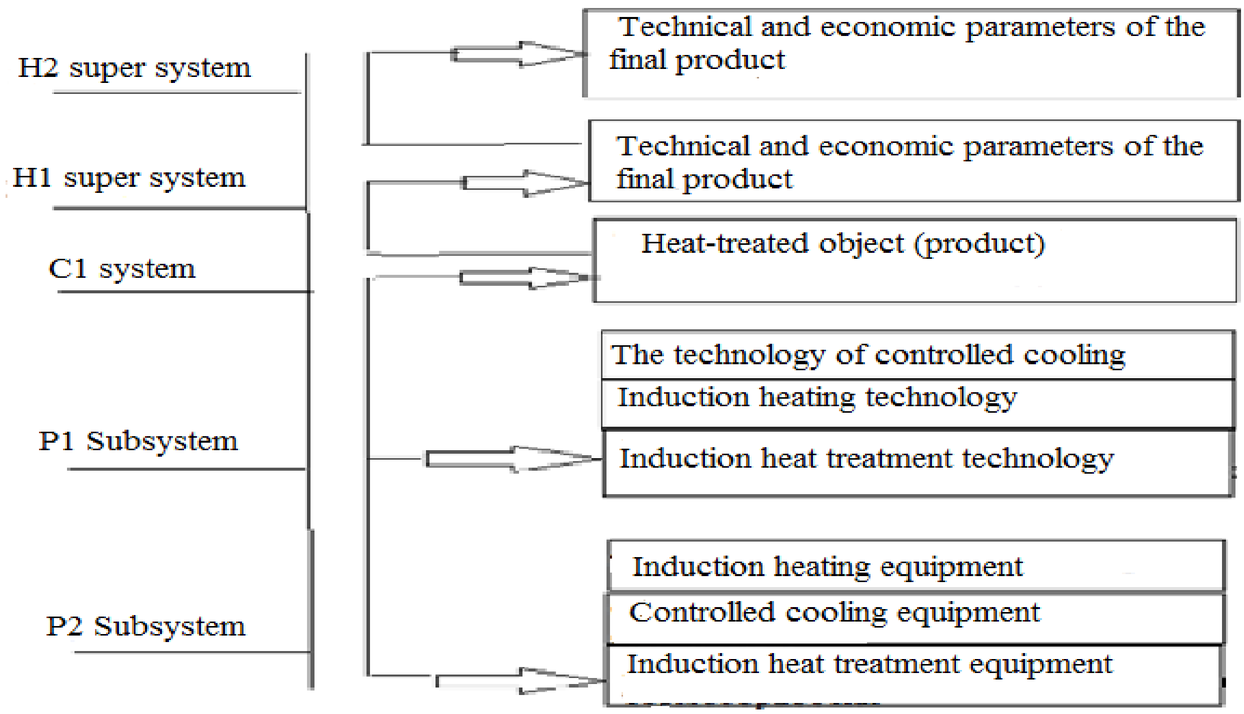

Figure 7.8 - Space-time diagram of the technical system "induction heat treatment»

The figure shows that the actual heat-treated object (part, billet, semi-finished product, metal) is hierarchically subordinate to the H1 and H2 super-systems. Moreover, this subordination determines the determining role of the requirements of the H2 super-system as the final product of the main technology for obtaining products (H1 super-system).To meet the requirements of the super-systems H1 and H2 in the considered technical system has to use the subsystem P1 (process) and P2 (induction equipment), and P1 is the dominant subsystem, and the subsystem P2 – driven or Executive.

To manage subsystems P1 and P2, you must use a control and monitoring system.

For the P1 subsystem in machine-building production, the following options are possible:

-heating for subsequent operations related to changing the shape;

-heating followed by controlled cooling associated with changes in structure and properties.

The P1 subsystem characterizes the technology. Induction heat treatment technology is a complex technical system of a temporary type with a set of parameters that are characterized by two components – dynamism and unevenness.

Figure 7.9 shows the parameters that are used in the development and implementation of induction heat treatment technologies.

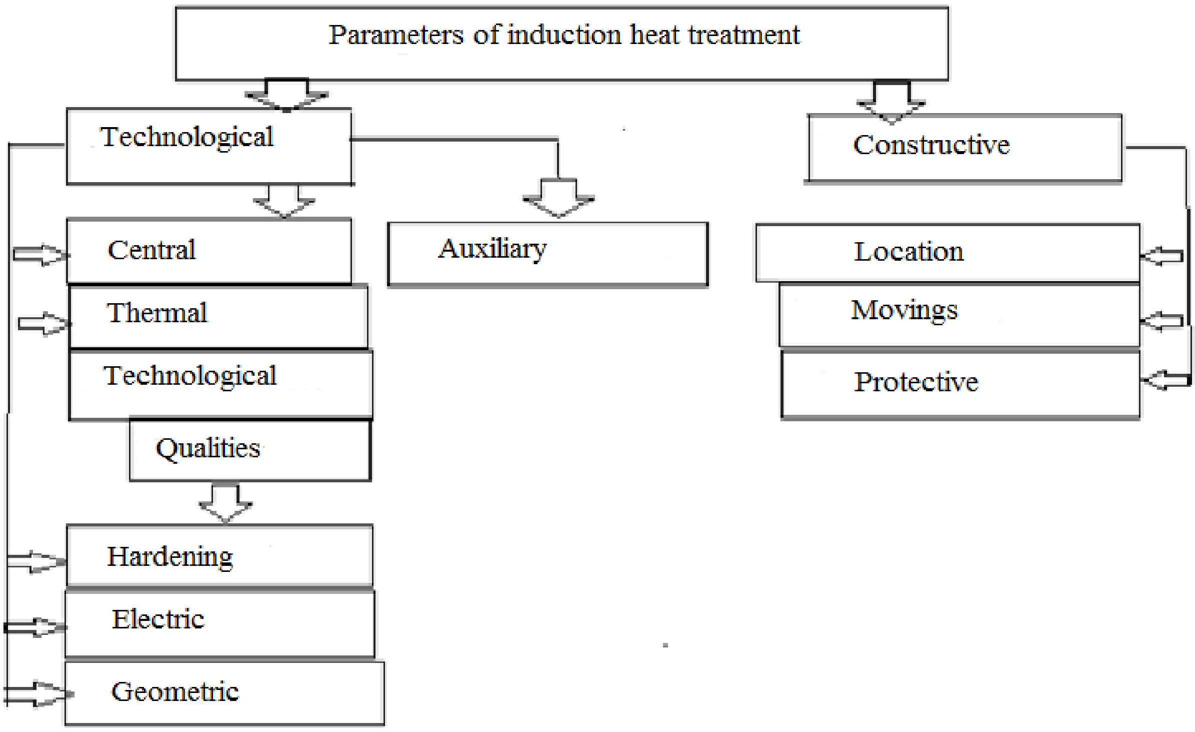

Figure 7.9 - Parameters of induction heat Treatment technologies used in mechanical engineering

These parameters can be divided into two large groups – technological, which are associated with the operation of induction heat treatment, and structural, which depend on the design features of the equipment used. At the same time, technological parameters are the main ones and are subject to mandatory presence, control and management.

The following process parameters are subject to control:

- thermal - heating temperature, self-starting temperature, heating speed, etc.;
- quenching - temperature of the quenching medium, duration and intensity of cooling – time, pressure and flow of the quenching medium;
- electrical – current, voltage, power, cosφ, etc.

The following quality parameters are subject to control on the finished product:

- thermal - surface hardness, location of the quenching zone, depth of the quenched structure and microstructure, etc.;
- geometric – the amount of deformation and warping during heat treatment.

Selecting and optimizing the values of technological and design parameters is an important task that determines the final quality of the product.

Subsystem P2 characterizes the induction equipment and its parameters that meet the requirements of the technological process – subsystem P1.All induction equipment in mechanical engineering can be divided into two large groups: induction heat treatment equipment and induction heating equipment.

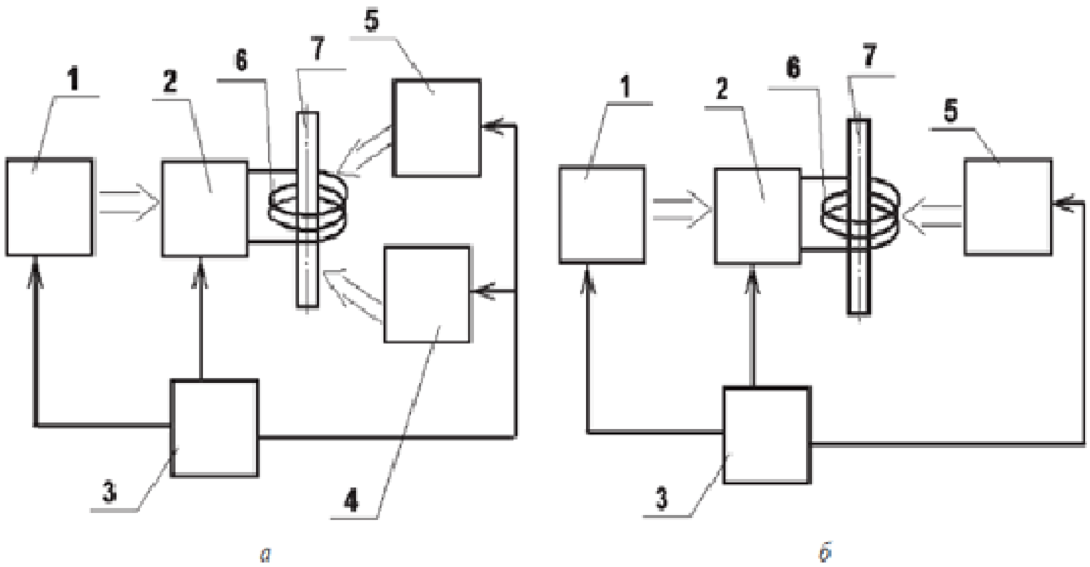

Figure 7.10- Block diagram of induction equipment for heat treatment a - for heat treatment, b - for heating: 1 - power supply, 2 - approval unit, 3 - control control system, 4 - cooling system,5 – mechanization system, 6 – inductor, 7 – heated part

Figure 7.10 shows a block diagram of both types of induction equipment. As can be seen from the figure, despite the variety of types of induction heating, heated products and surfaces, the composition of induction equipment has several main components or blocks. The correct choice and design of these units ensure the required quality of the technological operation.

Power supply. The power source in induction equipment is various types of frequency converters that convert 3-phase current of industrial frequency and voltage into a single-phase of the required frequency and voltage.

Currently, there are three types of frequency converters: machine, tube, and semiconductor (thyristor or transistor). Within each type, there are a large number of different models of frequency converters that can, if chosen correctly, meet the requirements of induction technology with an almost unlimited variety of its types. The main characteristics of any Converter are power and frequency.

Frequency is an important parameter of induction technology, since it determines the depth of current penetration into the metal and, as a result, the depth and geometry of the heated layer, which can range from fractions of a millimeter on the surface to the full size of the workpiece. The power required for a particular induction heating process depends on the volume of the metal being heated, the degree of heating, and the heating method.

In modern conditions, to create highly efficient induction equipment and technology, the type and design of the Converter, in addition to matching the power and frequency, must meet a number of additional requirements, among which the energy conversion efficiency, the level of control, repeatability and controllability of the process, reliability and durability should be highlighted.

When selecting a frequency Converter, the level of control, repeatability, and process control must be determined by the parameters to be controlled and their level of control. First of all, the Converter must provide control and management of electrical induction parameters of its operation. These settings include the current and the voltage value and the deviation from the nominal value (change) of frequency, real power Converter.

These parameters can be monitored or registered in several ways.

1. Arrow or digital display on control and measuring devices without registration and archiving. This method is the most effective it is easy to do, but it is difficult to control when there were deviations from the parameters set in the technology.

2. Indication on control and measuring devices with registration and archiving. This method ensures high quality and repeatability of results, and allows you to quickly respond to a violation of the technology.

3. Display on control and measuring devices with registration, archiving and adjustment of controlled parameters by comparison with the reference value. This method provides the highest quality of the operation, allowing you to quickly adjust parameters or reject parts. Thus, it is possible to formulate the main requirements for HDTV sources (converters) used as part of induction equipment:

1) the Converter is selected and must meet the requirements of the technological process in terms of power and frequency;

2) the Converter must have a high power conversion efficiency to ensure efficient technical and economic performance process indicators;

3) the Converter must have a monitoring and control system that provides control of output parameters, control of its own (internal) parameters, diagnostics of errors and deviations, and has the ability to adjust and reconfigure.

The matching unit. The main indicators of the induction equipment matching unit are the level and changeover time. These indicators are important for most induction heating installations where various types of parts or workpieces are processed. The main elements of the matching unit are a matching or step-down transformer and a capacitor Bank or capacitors. The main parameter of the matching transformer is the value of the K_{TR} transformation coefficient, which should change with an interval of no more than 2 units. For example, the matching transformer TK7 has the following values K_{TR}.: 12, 14, 16, 18, 20, 22, 24, 26.

The amount and size of the capacitance in the capacitor Bank must also change. For this purpose, special so-called tuning capacitors are used, which allow you to change the capacitance value within small limits. For specialized induction equipment, where one part or one surface is processed, the readjustment indicator is not relevant. The parameters of the matching transformer and capacitors are calculated or selected once and cannot be changed during operation. Thus, it is possible to formulate the main requirement for the approval block – readjustment in a wide range to ensure heat treatment of a wide range of parts or products.

Quenching cooling system. The main quality indicator of the quenching cooling system should be the constant parameters of its operation over a long period of time. In other words, the quenching medium must be applied to the quenched part at a constant temperature, at the same speed, and in the same quantity. Compliance with these requirements ensures stable quenching quality indicators – surface hardness and depth of the quenched layer with an accuracy of no more than ±2%. Temperature constancy must be ensured by the presence of a separate container with equipment for "draining–topping" and (or) "heating–cooling" of the cooling medium, the constancy of the cooling rate – by using a separate pump in the cooling system, which provides a constant pressure in the pipelines cooling medium – by applying a time–dosed on-off supply of the cooling medium.

Thus, the main characteristic of the quenching cooling system is to ensure the stability of the temperature, quantity and time of the quenching medium supply to the workpiece.

7.8 Technological process of metal heating

7.8.1 Inductors for heating external cylindrical surfaces

Induction heating of metal products is carried out using a special device called an inductor. The simplest type of inductor is an annular coil bent from a copper busbar or tube. When an alternating current is passed through an inductor, a magnetic field occurs around its wire, the strength of which periodically changes in time and direction.

The magnetic field strength, and hence the magnetic flux density - induction - will be greatest inside the coil of the inductor near the wire.

If you put a metal cylinder inside the inductor, the alternating magnetic flux that permeates this cylinder will cause an induced current to appear in it. The induced current due to the proximity effect will be concentrated under the inductor wire, and its path will have a ring shape. The higher the frequency of the current, the thinner the current flows in the cylinder, i.e. the stronger the surface effect is.

The current induced in the surface layers of the cylinder causes it to heat, and the surface temperature and heating depth depend on the power supplied to the inductor, the frequency and time of heating. On the other hand, the width of the heating band, its shape, and the uniformity of surface heating depend on the shape of the inductor.

Thus, with the help of an inductor, electromagnetic energy, and therefore the release of heat, is concentrated in a given area. The induced current is concentrated in a band whose width is close to the width of the inductor. Accordingly, the width of the heated strip also differs little from the width of the inductor. Surface heating of metal by high-frequency induced currents is used for surface hardening of steel parts.

The main part of the inductor is the inductor wire, the design of which largely determines the result of quenching. The other parts are auxiliary in nature, and their construction is usually not difficult. Inductors can be divided into two groups: inductors for quenching at medium (1000 - 10,000 Hz) frequencies; inductors for quenching at high frequencies (radio frequencies). There is no fundamental difference between the two groups. However, there is often a difference in the design, due to the fact that at high frequencies, the operation of the inductor occurs at lower specific powers and, most significantly, at lower currents, since the active resistance of the heated object increases with increasing frequency. With equal power, the voltage on the inductor in this case is much higher than when operating at medium frequencies.

An essential point in the design of the inductor is the choice of the width of the inductor wire and the gap between its internal working surface and the surface of the heated product. The width of the inductive wire with simultaneous heating method is determined by the required width of the quenched layer. There are two possible cases: a certain area on the surface of a long part is tempered; the entire side surface of the part is tempered. In the first case, the width of the hardened strip is determined by the distribution of the induced current on the surface of the part and the heat leakage in the axial direction. Usually, inductors for simultaneous heating have a relatively large width, several times greater than the gap between the surface of the part and the inducting wire. In these cases, the induced current is concentrated in a band whose width is close to the width of the inductor. Usually, the width of the hardened strip is 10-20% less than the width of the inductor, which should be guided when choosing the width of the inductor wire.

If the width of the inductor is less than ten gaps, the hardened layer in the longitudinal section becomes Crescent-shaped.

7.9 Development of a frequency Converter based on JGBT transistors modules with single-phase power supply

Frequency converters (FC) for induction heating of metal consist of IGBT or MOSFET transistor modules connected in a specific configuration with control drivers. At the same time, they are protected against short-circuit currents, overloads and over-temperature protection.

Currently, the use of *FC* for induction heating of metal in the industry of Kazakhstan is practically absent, since the unit cost of existing foreign analogues is very high, so their mass introduction is unprofitable. You should develop your own technologies with low cost, high efficiency, low weight and dimensions.

Frequency converters can be used in the following technologies:

- for induction heating of metals for the purpose of stamping,
- for melting metals in induction melting crucible furnaces,
- for induction heating of metals for the purpose of hot bulk quenching,
- for induction heating of oil in pipelines and tanks,
- for induction drying of grain, heating of liquid media, drying of wood and

coatings and obtaining milk powder.

The main objectives and goals are to create a technology for the production of FC, which should: provide the required range of frequency control of the FC, the choice of the minimum number of power transistors, have high efficiency and low prices, the minimum installed capacity of the entire FC or its individual elements with the same set parameters of the heating technology.

Figure 7.11 shows the circuit of the frequency Converter, which consists of input triacs 1, a three-phase rectifier 2 and an inverter 3. The feature of the inverter is that it is made on two transistors. A three-phase rectifier converts AC voltage to DC, and an inverter converts DC current to high-frequency AC voltage.

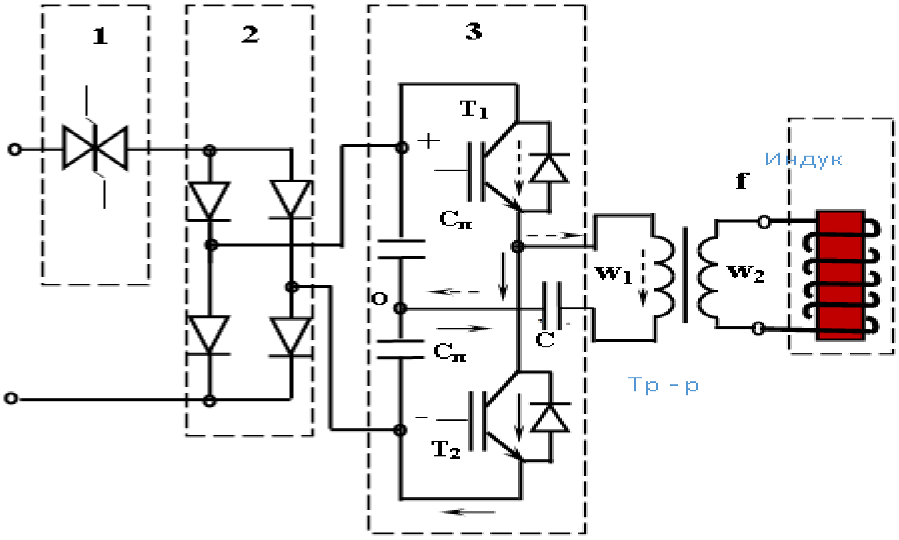

Figure 7.11- Electrical diagram of the frequency Converter of the induction heater with single-phase power supply

The inductor converts high - frequency electrical energy into thermal energy, and the transformer lowers the voltage to the required value. The rectifier and inverter are represented as a frequency Converter. The output transformer is used for matching the parameters of the inductor with the workpiece with the parameters of the high-frequency inverter. At the same time, the weight and size of the transformer is reduced several times.

Output triacs 1 are designed not only for contactless connection of the frequency Converter to the network, but also for regulating the input voltage. The fact is that when using an induction heater, the frequency Converter must be disconnected from the mains every few minutes, since the heated metal (blank) should be removed from the inductor and transferred for stamping.

Next, insert the new blank into the inductor and turn on the frequency Converter in the network. The half-bridge inverter formed by IGBT transistors T_1 and T_2 (figure 7.11) is connected to a DC voltage source, the C_P capacitors (lower and upper) are designed to divide the supply voltage into two equal parts.

Capacitor C in the output circuit of the inverter is designed to improve the quality of the output voltage and to achieve consistent resonance.

Known frequency converters, where transformers are used to lower the voltage. The task is to create a frequency Converter where the number of transistor modules would be minimal, and the step-down transformer would have the lowest weight and size indicators. Figure 7.11 shows the developed electrical circuit of a frequency Converter on two transistors with a single-phase power supply for an induction heater.

To form a negative half – cycle of the step voltage on the load at time t_1 + T/2, where T is the voltage period, transistors T_2 and T_3 are opened and a direct current from the $U_п$ UPS will flow through transistors T_2 and T_3, in the opposite direction.

The frequency Converter consists of an input triac 1, a single-phase rectifier 2 and an inverter 3 on two transistors. The rectifier converts AC voltage to DC, and the inverter converts DC current to high-frequency AC voltage. The inductor converts high-frequency electrical energy into heat, and the high-frequency transformer lowers the voltage to the required value. The rectifier and inverter represent a frequency Converter. The use of a high-frequency transformer reduces the mass and size of the frequency Converter by several times. Output triac 1 is designed for contactless connection of the frequency Converter to the network.

Thus, a negative half-life of the voltage and a step voltage on the load are formed. It should be noted that the frequency of the step voltage on the load is determined by the switching frequency of transistors and can reach tens of kilohertz.

The inverter converts a constant voltage to an alternating voltage of high intermediate frequency $f_п$ (figure 7.11). Next, from time t = 0, opens one of the two thyristors, T-p_1, and the load gets rectified half-wave voltage of predetermined frequency $f_п$, and at time t = T/2 is closed the first thyristor T- p_1.

To generate a negative half-wave of the output voltage from time t = T/2 to t = T opens the second thyristor T- p_2, and the load gets a rectified voltage of high intermediate frequency and at time t = T the thyristor T- p_2 is closed. This creates a negative half-wave of the output voltage. The thyristor control unit will adjust the frequency of the load voltage to the required value in the time interval t = 0 - T.

Thus, the output voltage of a non-transformer inverter has the form of a rectified sine wave consisting of single-period rectified high-frequency voltages, and this frequency of the load voltage will be equal to

$$f = \frac{f_n}{n}, \qquad (7.11)$$

where $f_п$ – intermediate frequency at the output of the inverter, n – the number of rectified periods of intermediate frequency voltage.

As can be seen from the last expression, the formation of a voltage at a given load occurs from rectified high-frequency voltages.

For example, if the intermediate frequency at the output of the inverter is $f_п$ = 20,000 Hz and the number of rectified periods is n = 40, the frequency of the load voltage will be equal to

$$f = \frac{f_n}{n} = \frac{20000}{40} = 500 \text{ Hz}. \qquad (7.12)$$

For a more complete analysis, modeling was performed in the MatLab R12 V. 6.0 environment.this package is designed for solving mathematical calculations of any complexity, for professional analysis and modeling of processes in electrical and electronic circuits, static processing of measurement results and experiments, as well as plotting. Simulink Library Browser and SimPowerSystems were used for modeling.

7.10 Induction heater (IH) for metal products

Induction heating of metal products is carried out using a special device called an inductor. When an alternating current is passed through an inductor, a magnetic field occurs around its wire, the strength of which periodically changes in magnitude and direction over time.

The strength of the magnetic field, and, consequently, the magnetic flux density – induction – will be greatest inside the coil of the inductor near the wire.

If you put a metal cylinder inside the inductor, the alternating magnetic flux that permeates this cylinder will cause an induced current to appear in it. The induced current due to the proximity effect will be concentrated under the inductor wire, and its path will have a ring shape. The higher the frequency of the current, the thinner the current flows in the cylinder, i.e. the stronger the surface effect is.

The main part of the inductor is the inductor wire, the design of which largely determines the result of heating.

Grain temperature can be measured using thermometers. The other parts are auxiliary in nature, and their construction usually does not cause difficulties.

The longer the heating time of each element of the cylinder surface passing under the inductor wire, the greater the width of the wire and the lower the speed of grain movement relative to the inductor. Therefore, the concept of heating time (formula 7.13) of a cylindrical surface is similar to the concept of heating time with a simultaneous heating method.

$$t_к = a/v \qquad (7.13)$$

where $t_к$ – heating time of the cylindrical surface, s; a – width of the inductive wire, cm; v – speed of movement, cm/s.

The current induced in the surface layers of the cylinder causes it to heat, and the surface temperature and heating depth depend on the power supplied to the inductor, the frequency and time of heating. On the other hand, the width of the heating band, its shape, and the uniformity of surface heating depend on the shape of the inductor.

A prototype of a frequency Converter and a 6 kW inductor with a frequency from 2 to 20 kHz when powered from a single or three-phase voltage were developed and manufactured. Experimental studies and tests of a prototype frequency Converter for induction heating of metal in real conditions were carried out.

Figure 7.12 shows the process of induction heating of a metal billet with a diameter of 44 mm and a length of 80 mm. At the beginning of the induction heating process, the metal was not evenly heated, i.e. in the middle of the workpiece, the temperature was lower than at the edges.

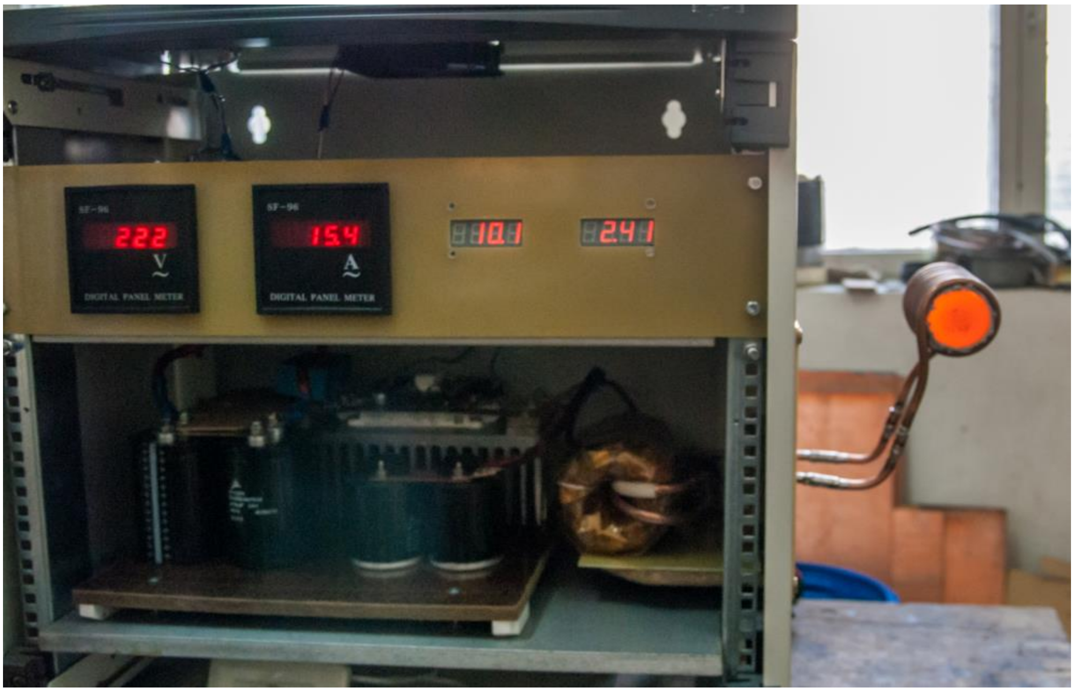

Figure 7.12 – Induction heater during the test period

This meant that the depth of penetration of the electromagnetic wave is not significant, so you should choose a lower current frequency, but this will increase the heating time of the metal. The heating time of the metal by the frequency Converter to a temperature of 600-650 degrees Celsius was 3.5 minutes at a frequency of 8 kHz and 2.41 minutes at a frequency of 10 kHz (figure 7.12). At the same time, the transistors did not overheat, which is required by the operating conditions.

The test results showed that the created induction heater is functional, passed a successful test, and the cooling system of the inductor was working properly. The process of induction heating of metal can be carried out to the desired temperature.

Figure 7.13 – The process of induction heating of metal to a temperature of 731^0C

When developing technical documentation for manufacturing a laboratory sample of a frequency Converter and selecting transistor JGBT modules, the main attention was paid to the topology of the module's power buses and methods for connecting electrical circuits and heat removal. Even with the most advanced chips, the design of powerful key modules is extremely important for ensuring reliability and efficiency. Distributed conductivity characteristics and values of spurious inductances of communication buses and terminals should have a minimum value to reduce losses and reduce the level of transient overvoltages.

Figure 7.14,7.15 shows the voltage waveforms at the output of the inverter without a capacitor in the primary circuit of the transformer.

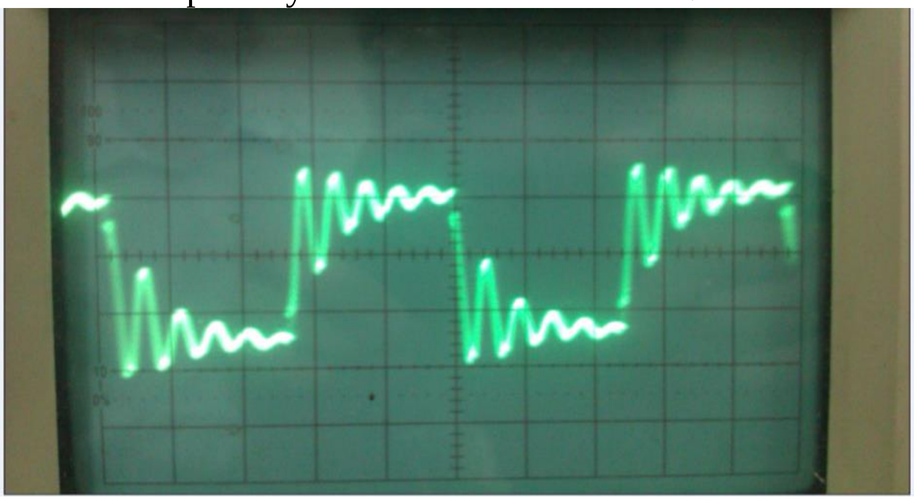

Figure 7.14 – voltage waveform at the inverter output
without a capacitor in the primary circuit of the transformer

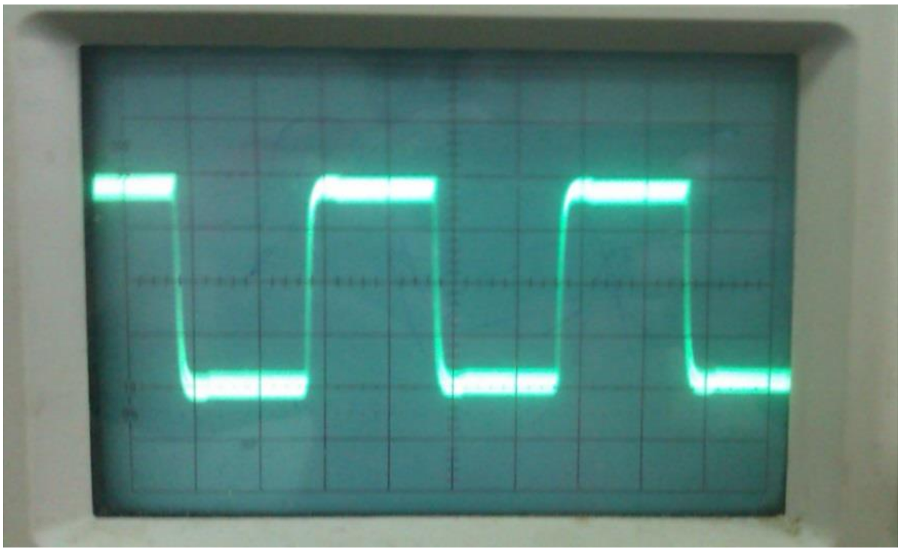

Figure 7.15 – voltage waveform at the inverter output
with a capacitor in the primary circuit of the transformer

As you can see from the graph, the voltage waveform is oscillatory, which means that the transistors are operating in active mode. At the same time, they will heat up and eventually fail. To switch the transistors to the key mode, it is necessary to turn on the capacitor C in series in the output circuit of the inverter, improve the quality of the output voltage and achieve a consistent resonance.

Figure 7.15 shows the voltage waveform at the output of the inverter with a capacitor in the primary circuit of the transformer. As you can see from the graph, the output voltage of the inverter has a rectangular shape, which means that the transistors operate in the key mode, and they will not heat up. In addition, by experimentally selecting the value of the capacitor C, you can not only improve the quality of the output voltage, but also achieve a consistent resonance. In case of resonance, the active power of the inverter will be transferred to the inductor, i.e. to the workpiece for heating.

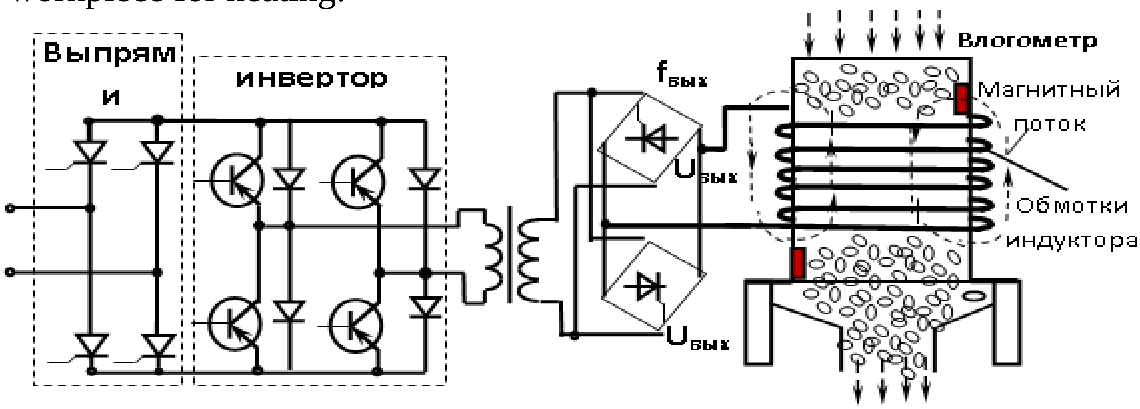

Figure 7.16 Transistor - thyristor frequency Converter with high frequency link for grain drying

The inverter converts a constant voltage to an alternating voltage of high intermediate frequency $f_п$ (figure 7.16). Next, from time t = 0 has T-p_1 of the two thyristor rectifiers, and the load gets rectified full-wave voltage $f_{вых}$ of predetermined frequency foutput, time t = T/2 is closed the first thyristor rectifier T-p_1.

To generate a negative half-wave of the output voltage from time t = T/2 to t = T opens the second thyristor rectifier T-p_2, and the load gets a rectified voltage of high intermediate frequency and at time t = T the second thyristor rectifier T-p_2 closes.

This creates a negative half-wave of the output voltage. The thyristor control unit will adjust the frequency of the load voltage to the set value in the time interval t = 0 - T. The advantage of this scheme is that the output voltage will be twice as high as in the first case (figure 7.15), since the two-half-period voltage rectification circuit.

Figure 7.17 shows a simulation scheme for a transistor – thyristor inverter with a purely active load.

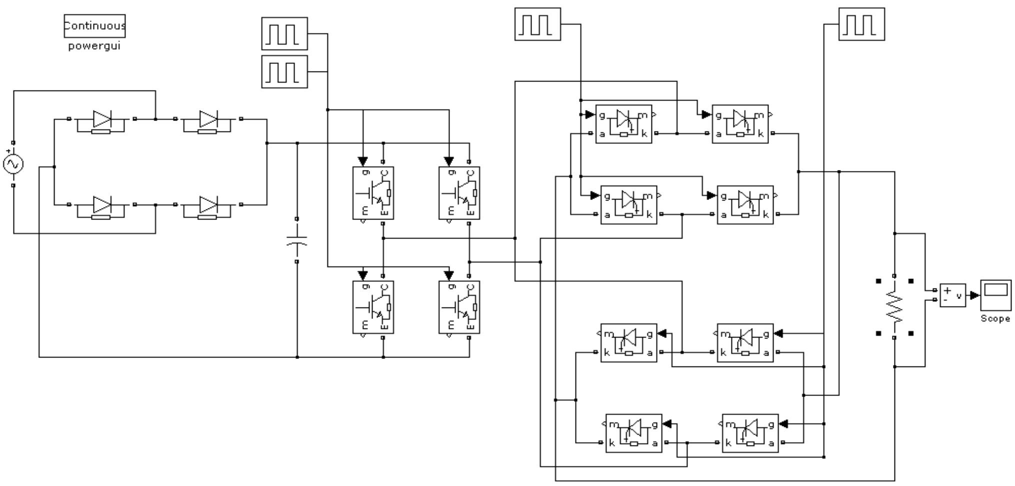

Figure 7.17 – Scheme of the modeling of transistor – Thyristor frequency Converter

An alternating voltage was applied to the input of the frequency Converter. The formation of the voltage form at the input of the inverter is carried out by dividing it into several stages with different voltage levels, and software-controlled switching time. The inverter on transistors was assembled on a bridge circuit. The bridge circuit consists of four transistors (figure 7.17).

The simulation results are shown in figure 7.18 with a net active load. As can be seen from the figure, with a net active load, the voltage and current in the load has a clearly defined graph. The principle of operation of a transistor – thyristor frequency Converter with a two-half-period voltage rectification scheme is confirmed.

At certain points in time, a pair of transistors must be switched at each stage to form a positive and negative half-wave of the sinusoidal voltage. The switching mode of transistors is organized so as to exclude short-circuit of voltage sources.

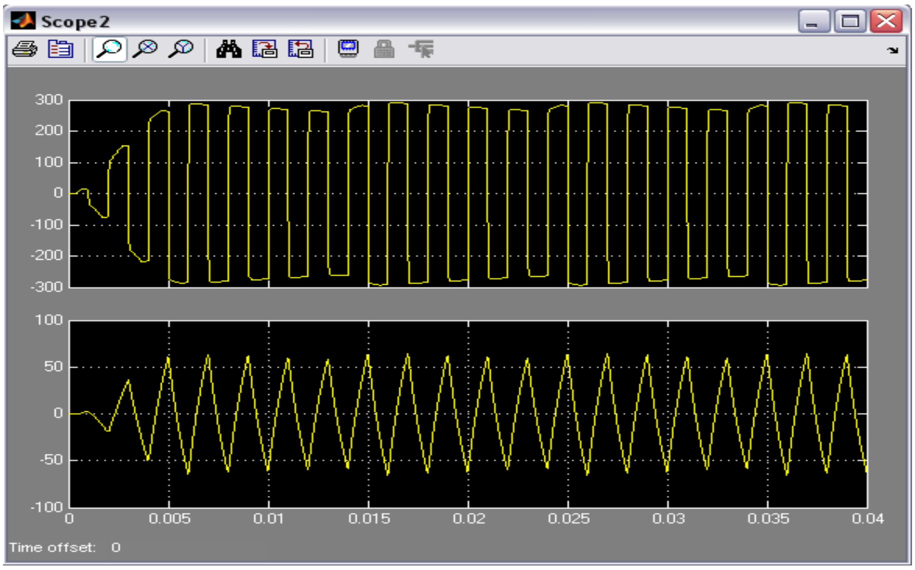

Figure 7.18 – Results of frequency Converter
Simulation under active load

There is experience in developing and manufacturing an experimental sample of a frequency Converter with microprocessor control, which is shown in figure 7.15.

The transistor frequency converters of induction heating will use SKYPER drivers. the task is to convert the low-current logic signal of the controller into a gate control signal, which should have enough power to quickly recharge the IGBT gate capacitances. Since the power switches operate at voltages significantly higher than the controller signal potentials, the gate control device must perform a high-voltage level shift or galvanic isolation of the control pulses and pulses arriving at the gates. In addition, modern SKYPER 52 drivers contain numerous protective and service functions that are necessary for IGBT uptime in all operating modes, including emergency ones.

7.11 Inductors. The design and application

Induction heating installations are widely used in various repair enterprises. Medium and high frequency currents are used for end-to-end heating of parts before hot deformation, when restoring them by surfacing, metallization and soldering methods, as well as for surface hardening of parts and other technological operations. The main element of this type of device is an inductor.

Inductors depending on the purpose and shape of the heated product are: 1) cylindrical; 2) oval; 3) slotted; 4) rod; 5) flat; 6) loop.

Rectangular products are heated in oval, flat and loop inductors. Almost all types of inductors are used for cylindrical parts.

Cylindrical inductors are the most simple in design and reliable in operation, and their overall efficiency is quite high. Structurally, the inductor consists of:

- multi-turn inductive wire made of copper tube or copper busbar;
- conductive tires; - contact pads;
- water supply device, cooling inductor.

In inductors, thermal insulation is used for end-to-end heating of products.

Currently, an inductor of the "multi-turn inductor in a ferromagnetic tube" type is used for low-temperature heating» They are used for heating floors, panels and walls in livestock buildings, for heating the soil and air in greenhouses and greenhouses.

Such a heater is a ferromagnetic tube, inside which there is an inductive single - or multi-core winding made of rods, installation wire or control cable. The ferromagnetic tube is both a receiver of magnetic field energy and a heat generator, serves as a supporting structure and protects the inductor winding from mechanical damage. The alternating magnetic flux f, created by the inductive winding of the heater, induces eddy currents in the ferromagnetic tube, which heat it. In the pipe, 80...85% of the total heat energy is released, in the inductor -15...20%. Due to the series connection of the inductor winding cores, the heater can be connected to the mains voltage. Depending on the material and diameter of the pipes, the air gap between the inductor winding and the pipe, the heater power factor is $cos\varphi = 0{,}88...0{,}92$.

Heaters with an inductor that cover the outside of the heated product are used for heating pipelines, heating water, etc. The heater consists of a ferromagnetic tube (or housing), on the outer surface of which is wound an inductive single - or multi-layer winding made of wire with heat-resistant insulation. Heaters are manufactured in single-phase and three-phase versions. Depending on the technological requirements, the heater can be connected to low or mains voltage.

Transformer-type heaters are also used, which are used for heat supply and hot water supply of livestock, industrial and household premises.

7.12 Power sources for induction and dielectric heating installations

For induction heating, it is customary to distinguish between power sources and installations of low (industrial) 50 Hz, medium (high) (0.15...10)· 03 Hz and high (0.15...100)· 05 Hz frequencies. For dielectric heating, sources and installations of high (3...100)· 06 Hz and ultra-high (0.3...220)· 08 Hz frequencies are used.

In low-frequency induction installations, an AC network with a frequency of 50 Hz is used as a power source. The operation of such installations is characterized by increased reliability due to the lack of additional electric power converters and has a number of distinctive features. Machine and thyristor (static) converters are power sources for induction heating installations with a frequency of up to 10 kHz.

The machine frequency Converter consists of a high-frequency generator and a three-phase drive motor.

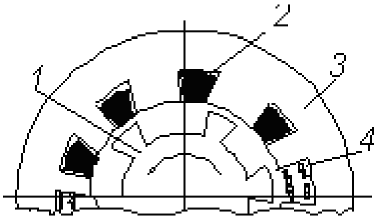

Figure 7.19 - inductive generator circuit: 1 –rotor; 2 –stator winding; 3 –stator; 4 –field winding

The generator belongs to the type of inductor machines. For their excitation, as well as synchronous ones, a direct current is used (figure 7.19). Unlike synchronous machines, in which when the rotor rotates, the field windings and the AC working windings move one relative to the other, in inductor machines, the relationship between the windings occurs due to the rotation of the ferromagnetic mass of the rotor.

The latter has no windings. The shape of the rotor is toothed, similar to the configuration of the rotor of single-pole synchronous machines. The working winding 2 and the field winding 4 are located on the stator 3. when the rotor rotates, its teeth and depressions are alternately installed against the stator groove in which the field winding is located. As a result, the magnetic flux generated by the field winding becomes pulsating and, crossing the turns of the working winding, induces EMF in them with a frequency of:

$$f = \frac{x_2 \cdot n}{60} \qquad (7.44)$$

where f - generator current frequency, Hz; z_2 - number of rotor teeth; n - rotor speed, min^{-1}.

The disadvantages of machine generators are the presence of rotating parts, significant overall dimensions, noise during operation, and relatively low efficiency.

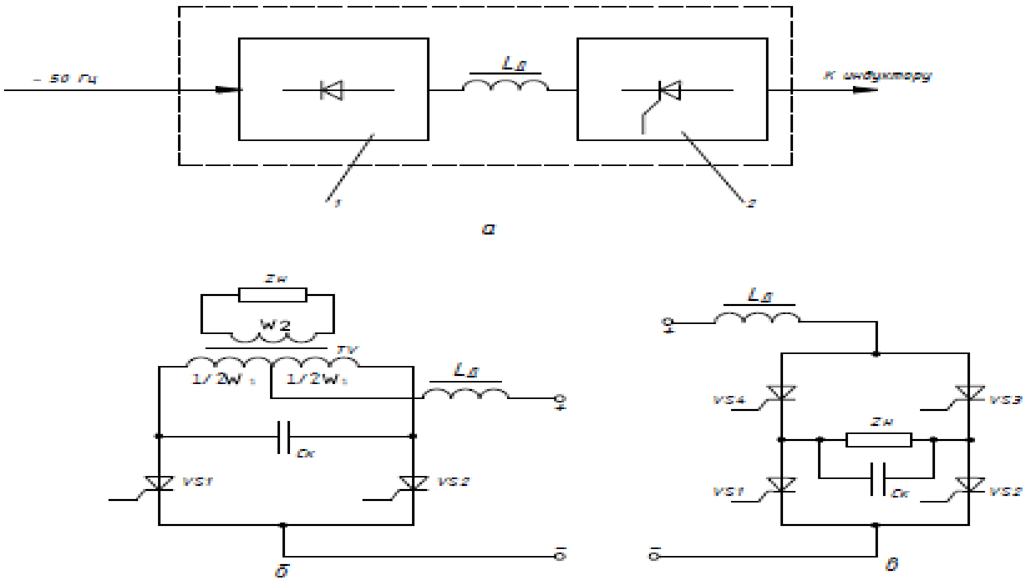

Figure 7.20 - Block diagram of thyristor frequency converters (a), schematic diagram of bridge (b) and zero (c) inverters: 1 –rectifier; 2 –inverter

In static converters, the increased frequency is obtained by switching DC controlled valves (thyristors). Thyristor frequency Converter consists of two main components: rectifier 1 (figure 7.20 a), converting the alternating current of industrial frequency in continuous and Autonomous inverter 2 that converts DC to AC high frequency. The smoothing filter that connects these nodes is often an element of the inverter circuit. By analogy with rectifiers, Autonomous inverters are performed according to the zero and bridge scheme.

The zero circuit (figure 7.20,b) of the inverter includes thyristors VS1 and VS2, a switching capacitor C_K , and a transformer TV. Its primary winding has an output of half the number of turns, and a ZH –inductor load is connected to the secondary. The control electrodes of the VS1 and VS2 thyristors receive pulses from the control circuit with a relative phase shift of 180°. Thyristors, alternately opening, provide recharging of the switching capacitor through the primary winding W_1 of the TV transformer. In this case, an alternating current of a certain frequency occurs in the secondary winding W_2 and the load.

In the bridge diagram (figure 7.20, c), the load ZH is included in the diagonal of the bridge formed by the thyristors VS1...VS4. when opening the thyristors VSI, VS3, the current in the load flows in one direction, and when opening the thyristors VS2, VS4 –in the opposite direction. For commutation of the thyristors used in the capacitor of the C_K.

Thanks to thyristor converters, you can smoothly change the operating frequency, which is necessary to maintain the optimal mode when working on a load with changing parameters. Thyristor converters have higher efficiency and higher reliability compared to machine frequency converters.

For power supply of electrothermal installations of induction heating at high frequencies (from 20...30 kHz) and installations of dielectric heating use lamp generators with self-excitation.

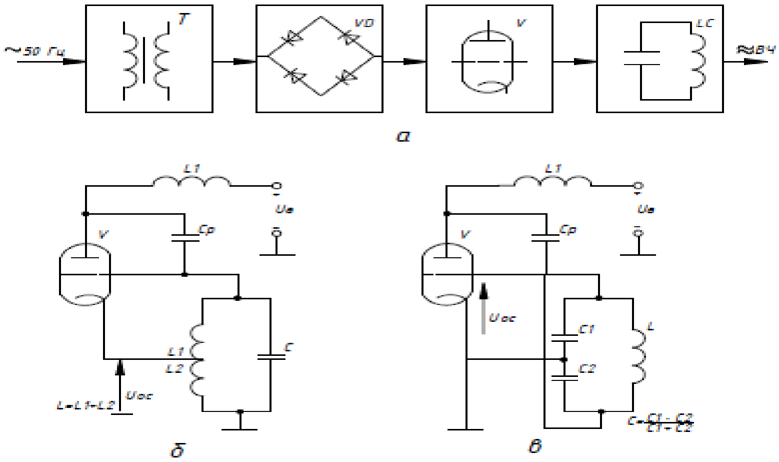

Figure 7.21 - Block diagram (a) and schematic diagrams of a tube generator with autotransformer (b) and capacitive (C) feedback

Block diagram (a) and schematic diagrams of a lamp generator with autotransformer (b) and capacitive (C) feedback the Main elements of lamp generators (figure 4.16, a): a power transformer T that increases the voltage to 6...10 kV; a rectifier unit VD on high-power fans for converting AC to DC with a voltage of 9...15 kV; a generator unit V with one or more generator lamps that converts DC energy into energy of high-frequency energy vibrations; an oscillating circuit LC.

In the circuits of lamp generators with autotransformer (figure 7.21, b) and capacitive (figure 7.21, C) feedback, the electronic lamp V, controlled by the feedback voltage U_{OC}, performs the function of a key that connects the LC circuit at certain times to the power source Ua to compensate for losses in the circuit and turn damped vibrations into non-damped ones. Рабочая частота, Гц, генератора:

$$f = \frac{1}{2\pi\sqrt{l \cdot C}} \tag{4.45}$$

where L - inductance of the loop coil, Hz; C - capacitance of the circuit capacitor, F.

To get the maximum power and high efficiency from the lamp generator, it is necessary to have a well-defined load resistance, i.e., the circuit. Matching the parameters of the circuit and the lamp is that the voltage on the working element of the copier (load) that consumes active energy (inductor or working capacitor) is reduced to the voltage on the generator (meaning alternating anode voltage).

In General, for voltage matching, you can change the parameters of the circuit while maintaining the same resonant frequency, use matching transformers, autotransformer circuit switching, and multi-circuit oscillating systems.

The main task of automatic control of high - frequency installations is to maintain or regulate according to a certain law of power or temperature in the heating process, which allows you to get high quality products and optimal energy and technical and economic indicators. The mode of operation of a high-frequency lamp generator is regulated by changing the voltage of the power source (rectifier, transformer) or the parameters of the anode and working copiers of the lamp generator.

To generate the microwave electromagnetic field, a special generator is used, in which the DC electric energy is converted into the energy of the microwave electromagnetic field. The magnetron is the main microwave generator used in electrothermics.

The magnetron consists of an anode block and a working magnet. In the center of the anode block there is a cathode 4 (figure 7.22, a), surrounded by an anode 1, which is a massive copper cylinder, the inner surface of which forms an even number of symmetrically mixed volume resonators 2, connected to the interelectrode space by a slit gap. According to the principle of operation, a volume resonator is an oscillatory system with concentrated parameters. All resonators are connected to each other, since the magnetic flux of one of them closes through neighboring ones.

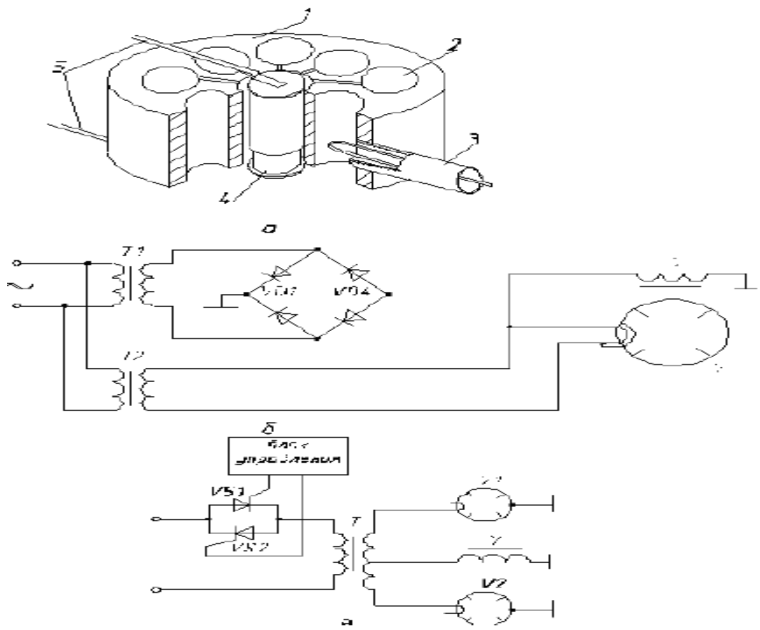

Figure 7.22 - Anode block (a) of a magnetron, schematic diagram (b) of a microwave generator and thyristor control (C) of power: 1 - anode; 2 –volume resonator; 3 –energy output device; 4 –cathode; 5 –cathode circuit

Power sources for magnetron microwave generators can be single - and three-phase. Figure 7.22 b shows the basic electrical diagram of the magnetron power supply, which includes a high-voltage transformer T1, a high-voltage rectifier VD1...VD4, a transformer T2 of the magnetron filament power supply and an electromagnet Y.

To simplify and reduce the cost of electrothermal microwave installations, alternating current is used to power magnetrons. This eliminates the need for rectifiers. Magnetrons are included in the secondary winding of a high-voltage transformer according to the two-period rectification scheme (figure 7.22, c). In this case, each of them runs one half-cycle.

Regulating the power of a microwave power source increases its functionality, and in some technological processes it is simply necessary. Regulation can be discrete (stepwise) or smooth. Step – by-step control is performed by switching the terminals of a high-voltage transformer, and smooth- by using full-water power regulators, as well as thyristor voltage regulators.

In this case, two thyristors VS1 and VS2 are used, connected to each other in parallel and in series with the primary winding of the anode voltage transformer. Depending on the opening angle of the thyristors, the anode voltage of the magnetrons VI and V2 changes. consequently, the generated microwave power. The thyristor control signal is generated by a special unit. Microwave installations are used for heating and drying various agricultural materials, stimulating biological processes, destroying weeds and plant pests, sterilizing agricultural products, treating animals and poultry.

Dielectrics are heated due to dielectric losses. High-frequency heating units with a capacity of up to 60 kW are commercially available, and special units can reach a capacity of 1 MW.

Table 7.1 -Technical data of installations for dielectric heating of various materials

Material	Frequency, MHz	Electric field strength, kV/cm	Specific power, W/cm^3	The duration of treatment
Wood (drying)	0,3…0,75	0,1…1,0	0,003…0,05	8…30 w
Wood (gluing)	5…30	1,5…2,5	Less than 12	15…80 seк
Casting rods (drying)	6…50	_	1…3	2…20 min
Sheet paper (drying)	20…30	0,1…1,0	100…300	5…60 seк
Plastic (roller welding)	40…200	10…50	1000…1500	0,03…02 seк

In dielectric heating installations, the processed material is placed between the coolers of the so-called working capacitor, to which high-frequency energy is supplied from the lamp generator, at f = 500...200,000 kHz.

High-frequency and ultra-high-frequency installations for dielectric heating are used for various types of heat treatment of non-conductive materials (drying of wood, ceramics, fruit, etc., welding of thermoplastic materials, heating of thermosetting materials, gluing plywood, plastics, etc., heating of food products).

8 SPECIAL SECURITY ISSUES

8.1 Electromagnetic safety. Harmful factors of electromagnetic fields

An induction electrothermal installation is a rather complex electrotechnological complex consisting of an inductive coil of a certain shape (inductor), a battery of compensating capacitors, and a power source. This installation is serviced by electrical personnel. From all the variety of dangerous and harmful factors, the characteristics of which are given in GOST 12.0.003-74, in this section, electromagnetic fields are selected, the risk of exposure to which should be assessed at the preliminary stage of plant design. Electromagnetic fields can be harmful factors, but under certain conditions they can also turn into a dangerous factor, as noted in the book [81].

Taking this into account, we have to talk about electromagnetic safety as a system of organizational and technical measures that ensure safety for the population from the negative effects of the electromagnetic field. It can be said that there are still certain problems associated with EMF of induction installations, and the situation in the field of electromagnetic safety is not always satisfactory.

The main reasons for this are listed below:

-high level of external electromagnetic fields from inductors due to high voltage and current;

- use of medium and high frequencies when heating, in which the effect of induced currents in the human body is more pronounced than, for example, at a frequency of 50 or 60 Hz;

-or lack of knowledge about the distribution of the external electromagnetic field in the surrounding space;

- lack of funds to conduct detailed research; lack of funds to purchase materials and manufacture protective equipment; lack of materials that have good magnetic properties and can withstand high temperatures; insufficiently strict rationing;

- specialized calculation programs that take into account a wide variety of physical characteristics, such as the magnetic properties of magnetic circuit materials; lack of funds for the purchase of software and high-speed electronic computers capable of solving three-dimensional problems; organizational shortcomings, such as insufficient attention of managers of enterprises and workshops to existing problems, poor technological development of processes, and others [80].

8.2 Ensuring electromagnetic safety during operation of induction installations

The safety of the test product must be ensured in accordance with GOST 12.2.007.9-93 (IEC 519-1-84), GOST 12.2.007.9.1–95 (IEC 519-3-88), GOST

12.2.007.10–87, GOST R 50014.3–92 (IEC 519-3-88) and other regulatory documents. Electromagnetic safety is ensured by meeting the requirements of SanPiN 2.2.4.1191-03. The main emitters of the electromagnetic field in induction installations are the power sources of the generator and the terminal device (inductor). Depending on the value, different components of the electromagnetic field appear in the power source and inductor. Thus, due to high voltages in the supply part of the generator, the electric field mainly prevails, while large currents supplied to the inductor form a magnetic field.

The task of the inductor is to create an electromagnetic field for the subsequent transfer of magnetic field energy to heat, by means of heating the object with eddy currents. The EMF is formed in such a way that its main concentration is located inside the inductor. On the outside and in the end zones of the coil (inductor) on the path of closing the magnetic flux, there is an external electromagnetic field, which is less intense due to the larger propagation area. It is not useful, and it has to be fought both from the position of electromagnetic compatibility for radiated electromagnetic interference, and from the position of electromagnetic safety. The General principles of protection against harmful and dangerous factors characteristic of induction installations are based on the following:

- the principle of rationing-prevention of exceeding the permissible limits of the impact of the factor in question;
- the principle of justification-prohibition of work under the influence of a factor when the benefit to people and the public is not associated with an increased risk of the alleged negative impact that is caused by this factor;
- the principle of optimization-maintaining the factor at the lowest possible and achievable level, taking into account economic and social opportunities.

8.3 Evaluation of electromagnetic safety of the induction system

The principles of rationing are based on the prevention of dangerous and harmful effects of EMF on humans according to the following two characteristics:

- thermal threshold;
- biological effects that can affect the cardiovascular and Central nervous systems in an unacceptable way.

Normalization of human exposure is made depending on the type of EMF and frequency. At the frequency of electromagnetic radiation of the source up to 10 MHz, the wavelength is more than 30 m, so the service personnel of the induction unit, being in the induction zone, are exposed to as a rule, only one predominant EMF component (magnetic or electric) is affected. In this case, the EMF is normalized separately by the strength of the magnetic and electric fields. The maximum permissible values of the RF EMF parameters, which are not recommended to exceed even for a short time, are determined from the thermal threshold with certain reserve coefficients.

At the same time, time-dependent EMF PDUs are determined based on the permissible absorbed energy (the principle of dosing in the form of energy load or energy exposure, similar to the dose or dose rate for ionizing radiation). As a basis for calculating the limits of professional exposure, a "safety multiplier" is adopted, which is determined mostly from the conditions that guarantee an acceptable risk of diseases from electromagnetic energy absorbed by the human body. In this case, the following factors can be taken into account:

-technically achievable capabilities at this stage of technology development that implement the principle of reducing the electromagnetic field from the equipment "as low as possible". [82]

The main Russian regulatory documents for limiting non -ionizing EMF in relation to the frequency range from 50 Hz to units of megahertz, in which induction installations operate, are GOST 12.1.002-84, GOST 12.1.006-84 and SanPiN 2.2.4.1191-03. At the same time, sanitary and epidemiological rules and regulations of SanPiN 2.2.4.1191-03 "Electromagnetic fields in production conditions", released in 2003, are more detailed than state standards. In they include a range from 10 to 60 kHz, and there are industrial frequency magnetic field intensity control units, which were previously absent.

Table 8.1,8.2 shows limits on the energy exposure, the maximum EMF levels at short-term exposure and remote control, with 8 hour working day for industrial frequency of 50 Hz and the frequency range 10 kHz...10 MHz, operating at the moment in Kazakhstan.

Table 8.1-Remote control for short-term exposure and an 8-hour working day.

current frequency, f	$E_{max}(E_{ПДУ8ч}$ $В/м)$	$ЭЭ_{Eпд,}(В/М^2)*ч$	$H_{max}(H_{ПДУ8ч})А/м$	$ЭЭ_{Hпд},(А/м)^2*ч$
50 Hz	25000*(5000)	-	1600*(80)	-
10….30 kHz	1000*(500)	-	100(50)	-
0,03…3 MHz	500(50)	20000	50(5)	200
3…10 MHz	300(30)	7000	-	-

Table 8.2-Recommendations ICNIRP

current frequency, f	E, B/m	H, A/m	B, мкТл
8…25Hz	20000	$2*10^4/f$	$2,5*10^4/f$
0,025…0,82 kHz	$500/f$	$20/f$	$25/f$
0,82…65 kHz	610	24,4	30,7
0,065…1MHz	610	$1,6/f$	$2/f$
1 …10 MHz	$610/f$	$1,6/f$	$2/f$

8.4 Analysis of dangerous and harmful factors during operation, testing and adjustment of the product

In accordance with GOST 12.0.003-74 (Hazardous and harmful production factors. Classification) the main dangerous and harmful factors (and VF) are physical:

-increased or decreased temperature, excess voltage in the electrical network,

- exceeded the permissible level of electromagnetic radiation,

-the absence or lack of daylight or artificial lighting,

-the noise level is exceeded that may cause fire (very high temperatures, sparks);

- psychological: physical overload (static) and neuropsychic overload.

8.5 O and VPF protection

Installation safety must be ensured in accordance with GOST 12.2.007.9-93 and GOST 12.2.007.9.1-95 Safety of electrothermal equipment (General and specific requirements).

All equipment must be assembled and installed so that it is stable during use in any position that it can be. Handles, working levers, toggle switches and similar devices need to be tightly secured. The movements of the handles and levers must be the same as the direction of the mechanical movements that they report. On boards and control panels must be present light an alert that helps you determine whether the equipment and its components are turned on or off.

8.6 Fire safety

Fire safety of the structure with its elements must be observed in both normal and emergency modes of operation. Reducing the fire hazard of electrical devices and their components is achieved by:

- refusal to use highly flammable materials in the device in accordance with GOST 12.1.04489. Fire safety of the product and its elements must be maintained both in normal and emergency operation modes (short circuit, overload, poor contact, etc.);

- maintaining the mass norm of combustible materials, and replacing them with more heat-resistant ones according to GOST 8865-93;

- reduce the possibility of penetration of combustible materials (substances) from the outside to the fire-hazardous components of electrical products;

- the use of steel cabinets and water-cooled walls, lead to a reduction in the release of hot and (or) hot particles;

- introduction into the installation design of means and elements of electrical protection that reduce the possibility of

fire, in accordance with the standards that are prescribed in GOST12. 1.

004591;

- bringing the value of transient resistances in contact connections to the level that is set in the norms for certain components;
- refusal to use structures that can emit harmful and dangerous combustion products in quantities that pose a danger to human life and health Gorenje;
- the upper limit of the temperature of possible ignition sources and the choice of the operating mode of electrical products that provide conditions for fire and explosion safety of substances and materials in accordance with GOST 12.1.04489;
- use of means and (or) elements that are necessary for automatic shutdown of equipment in emergency mode (overload, overheating, short circuit, etc.) and prevent fire of parts of structures made of electrical insulation materials.

If there is a fire source, fire protection must be provided by the use of fire extinguishing equipment. Fire extinguishing agents are powder fire extinguishers, fire auto fire suppression, the protection of people in case of fire.

The required level of fire safety of the population these systems should not be below 0, 999999 prevent hazards for the calendar year, given each person, the limit of Flammability for people can not be below 10-6 the effects of harmful factors of fire that exceed the possible normalized values and parameters, per year per person. Fires in a laboratory furnace can occur as a result of: strong heating and radiation of the heat of the melt, which can ignite nearby objects made of flammable materials; passing through transformers, chokes and resistors of an electric current exceeding the permissible value; violation of the insulation of connecting wires, breakdown of capacitors, short circuit, resulting in breakdown of parts. The temperature on the surface of the controls that are necessary for performing operations without the use of personal protective equipment for hands and KST, including for performing operations in emergency situations in all cases, should not exceed 40 ° C for controls that are made of any steel, and 45 °C for those made of materials with low thermal conductivity.

To analyze electromagnetic safety from EMF, we used a 3- dimensional induction system for heating thick tape created in the commercial package Ansys multiphysics. The rated current of the inductor is 1200 A, and its frequency is 500 Hz.

8.7 Protection against lightning surges in rural electric networks

In recent years, distribution electric networks (PC) with a voltage of 0.4-10 kV have been equipped with electrical equipment, devices, devices, insulators and wires manufactured on a new modern technical basis.

The operation of such network facilities requires a reliable system of protection against lightning surges using modern technical means. The development of technical means and methods of protection against PC overvoltage is related to the quantitative assessment of lightning parameters and the likely number of thunderstorm damage.

To calculate the density of direct lightning strikes on the ground, information about the intensity of thunderstorm activity is used [85]. It is necessary to take into account the shielding of network objects by buildings, structures, trees, etc. In some cases, shielding can reduce the number of direct hits to network objects by ~ 70%.

Reliable protection is achieved if the equipment and structures have a sufficiently high insulation strength or if effective lightning surge protection devices are installed in the PC [86,87].

To protect a PC with a voltage of 0.4-10 kV from lightning surges, the following devices are used::

- non-linear surge limiters (OPN);

-long-spark arresters (RDI);

- valve arresters (RV) and tubular (RT);

- protective spark gaps (SP). the

Type, number and place of installation of protection devices is selected when designing specific network objects. When installing protection devices, the requirements for the value of the ground resistance are selected according to the PUE [85].

Protection of RU 6-10 kV.

6-10 kV switchgears to which overhead lines are connected must be protected by OPN (or RV) installed on buses or at transformers (figures 8.1 and 8.2) [86,87].

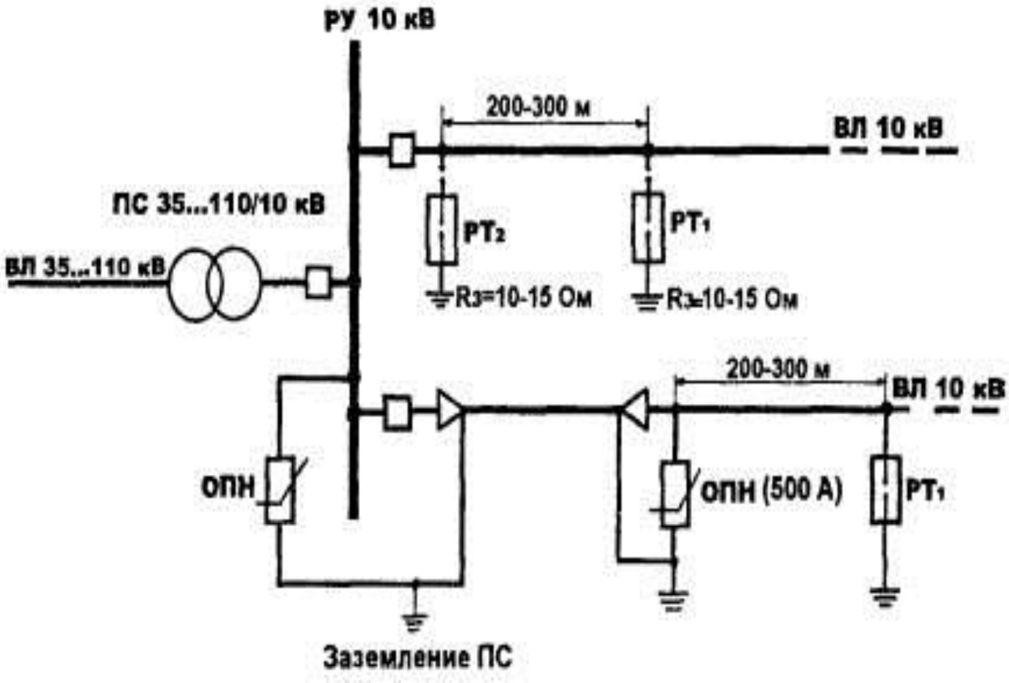

Figure 8.1 - protection of a 10 kV RC FROM incoming thunder waves with a 10 kV overhead line on wooden supports (the overhead line is equipped with an OPN with a discharge rated current of 10 kA and a current of throughput 500 A on a rectangular pulse with a duration of 2000 microseconds)

For main lines with a voltage of 6-10 kV, made in the dimensions of 35 kV overhead lines, it is recommended to use cable lightning rods at the approaches to substations and distribution points.

The problem of protection against lightning overvoltages of overhead lines and substations is very relevant for PC voltage of 0.4-10 kV, since they have a low impulse insulation strength compared to electrical installations of other voltage classes and have a large length.

The causes of lightning overvoltages on overhead lines are direct lightning strikes (PUM) in the line, as well as close strikes to the ground, causing induced (induced) overvoltages on the line wires.

The insulation of substation equipment is affected by lightning surge waves coming from overhead lines when they are struck by lightning, and overvoltage when direct lightning strikes the equipment and structures of substations.

Overvoltages induced on current-carrying parts during lightning strikes in the ground or other objects near the substation are also dangerous for 6-10 kV RC.

When connecting transformers to buses with cables, the distance from the OPN (or RV) installed on the buses to the transformers is not limited.

When installing protection devices (OPN or RV) at all line inputs to the control UNIT with distances to the equipment according to the Instructions [83], under the conditions of protection against lightning overvoltage, protection devices may not be installed on the PS buses.

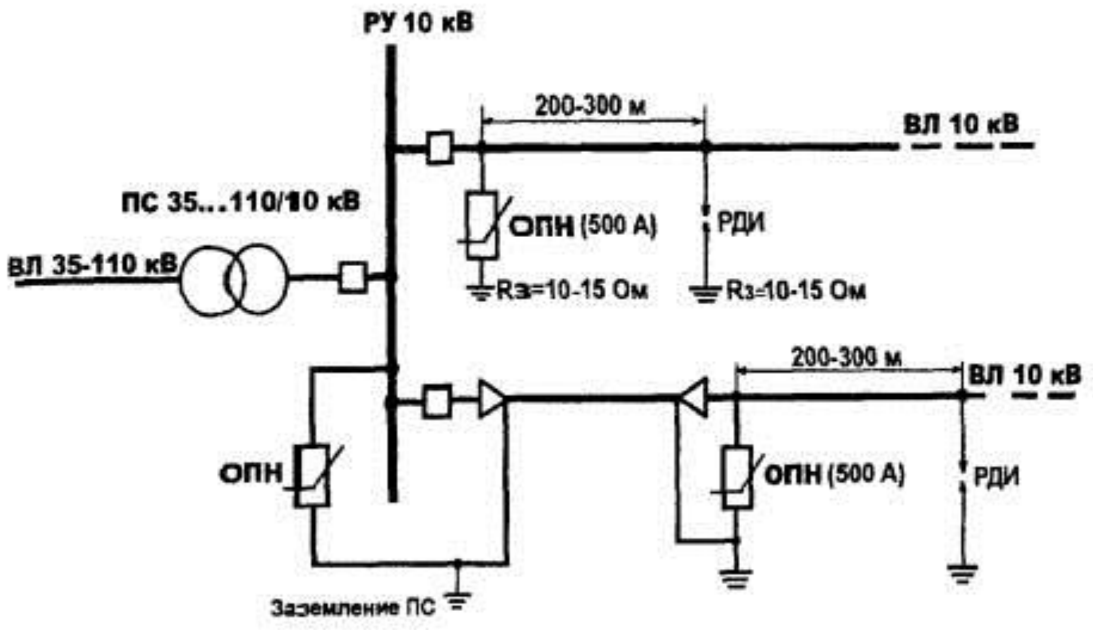

Figure 8.2 - diagram of the lightning protection PN 10 kV outgoing overhead lines on wooden poles (for overhead lines installed surge arresters with a nominal discharge current of 10 kA and a current bandwidth of 500 A, a rectangular pulse of duration 2000 MS and RDI in accordance with section 3.2 of Annex D)

Lightning resistance of overhead lines with a voltage of 0.38-10 kV is significantly increased when using wood insulation on constructed overhead lines with wooden supports, and on overhead lines with reinforced concrete and metal supports (hereinafter referred to as reinforced concrete supports) - when using insulation traverse.

In justified cases, additional protective containers are used.

An overvoltage limiter (or gate arrester) in the same cell with a voltage transformer must be connected to its fuse.

When using air communication of transformers with 6-10 kV RU tires, the distance from the OPN (or RV) to the protected equipment should not exceed 60 m for overhead lines on wooden supports and 90 m for overhead lines on reinforced concrete supports.

TP protection 6-10/0.4 kV.

Protection of TP 6-10/0,4 kV (ZTP, KTP, column (STP) and mast (MTP) substations) is carried out by a set of OPN (or RV).

on MTP and STP, protection devices are installed on supports (support) after or before the disconnector.

On KTP of Cabinet or kiosk design with air input, protection devices are installed on the Cabinet of the high-voltage input device.

On a ZTP with an air input, protection devices are installed on a 6-10 kV bus Assembly (figure 8.3).

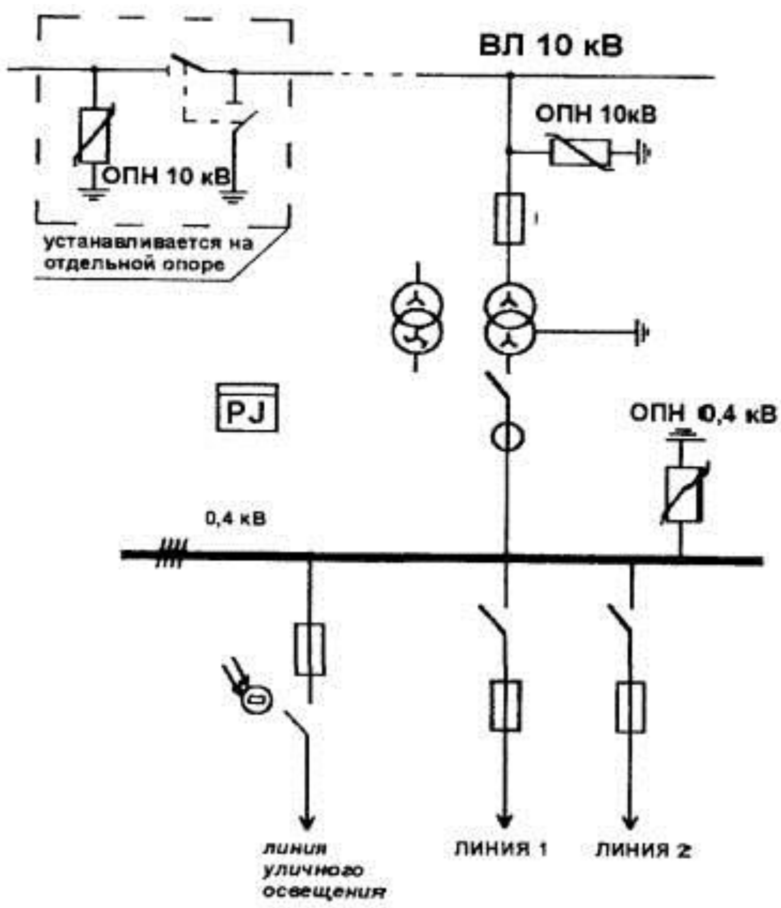

Figure 8.3-Protection scheme of TP 6-10/0.4 kV from exposure lightning overvoltages

Protection of electrical equipment TP 6-10/0,4 kV, directly connected to overhead lines with voltage of 0,38 kV, is achieved by installing on the tire 0.4 kV surge arresters (or RV), and the approaches VL - two protective earthing at a distance of ~ 50 m from the transformer and at the same distance from each other attach them to the neutral wire and the hooks or pins of insulators phase wires. The ground resistance should not exceed 30 ohms. Protection of substations 10/0. 4 kV connected to the overhead line with a voltage of 0.38 kV through a cable insert from overvoltages from the overhead line is carried out by installing an OPN (or RV) on a support with an end cable coupling and approach protection according to [23].

The use of heat-absorbing and heat-reflecting glazing to reduce heat access to the premises from solar radiation, which leads to comfort in the premises.Overhead lines on wooden poles when crossing the cable line ground wire must be attached to the PEN-conductor overhead lines and a metal cable sheath (PEN-an Explorer - a combined zero defensive and zero working Explorer).

Protection of High-Voltage Lines with a voltage of 0.38 kV.

Lightning overvoltages must be protected:

- electrical equipment and devices installed on the supports of high-voltage lines
- branches from the highway to the entrances to buildings;
- Protection of insulation of high-voltage line wires.

Protection of branches from the main line to the entrances to buildings and reduction of the magnitude of lightning overvoltages penetrating into the internal wiring is achieved by diverting the lightning current to the earthing device through a grounding descent mounted on a support with a branch to the consumer input.

High-voltage lines with a voltage of 0.38 kv, passing through a populated area with one and two-story buildings, must have grounding devices designed to protect against lightning overvoltages.

the grounding devices must be connected to the zero wire, hooks or pins of phase wires and wires of all other lines (wired broadcasting, communication, etc.) suspended on wooden and reinforced concrete supports, as well as reinforcement of reinforced concrete supports.

The resistance of the grounding devices of the supports should not exceed 30 ohms. the distance between the supports with grounding devices must not exceed:

- 200 m for areas with an average annual duration of thunderstorms of 40 hours;
- 100 m - for areas with an average annual duration of thunderstorms of more than 40 hours.

Additionally, the grounding devices must be made:

- on supports with branches to the entrances to buildings in which a large number of people can be concentrated (schools, nurseries, hospitals), or which are of great material value (livestock, poultry premises, warehouses);
- at the end supports of lines with branches to the glands, with the greatest distance from the adjacent ground, these lines must be no more than 100 m for areas with annual average number of hours of thunderstorms to 40 and 50 m - for areas with annual average number of thunder 40.

It is recommended to install additional low-voltage OPN at the entrances to buildings and at the end supports of lines.

To protect electronic equipment (computers, televisions, etc.) from lightning overvoltages penetrating the wiring of the building, special spark arresters and OPN should be used, located in the immediate vicinity of the protected equipment. special transformers, filters and power supplies should be provided to protect particularly sensitive equipment.

Hooks, pins of wooden supports are not subject to grounding, except for hooks and pins on supports where repeated grounding is performed to protect against lightning overvoltages.

The hooks, pins and fittings of the supports that limit the crossing span, as well as the supports on which the joint suspension is made, must be grounded.

Protection of high voltage transmission lines with a voltage of 0.38 kV.

On high-voltage Lines with a voltage of 0.38 kV with insulated self-supporting wires (High-voltage transmission lines of 0.38 kV), grounding devices designed for re-grounding the zero wire, protection against lightning overvoltages, grounding of electrical equipment installed on supports with High-voltage transmission lines of 0.38 kV must be made.

Grounding devices for re-grounding the zero wire and for protection against lightning overvoltages must be carried out in accordance with the requirements [93]. In the case of an isolated zero wire, it is connected to the ground by means of a piercing clip.

To protect electrical equipment, devices and High-voltage transmission Lines of 0.38 kV, OPN (or RV) installed in the immediate vicinity of the protected objects should be used.

OPN (or RV) on the VLI must be connected to the phase wire by means of piercing clips.

Surge arresters and arresters installed on the supports of high-voltage transmission lines of 0.38 kV to protect cable inserts from lightning overvoltages must be connected to the ground conductor by a separate descent.

Lightning protection zones.

1. The lightning protection zone is a part of the space within which a building or structure is protected from cougars with a certain degree of reliability. As you move along the surface into the zone, the reliability of protection increases.

In 6-10 kV networks, 6-10 kV opus, 35 kv substations and above, as well as 6-10 kV bus bridges and flexible connections from step-down transformers to 6-10 kV opus must be protected by lightning rods from pum.

2. The protection zone of a single rod of lightning rod height h < 150 m is a cone-shaped space (figure 9.4), with a peak at a height of $h_0 < h$. The horizontal section of the zone at a height hx (active height of the lightning rod) is a circle with radius r_X. At ground level, the protection zone forms a circle with a radius of r_0. The boundary of the protection zone (with a breakout probability of 0.05) is described by the formulas:

$$h_0 = 0{,}92h;\ r_0 = 1{,}5h;$$

$$r_x = 1{,}5(h - h_x/0{,}92),$$

where h_0 – excess of the lightning rod under the considered level r_x; r_0 – radius of the protection zone at ground level.

The protection zone of the lightning rod has a radius at the level under consideration h_x:

- for lightning rod height $h \leq 30м$:

$$r_x = \frac{1{,}6 \cdot h_0}{1 + \frac{h_x}{h}};$$

- for lightning rod height $30 < h \leq 100\ м$:

$$r_x = \frac{1{,}6 \cdot h_0}{1 + \frac{h_x}{h}} \cdot \frac{5{,}5}{\sqrt{h}}.$$

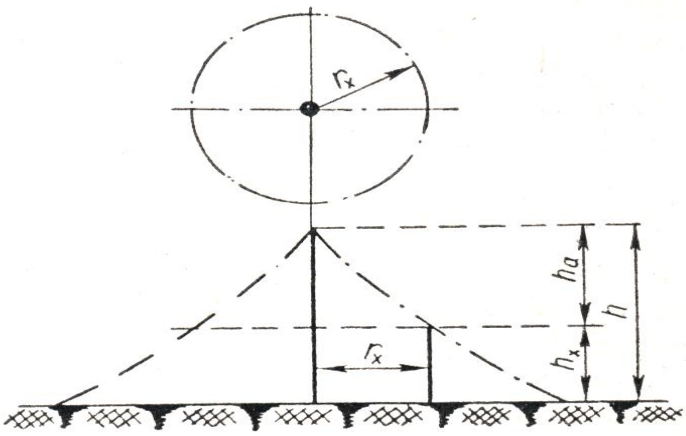

Figure 8.4-Protection zone of a single rod lightning rod

the height of a single rod lightning rod at known values for the protected object h_x and r_x is determined by the formula:

$$h = \frac{r_x + 1{,}63 \cdot h_x}{1{,}5}.$$

Equipment located in the protection zone of the dome limited to radii r_0 on the ground and r_x at the active height of the lightning rod will be protected from GUM (direct lightning strike).

The most remote elements of the protected equipment should be located from the lightning rod at a distance of no more than r_x .

3. The protection of two lightning rods is more effective than one. The protection zone of two lightning rods is greater than the sum of the protection zones of single lightning rods.

The outline of the protection zone of the two lightning rods is shown in Figure 9.5.

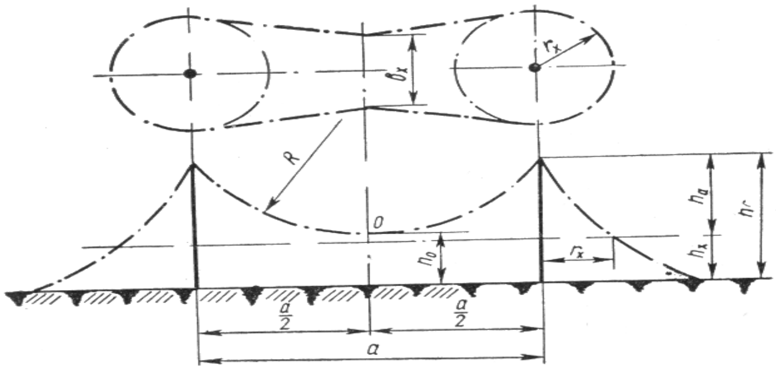

Figure 9.5-Protection zone of two rod lightning rods

The radius of the r_x protection zone for external areas is defined as for a single rod lightning rod.

The smallest height of the protection zone h_0 is equal to:

- by h < 30 м:

$$h_0 = h - \frac{a}{7};$$

- by *30 <h ≤ 100 м:*

$$h_0 = h - \frac{a \cdot \sqrt{h}}{7 \cdot 5{,}5},$$

where a - is the distance between the lightning rods.

If the height of the protected objects is equal to h_x, the distance between the two lightning rods should not be greater than:

$$a \le 7 \cdot (h - h_x);$$

or

$$a \le \frac{7 \cdot 5{,}5}{\sqrt{h}}(h - h_x).$$

Наименьшая ширина зоны защиты $в_{x1}$ определяется по графикам (рисунок 9.6 и рисунок 9.7).

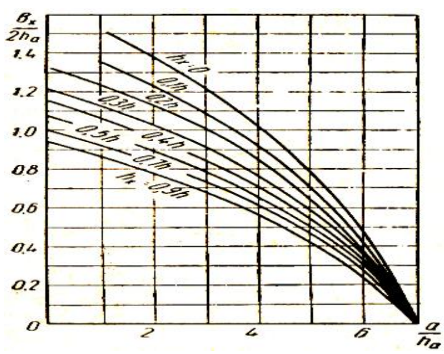

Figure 9.6-values of the smallest width of the protection zone $в_x$ of one rod lightning rods

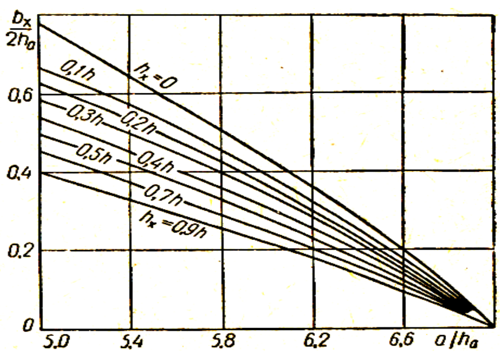

Figure 9.7-Values of the smallest width of the protection zone $в_x$ of two rod lightning rods

For lightning rods with a height of 30 to 100 m, the coordinate scales shown in the figures should be multiplied by $\frac{5{,}5}{\sqrt{h}}$ a factor substation areas are usually protected by several lightning rods. the protection zones of the four lightning rods located at the corners of the quadrilateral are shown in figure 9.8.

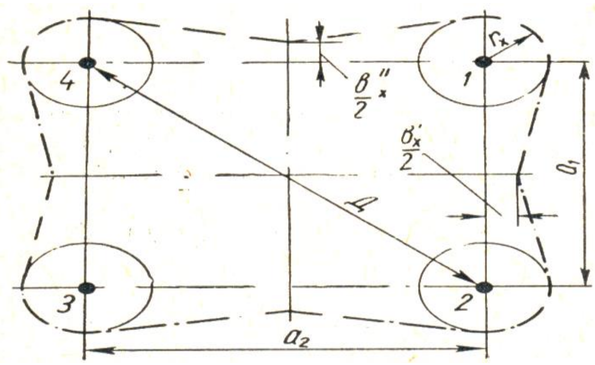

Figure 9.8-Area at the level of h_x , protected by four lightning rods of the same height

The security conditions for the entire area at a given h_x level are as follows:

- for lightning rod height $h \le 30м$:

$$Д \le 8 \cdot h_a;$$

- for lightning rod height $30м \le h \le 100\ м$:

$$Д \le 8 \cdot h_a \cdot \frac{5{,}5}{\sqrt{h}},$$

where D is the diagonal of a quadrilateral with lightning rods at its vertices.

With a three-rod lightning rod, D is equal to the diameter of the circle passing through the vertex of the triangle formed by the three lightning rods (Figure 9.9).

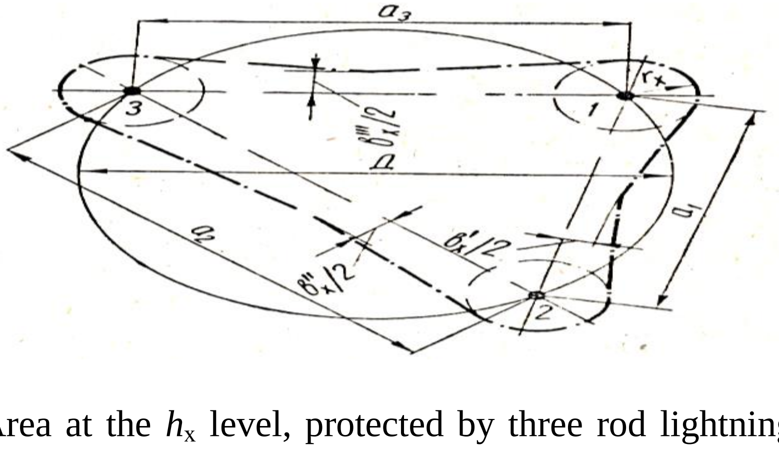

Figure 8.8-Area at the h_x level, protected by three rod lightning rods of the

same height

Attach the grounding of lightning rods on podstantsii voltage of 35 kV and above must join the common earthing loop of the substation so that the connection was not closer than 15 m from the point of attachment of the transformer to ground circuit [96,97].

CONCLUSION

In conclusion, it should be noted that energy saving and improving energy efficiency is a key factor in the sustainable development of various areas of the economy and ensuring energy security of the Republic of Kazakhstan.

We will briefly discuss the main provisions of the course.

1. Reviewed legislative and regulatory base of energy saving and energy efficiency of the Republic of Kazakhstan, which allows you to successfully implement energy saving activities different organizations to achieve the goals and targets set by the Government.

2. The economic and informational aspects of energy saving and energy efficiency improvement are considered, the analysis of contractual relations in the field of energy services is given.

3.The physical foundations of energy saving are described, using which the problems of determining the heat losses of buildings and structures, determining the heat transfer resistances of enclosing structures are considered.

4.The analysis of various methods of accounting for energy resources and the principles of operation of metering devices is carried out, the measurement error is estimated and the criteria for choosing adequate methods and means of accounting for energy resources are given.

5. The goals and objectives of the energy survey of buildings and structures, energy audit and preparation of the energy passport of the organization are formulated.

Methods and means of increasing the energy efficiency of engineering systems and networks of buildings and structures, as well as promising energy-saving technologies, are considered.

6. The analysis of modern technological methods of grain drying and specific features of the use of induction heating showed that despite the achieved results, it is necessary to conduct comprehensive research with the development of physical and mathematical models that allow us to qualitatively and quantitatively assess the efficiency of grain drying by means of induction heaters.

7. Increasing the efficiency of the drying process of wheat grain is provided by induction heating and grain movement on the screw surface.

8. A mathematical model of grain movement along a helical (helical) surface with a variable pitch in a drying plant is obtained, which reflects the dependence of grain moisture on the screw parameters.

9. Based on the results of multi-factor planning of the experiment by computer modeling with the program Statistica 10, a mathematical model of the drying process is constructed, which is a regression function of the dependence of humidity on the drying temperature, the thickness of the grain layer and the heating time in the drying chamber. At the same time, the optimal parameters of the grain drying process are: heating temperature τ=52 ° C, grain heating time t=26 min, layer thickness h=5 cm, specific energy consumption of the process is 4.1 kWh/t.

10. The experimental setup eliminates emissions of harmful substances into the atmosphere.

The material of the training manual allows you to prepare a wide-profile specialist who is able to carry out successful implementation at various levels within the framework of the acquired competencies.

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Sagyndykova Aigul Zhursinovna

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